Foraging and Menstruation in the Hadza of Tanzania

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In memory of Robert J. Deierlein and Bill Fitzpatrick

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and acknowledgements. This dissertation contains fewer than 80,000 words excluding the bibliography, cited references and appendices.

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Acknowledgements

Abstract

The Hadza, residing near Lake Eyasi in northern Tanzania, represent one of the last remaining hunter-gatherer populations. Inhabiting the same area as our hominin ancestors and exploiting very similar resources, the Hadza maintain a foraging lifestyle characterised by a sexual division of labour. Studies of their foraging and food sharing habits serve as the foundation to numerous hypotheses of human behaviour and evolution.

Data from the Hadza have featured heavily in debates on the sexual division of labour. These debates focus predominantly on men's foraging, including how and why men provision. Women's provisioning, on the other hand, is seldom explicitly examined and is often presumed to be constrained by reproduction.

This thesis contributes to debates on the sexual division of labour by investigating how a woman's reproductive status affects her foraging behaviours. Observational data on women's foraging are investigated from 263 person/day follows (1,307 hours total) across 10 camps between 2004 and 2006. These data present the first quantitative documentation of forager women's eating and sharing outside of camp. Interview data on women's reproductive timeline are also analysed from in-depth interviews with 58 women from 9 camps in 2015. Spanning from menarche to menopause, these data offer the first quantitative and qualitative documentation of forager women's menstruation.

The results demonstrate that Hadza women eat and share over 800 kilocalories outside of camp per person/day. They regularly give and receive food, including gifts of honey from men. Breastfeeding women are more likely to give gifts and give more gifts than non-breastfeeding women. When they bring nurslings with them outside of camp, they forage less kilocalories per hour. Post-menopausal women eat less relative to what they forage, are less likely to receive gifts, rest less and forage more than pre-menopausal women. Although Hadza women describe their foraging workload as most difficult during late pregnancy, no significant differences in eating, sharing, resting or foraging are observed for pregnant women.

Menstrual data from the Hadza reveal that menstruation is not only culturally relevant to the sexual division of labour, but it is also biologically relevant to current understandings of fertility. The majority (60%) of Hadza women report not doing their normal work during menstruation. They also report menstruation-related taboos for berry picking. The thesis presents an in-depth review of women's menstruation, from the duration of menses to the menstrual cleaning process.

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1 Introduction

1.1 Overview & Motivation

Contemporary hunter-gatherer data are used to understand total human variation and draw inferences about past human behavioural ecology. These data also allow in-depth examinations into traits that are shared across groups, like the sexual division of labour. Hypotheses have sought to explain the sexual division of labour by focusing on how and why forager men provision women. Yet these hypotheses have taken for granted how women provision themselves. Moreover, these hypotheses include the underlying assumption that a woman's reproductive status limits her foraging capacity.

The following thesis investigates that underlying assumption through analysis of contemporary forager data. The motivation for the thesis is twofold: firstly, to present new information on the lived experiences of forager women and secondly, to explore the relationship between women's reproductive status and foraging behaviours. Women's data are analysed from the Hadza of Tanzania, a hunter-gatherer population residing near Lake Eyasi in northern Tanzania.

This chapter introduces the use of hunter-gatherer data generally. Next, the chapter provides an overview of the sexual division of labour and an introduction to the Hadza of Tanzania. Included in the introduction to the Hadza is a review of Hadzaland, the Hadza's sexual division of labour and women's targeted foods, daily routine and lifetime reproduction. The chapter culminates in the research question which guides the remainder of the thesis.

1.2 The Use of Contemporary Hunter-Gatherer Data

The following content has been adapted from Fitzpatrick & Berbesque (2016).

Broadly defined, contemporary hunter-gatherers encompass those groups which have hunting and gathering as subsistence activities. Specifically, however, various anthropologists distinguish hunter-gatherer groups by their technologies, by their ecologies, and by the extent to which they rely solely on hunting and gathering for subsistence.

Subsistence through hunting and gathering has characterised over 95% of human history. As such, data from contemporary hunter-gatherers, or foragers, have long been used to draw inferences about Pleistocene foragers. While the archaeological record supplies direct evidence from our pre-agricultural ancestors, data from hunter-gatherers has been used to supplement and inform the understanding of these ancestors. These data also help test and enrich our interpretation of the archaeological record (e.g. Binford, 1980).

Early observations of modern hunter-gatherers, from the travelogues of 19th century explorers to the ethnographies of early 20th century anthropologists, focused mainly on hunting. In 1966, the Man the Hunter symposium, organized by Richard B. Lee and Irven DeVore, synthesized a wide range of ethnographic hunter-gatherer data and discussions for the first time. The result was a depiction of the hunter-gatherer way of life, with men hunting, women gathering, and both sharing the products of their labour (Lee & Devore, 1968). Male hunting, in particular, was positioned as the driving force behind a suite of human traits (e.g. Washburn & Lancaster, 1968). A hunting-driven model for human evolution emerged and endured, paralleling the ethnographers' focus on hunting behaviour.

By the 1980s, however, some ethnographers had shifted focus. Anthropologists, archaeologists and primatologists turned their attention to a neglected area of study: women the gatherers. Woman the Gatherer, edited by Frances Dahlberg (1981), highlighted the importance of women's various roles in present and past hunter-gatherers. The evolutionary framework was no longer confined to men's hunting, but opened to women's activities, alongside men's, as drivers of human evolution.

That same decade saw the emergence of the Kalahari Debate, a debate which continues even today (e.g. Horsburgh *et al.*, 2016). Though begun as a disagreement over data from one hunter-gatherer group (Wilmsen, 1989), the debate has come to represent a larger

critique about the use of hunter-gatherer data generally. This critique reacts against portrayals of hunter-gatherers as 'pristine' or unaffected by neighbouring cultures.

Certainly, modern hunter-gatherers are not direct analogues of past hunter-gatherers. Modern foragers and Pleistocene foragers are separated not only by a long time span, but also by large technological differences. Yet researchers acknowledge that hunter-gatherer data are useful for evolutionary models, depending on the question asked. Modern foraging data may help build or test models of human evolution. As Kelly (2013) points out, these data give critical insights into the decision-making process: the on-the-ground behaviour that plays out in the foraging niche.

Because most human adaptations are a consequence of selection in the foraging niche, a critical way to understand the selective pressures in this environment is to study its modern manifestations. The modern foraging niche, however, gives rise to numerous forms, with varying combinations of social and ecological factors. From the Netsilik Inuit of the Arctic tundra (Balikci, 1989) to the Batek in the rainforests of Malaysia (Endicott & Endicott, 2008), the foraging niche embodies a wide spectrum. Which particular group or setting should be examined again depends on the question being asked.

Despite the large variation in modern hunter-gatherers, cross-cultural examination has revealed certain universal features shared by all hunter-gatherers. Such features are of interest to the study of human evolution because by parsimony, they are most likely shared with Pleistocene foragers. One such feature is the sexual division of labour, discussed in the following section.

1.3 The Sexual Division of Labour

Food sharing and the sexual division of labour are two traits considered ubiquitous to hunter-gatherers. Though various forms of food sharing are evident in other animals [see review by Stevens and Gilby (2004)], consistent food sharing, particularly across unrelated, non-mated adults, is uncommon. Many other animals also demonstrate sex differences in diet and behaviour [e.g. female bias toward insectivory in apes (McGrew, 2001, 2014)]. However, humans are the only animal to routinely combine both the sexual division of labour and food sharing (Marlowe, 2007).

George Peter Murdock (1937) pioneered a cross-cultural study examining the sexual division of labour in over 200 societies. He revealed a striking uniformity across foragers. Traditionally, this uniformity has been simplified into a single division: men as hunters and women as gatherers. The simplicity belies a broad range of behaviours, however. In many groups, men partake in gathering activities [e.g. Hiwi of Venezuela (Hurtado & Hill, 1990) and the Hadza (Berbesque *et al.*, 2016)]. Similarly, women participate in

hunting activities: in small-game hunting, both opportunistically and intentionally [e.g. Batek of Malaysia (Endicott, 1979; Endicott & Endicott, 2008)] and in communal hunting [e.g. Efe and Mbuti of the Ituri Forest (Bailey & Aunger, 1989)]. Although the presence of the sexual division is uniformly distributed across foragers, its expression is far from uniform.

There is considerable variability in the extent to which male and female activities overlap. For example, the Martu of Western Australia have a significant overlap in activities, with "very few" resources limited to one sex (Codding *et al.*, 2011, p. 2505). The Aleut of Alaska, on the other hand, are more extreme in their division, with men providing 90% of the total diet (Kelly, 2013; Marlowe, 2007). Murdock and Provost (1973) documented a number of 'swing activities', activities which were predominantly female in some groups yet predominantly male in others. Of the 50 technological activities listed, more were labelled swing activities than any other category (strictly masculine, quasi-masculine, or quasi-feminine). None of the 50 activities were found to be exclusively female.

Despite the varying degrees of overlap, in no foraging group do men and women target the same foods in the same proportions (Marlowe, 2007). Furthermore, in no foraging group[1] do women regularly participate in non-communal, big-game hunting [an observation first formally articulated by Watanabe (1968)]. This singular observation has become the defining characteristic of the sexual division of labour. As Panter-Brick (2002) summarises, "the phrase '*the* sexual division of labor' refers specifically to lack of big-game hunting by women, but is often misleadingly applied to the gamut of subsistence activities" (p. 631).

The question of why men and women target different foods is supplanted by a more specific question: why men hunt large game and women do not. Answers to this question differ in their focus on cooperation, conflict or both (Bliege Bird, 1999). The traditional answer focuses on cooperation in pair bonds. The provisioning model (Washburn & Lancaster, 1968; Isaac, 1978; Lancaster, 1978; Lovejoy, 1981; Lancaster & Lancaster, 1983) links the division of labour to mutual dependency in pair bonds, whereby a cooperative couple shares food between themselves and their dependent offspring. The mutual dependency maximises the productivity of the household and

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[1] An oft-cited exception is the Agta women hunters of the Philippines (Estioko-Griffin & Griffin, 1981; Goodman *et al.*, 1985b). However, their hunting is "nearly always" communal and with dogs (Goodman *et al.*, 1985b, p. 1204). Martu women also occasionally hunt larger game like kangaroo, but they spend the majority of their time hunting goanna lizards (Bliege Bird *et al.*, 2008, 2009).

ensures efficiency through avoidance of the same foodstuffs. The result is a pair bond with specialised foraging skills sharing a broader diet.

An alternative model posits that men hunt not to provision their families but to compete for mating opportunities and social standing. The costly signalling model, drawing on earlier ideas from Zahavi (1975, 1979) and later incorporating the show-off model (e.g. Hawkes, 1991), views big-game hunting as a way to signal the phenotypic or genotypic traits of the hunter (Bliege Bird, 1999; Bliege Bird *et al.*, 2001; Hawkes & Bliege Bird, 2002). Because big-game hunting is risky and a kill cannot be 'faked', a hunter's kill is an honest signal of his abilities. The signal functions in front of the 'audience' of potential mates and potential allies to increase his mating potential and status.

Both models draw on support from the ethnographic record, but neither fully encapsulates its variability. Recent explanations embrace a more flexible approach that combines both parenting and mating trade-offs (e.g. Gurven & Hill, 2009). Bliege Bird and Codding (2015) argue that a broader approach is needed for explaining the variability of the sexual division of labour[2]. Such broader approaches may entail more trade-offs to be considered, including ecological and social factors. In terms of ecological factors, Marlowe (2007) found that male gathering increases in richer, less seasonal habitats. Additionally, Codding *et al.* (2011) documented greater overlap in activities for habitats with low-risk, high-energy resources. As for social factors, the operational sex ratio (Geary, 1998), the potential for alloparental care (Codding *et al.*, 2011), and cooperation between other units outside the stereotypical heterosexual couple (Bliege Bird & Codding, 2015) are important variables for consideration.

Amidst the contentious debate on why men hunt, and the calls for broader approaches, there is a resounding gap in the literature. Why do women not hunt? Implicit in the debate on men's hunting has been the assumption that women cannot or do not hunt large game. Rarely explicit is the reasoning or the empirical evidence for why not. When Murdock and Provost (1973) first presented their comparative study, they suggested that men were stronger and had superior skills for mobilising short bouts of energy. They also enlisted the reasoning of Brown (1970), citing a lengthy quotation from her paper. Brown argued that the degree to which women participate in subsistence reflects the degree to which their activities are compatible with childcare constraints. She suggested certain characteristics of work as compatible: proximity to home, monotony, interruptibility, and lack of danger.

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[2] They also readily admit that evidence for costly signalling has been difficult to provide (Bliege Bird & Codding, 2015, p. 7).

More than twenty years later, anthropologists' reasoning had deviated little from the assumptions related to childcare constraints. Brightman (1996), in a well-argued critique, writes:

> "The sociobiological theories of reproductive penalty all exhibit a failure to substantiate the claim that the reproductive costs of hunting exceed those of gathering. The other physiological theories – those involving strength, disposition, odors, and maternal immobilization – all suffer from the logical fallacy of deriving a dichotomous division of labor from continuous distributions of characteristics between the sexes" (p. 702).

For Brightman, the only relevant reproductive constraints are late pregnancy and nursing infants, and even these render hunting less efficient, not impossible. Twenty years on from Brightman, and still relatively few have developed hypotheses on why women forage differently than men (Bliege Bird & Codding, 2015). Those that have added to the discussion still hold assumptions about childcare constraints (see further discussion in Section 1.3). For example, Gurven and Hill (2009) argue[3] that the long acquisition period for hunting skills precludes women, again resting on the presumption of women's reproductive constraints (as well as the assumption that hunting requires more skill than gathering).

To determine why women forage differently requires a better understanding of how women forage generally. Women's provisioning of themselves and others are important functional aspects of the sexual division of labour. Yet to date, no study has documented how much forager women eat and share outside of camp. Even with in-camp data, women's sharing patterns are rarely examined (Gurven & Hill, 2009). In both the provisioning model and the costly signalling model, women are recipients of men's food. But how much have the women already provisioned themselves? Furthermore, both models presume that women cannot or do not forage for large game meat. The long-standing presumption is due to reproductive constraints. But how do reproductive constraints affect how women eat or share outside of camp? Do women themselves view their foraging work as affected by reproductive constraints? The following study seeks to answer these questions with data from the Hadza of Tanzania.

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[3] A much earlier comment by Kaberry (1939, p. 14) is suggestive of the same logic: the "long training" needed to use a spear in Kimberley Aborigines.

1.4 The Hadza of Tanzania

The Hadza are a hunter-gatherer population of approximately 1,000 individuals residing near Lake Eyasi in northern Tanzania. The majority of studies have been conducted on the 750 individuals occupying the eastern regions of Hadzaland. These Hadza are considered a relatively closed population (Blurton Jones, 2016).

The first documentation of the Eyasi Basin is a report by German explorer Oscar Baumann (1894). Geographer Erich Obst was the first to document living amongst the Hadza in 1911 (Obst, 1912). Nearly fifty years later, anthropologist James Woodburn conducted his first fieldwork with the Hadza, resulting in two key publications in the Man the Hunter symposium, including "An Introduction to Hadza Ecology" (Woodburn 1968a). Since Woodburn's introduction to the Hadza in the 1960s, the Hadza have been studied from a wide range of disciplines, from linguistics (e.g. Sands *et al.*, 1993) to the gut microbiome (e.g. Schnorr *et al.*, 2014). Two important books have synthesized long-term research on the Hadza: Frank Marlowe's *The Hadza: Hunter-Gatherers of Tanzania* (2010) and Nicholas Blurton Jones's *Demography and Evolutionary Ecology of Hadza Hunter-Gatherers* (2016).

Referring to themselves as *Hadzabe*, the Hadza speak their native language, Hadzane. Because Hadzane is a click language, it was originally assumed to belong within the southern African Khoisan language families[4]. However, the language was determined to be its own language family (and thereby a 'language isolate'), with minimal ties to all other African families, even those of neighbouring groups (Ruhlen, 1991; Sands *et al.*, 1993; Sands, 1995; Sands, 1998). Genetic evidence from Y chromosome and mtDNA analyses further confirm the Hadza as highly divergent from southern African Khoisan speakers[5] (Knight *et al.*, 2003; Tishkoff *et al.*, 2007). Indeed, the Hadza are genetically distinct both within Africa and globally (Tishkoff *et al.*, 2009). Scheinfeldt *et al.* (2010) offer a useful summary for placing the Hadza in the linguistic and genetic context of other African hunter-gatherers.

In line with the Hadza's genetic and linguistic distinctiveness, Blurton Jones (2016) describes minimal migration into and out of the Hadza community (at least with respect to the eastern Hadza). Although the rate of intermarriage has been increasing since 1975,

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[4] Woodburn (1968a) was the first to cast doubt on the claims that Hadzane may be related to these language families.

[5] The Hadza diverged from the southern African Khoisan speakers at least 35,000 years ago (Tishkoff *et al.* 2007). The high divergence between the Hadza and the Ju/'hoansi San demonstrates the possibility of "the most recent shared ancestry of these two populations coinciding with the earliest divergence among extant human populations" (Knight *et al.* 2003, p. 470).

the rate is relatively low: 6% of married women are married to non-Hadza on average [census data between 1985 and 2000 (Blurton Jones, 2016)]. One route for maintaining such cultural identity is their language. Marlowe (2010, p. 15) writes that speaking Hadzane is the 'best criterion' for determining who is Hadza. Another route for cultural maintenance has been the Hadza's reliance on foraging. Despite continued encroachment from agriculturists and numerous 'settlement' attempts (by both British and Tanzanian governments), the Hadza have demonstrated strong resilience in maintaining their foraging lifestyle (Woodburn 1968a, 1979; McDowell, 1981; Mabulla, 2007).

Marlowe (2010) estimated that approximately 40% of the Hadza practice foraging exclusively. The remainder supplement the foraging diet with agricultural produce (Blurton Jones *et al.*, 1992). For instance, some Hadza receive maize in exchange for guarding maize fields (Blurton Jones *et al.*, 1992). For the foraging Hadza, agricultural supplementation appears to be minimal: less than 7% of the diet (see overview of Hawkes and O'Connell's data from 1985-1986, Marlowe's data from 1995-1996 and Marlowe's data before 2005 in Blurton Jones, 2016, p. 48).

The Iraqw maize farmers and the Datoga pastoralists interact the most frequently with their Hadza neighbours (Marlowe, 2002). These same neighbours have been present and interacting with the Hadza since the earliest descriptions of the Hadza. Honey, meat and skins are traded for scrap iron, tobacco, and beads (Marlowe, 2002, 2010; Blurton Jones, 2016). Although contact with agricultural societies has the potential to drastically change foraging lifestyles, Marlowe (2002, 2005) argues that this has not been the case with the Hadza. From the earliest direct observations by Erich Obst (1912) to the most recent ethnographic descriptions, Marlowe (2010) chronicles the consistency in mating habits, camp sizes, diet, hunting and foraging toolkits, and hunting and foraging behaviours.

This consistency in hunter-gatherer subsistence combined with a sub-Saharan savannah locale positions Hadza ecology as one of the most important reference points for our evolutionary past. The designation of 'reference point' supposes that Hadza ecology is not immediately transferrable to that of early *H. sapiens*. Rather, as Blurton Jones (2016) notes, observations of the Hadza contribute to the total observed range of hunter-gatherer variation.

The Hadza ecology also contributes to understanding the central tendency of hunter-gatherer variation. Of all the warm climate, non-equestrian foragers ($n = 237$), the Hadza fit at or near the median for numerous traits (e.g. infant mortality rate, interbirth interval and camp population size), leading Marlowe (2010) to assign them the status of the 'median forager'. More recently, Blurton Jones (2016, p. 179) supported this status, confirm-

ing that Hadza mortality and fertility rates are close to the median of foraging populations. This status alone highlights the need for continued documentation and investigation of the Hadza lifestyle.

1.4.1 Hadzaland

Hadzaland comprises an area of approximately 4,000 km^2 around Lake Eyasi. This landlocked, salt water lake is situated in the Great Rift Valley. The Hadza occupy four regions surrounding the lake: to the west, Dunduiya, or Han!abe, region and to the east, Tli'ika, Mangola, and Sipunga regions. The vegetation consists primarily of a mixture of woodlands, savannah grasslands, shrub lands, and deciduous bushlands (Mabulla, 2007). From December through May, the wet season prevails (with total rainfall[6] of 300-600 mm) and from June through November, the dry season prevails (with almost no rainfall) (Marlowe & Berbesque, 2009). While the average annual temperature demonstrates little variation from the mean of ~28° C, the difference between day and night temperature is greater, e.g. 14° C compared to 35° C (data from Mangola, August 2008-2009, Marlowe, 2010).

The ecology of Lake Eyasi is characterised by long-term stability (Lovett *et al.*, 2005). Though some extinct large mammalian species have been identified in the Eyasi Beds (Mehlman, 1987), the majority of the fauna match those consumed by the Hadza today (Mabulla, 1996, 2007). Analysing the palaeoenvironmental changes associated with the emergence of anatomically modern *H. sapiens*, Basell (2008) notes the stability of vegetation around Lake Eyasi. She identifies lake margins in eastern Africa as important habitats for maintaining hominin populations during genetic bottlenecks associated with rapid climate changes. During the prolonged aridity of OIS 6 (Oxygen Isotope Stage 6, 190,000 years to 130,000 years ago), Lake Eyasi would have offered greater tree covering and vegetation, providing refugia or an 'oasis' from open grasslands and deserts (Basell, 2008).

Near the shore of Eyasi, the Mumba rock shelter hosts the longest continuous archaeological record in eastern Africa (Eren *et al.*, 2013). The archaeological site (~2 to 4 km from Eyasi, depending on water levels) has been undergoing excavation since the discovery of hominid remains by Kohl-Larsen in the mid-1930s (Reck & Kohl-Larsen, 1936). Archaic *H. sapiens* cranial fragments (Mehlman, 1984; Mehlman, 1987; Domínguez-Rodrigo *et al.*, 2008), anatomically modern *H. sapiens* molars (Bräuer & Mehlman, 1988), and tools and other artefacts associated with the Middle Stone Age (MSA) and Later Stone Age

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[6] Blurton Jones (2016) offers an excellent overview of historical rainfall patterns in the Eyasi Basin.

(LSA) (Domínguez-Rodrigo *et al.*, 2007; Gliganic *et al.* 2012) have been excavated there. Though defining the boundaries of LSA and MSA is not entirely straightforward, Gliganic *et al.* (2012) argue that the cultural artefacts from Mumba may be the earliest evidence of LSA in Africa.[7]

Reviewing archaeological and skeletal data, Mabulla (1996, 2003, 2007) establishes a record of hunting and gathering in the Eyasi Basin since 130,000 years ago. This record suggests *continuous* occupation of rock shelters in the Basin by hunter-gatherers. Whether or not the Hadza are related to earlier hunter-gatherers (and, indeed, which ones?), Mabulla (2007, p. 28) suggests that the Hadza ancestors have occupied this region for tens of thousands of years. He argues that, cultural continuity, though not directly implying a biological connection, is the most parsimonious explanation.

1.4.2 The Hadza's Sexual Division of Labour

The Hadza are highly mobile within Hadzaland, moving camps freely (Woodburn, 1968b) and frequently (Marlowe, 2010). Camp membership is non-restrictive and no set hierarchy exists; the Hadza are both non-territorial and egalitarian (Woodburn, 1968b, 1979, 1982). Residency patterns vary, although remaining with the wife's kin is common (Woodburn, 1964; Blurton Jones *et al.*, 2005). Camp size is larger in the dry season, when water sources are more limited (Marlowe & Berbesque, 2009). In fact, the division of Hadzaland into four regions is the result of such clustering in peak dry season (Woodburn, 1968b).

Average camp size is around 30 individuals or fewer. [Marlowe (2010) reports a mean of 30 (*n* = 53 camps, range = 6 to 139 individuals), Blurton Jones (2016) reports a mean of 21 individuals, and Woodburn (1968b) reports a mean of 18 individuals]. In the wet season camps, the Hadza sleep in simple grass huts and in the dry season, they often switch to sleeping outside (Marlowe, 2010). Figure 1.1 depicts a simple hut composed of a wooden frame covered with grass and bark. When a couple resides in a hut together, they are soon recognised as married, even without a marriage ceremony as such (Woodburn, 1968b). Yet the married couple will spend many hours of their day apart, due to the Hadza's sexual division of labour.

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[7] In particular, the combination of MSA-like stone points and LSA-like ostrich eggshell beads and geometric microlithics suggest a 'transitional' industry between MSA and LSA in the Mumba rock shelter; therefore, the Hadzaland shelter is an important site for studying the emergence of modern human behaviour (Gliganic *et al.* 2012).

Figure 1.1 Hadza Hut after Sunrise. Photograph: Fitzpatrick, 2015.

The sexual division of labour (see Section 1.3) is marked at an early age in the Hadza: boys receive bows and arrows and girls receive digging sticks as young as two years old (Blurton Jones & Marlowe, 2002; Marlowe, 2010). The boys and girls are very active producers (Blurton Jones *et al.*, 1994), but differ significantly in their foraging patterns (Blurton Jones *et al.*, 1997; Crittenden *et al.*, 2013). Hadza girls return with more food, eat less outside of camp and target different food types than Hadza boys (Crittenden *et al.*, 2013).

The Hadza diet is generalized into five food types: meat, tubers, berries, honey, and baobab (Marlowe & Berbesque, 2009). [There is also the marula nut which is consumed only in the western region of Hadzaland (Berbesque & Marlowe, 2009; Marlowe & Berbesque, 2009)]. Of the five categories, the men predominantly target and acquire more honey and meat and the women more tubers, berries, and baobab (though baobab has the greatest overlap) (Marlowe, 2010; Marlowe *et al.*, 2014).

Hadza men hunt and scavenge for meat using bows and arrows to target small and large game. For larger-sized game, poisoned arrows are utilised. The women's main tool is their wooden digging stick. Other tools include hammerstones and carrying devices. Women also sometimes borrow and use their husband's tools (e.g. knives for sharpening

digging sticks or machetes for accessing honey). A full overview of the women's toolkit, including its evolutionary significance, is provided in Appendix E.

Hadza men typically hunt alone, though occasionally they may hunt in pairs or groups. Of 118 focal follow days analysed by Berbesque *et al*. (2016), men hunted alone in 89% of them. Women, on the other hand, nearly always forage in groups, with an average group size of eight (median = 7, see Chapter 3). For the sample of 263 follow days investigated in Chapter 3 and Chapter 5, no follow day had a woman foraging alone.

Two season-dependent exceptions should be noted to the division of labour in the Hadza. During peak berry season and during *Quelea* nesting (both foods described in Section 1.4.3), everyone in camp partakes in foraging these resources (Marlowe, 2010; Blurton Jones, 2016; Crittenden, 2016). Additionally, honey presents an occasional exception, as men and women may forage for honey together, either as a couple or family unit (see Section 1.4.3).

Other non-food producing activities are divided by sex; women fetch firewood and water and build the grass huts whereas men acquire trade goods (Woodburn, 1964). Rituals, too, are marked by sexual division. In all the ceremonial events observed by Woodburn (1964), sexual groups were divided. Recently, Power (2015) further described the Hadza's *epeme* and *maitoko* rituals as gendered rituals, counterparts in a dynamic relationship between Hadza men and women.

Even food preferences demonstrate differences between the sexes. While honey was most preferred and tubers least preferred overall (mirroring their respective calorific returns), Hadza men preferred meat to berries and women preferred berries to meat (Marlowe & Berbesque, 2009; Berbesque & Marlowe, 2009). These different preferences, along with different foraging targets and sex differences in in-camp eating (Berbesque *et al*., 2011), may even have translated to differences in gut microbial compositions. Schnorr *et al*. (2014) discovered a significant difference in the gut microbial composition of Hadza women and men, suggestive of differences in diet related to the sexual division of labour. Nonetheless, further data would be needed from Hadza women (since their sample includes only nine women).

Though the sexes forage independently, they share their returns. Meat brought back to camp, with the exception of the sacred *epeme* meat for men, is shared by all. Any camp member, indeed any Hadza, can partake in the rapid consumption of meat (Woodburn, 1968a). Large meat, small game meat, honey and fruit that men bring into camp are shared with other households, though the producer's household retains a majority share [see Table 5 of Wood and Marlowe (2013)].

The food sharing which accompanies the sexual division of labour is of particular interest to debates about the provisioning model and costly signaling model (see Section 1.3). Hadza data have featured heavily in the debates, eliciting disagreement over whether Hadza men are 'big-game specialists' (Hawkes *et al.*, 2001; Wood, 2006; Wood & Marlowe, 2013; Hawkes *et al.*, 2014; Wood & Marlowe, 2014). Despite the extensive documentation of Hadza men's foraging and food sharing, basic details about Hadza women's foraging are still lacking.

Woodburn describes women's food stuffs as "less widely shared but […] not narrowly reserved for each gatherer and her immediate family" (1982, p. 442). Berbesque *et al.* (2011) found that women both had greater producer control over their foods than men did and that women consumed more of their own foods. Yet no study of actual kilocalories has corroborated these descriptions. No study has published how much Hadza women eat and share inside camp, nor how much they eat and share outside of camp.

Women's eating and sharing outside of camp serves as a critical context to the Hadza's sexual division of labour. To understand fully how a hunter provisions his wife or signals to a potential wife requires knowledge of the woman's *demand* for provisioning. Context is needed for how much women provision themselves before men's foods are shared in camp. Because Hadza women forage in groups, such provisioning could take two forms: a woman may provide food directly to herself or a woman may receive gifts of food from others.

Provisioning outside of camp may also differ by reproductive status. A long-prevailing assumption of the sexual division of labour is that females face reproductive or childcare constraints (see Section 1.3). Whether explicit or not, this assumption underlies most explanations for why women target different food stuffs. The remainder of this chapter establishes the Hadza women's targeted foods and their potential reproductive constraints.

1.4.3 Women's Targeted Foods

The following section reviews the foods targeted by Hadza women, with special attention to foods in the follows dataset of Chapter 3 and Chapter 5. The full breakdown of species names and Hadzane names are provided in the relevant food charts of Appendix B and Appendix C. To acquire these food stuffs, the women utilise a very simple toolkit. Appendix E offers a full review of the toolkit and its relevancy to past ecology.

Hadza women's targeted foods have evolutionary significance because they are wild foods; they are acquired with simple technology; and they are consistent with past veg-

etation in the same region. The Eyasi vegetation has been notably stable since the emergence of *H. sapiens* in eastern Africa (Basell, 2008). As mentioned previously, Eyasi's long-term, stable ecology (Lovett *et al.,* 2005) entails a deeper time depth to the fauna and flora consumed by the Hadza today. Even the baobab tree, a species spread across Hadzaland, is the oldest lived angiosperm in the world (Patrut *et al.,* 2013). The long-term stability of Hadzaland's flora and fauna is paralleled by a long record (130,000 years) of hunting and gathering activities in Hadzaland (Mabulla, 1996, 2003, 2007).

1.4.3.1 Berries & Fruits

Hadza berries tend to have minimal flesh with large seeds or stones. The seeds are expectorated or passed through the digestive system without being broken down (Murray *et al.*, 2001). Woodburn (1964) describes the Hadza as saying their hunger is more easily satiated when seeds are swallowed rather than spat out. *Grewia* species are sometimes consumed as a sweet mush or soup, a mixture formed with water and berry flesh (Woodburn, 1970; Blurton Jones, 2016). In this study, the berries of *Salvadora* and baobab fruit (discussed below) were consumed in that same fashion.

Grewia have a wide range in Hadzaland, encompassing nearly everywhere but open grasslands, while *Salvadora* and *Cordia* are more patchily distributed across 'berry flats', low, flat areas like those along lakeshore plains (Blurton Jones, 2016). Berries are available from the late dry through the rainy season, with key ripening from December to May (Marlowe, 2010). The seasonality of particular species may vary. For instance, McDowell (1981) found *Salvadora* limited to a shorter period of October to November compared to *Cordia* from November through March in data from Mangola.

Vangueria and *Sclerocarya* (or marula fruit) are both drupes with large stones or nuts in their centres. Flesh is eaten around the stone, and in the case of marula fruit, the energy-dense nut is processed. *Ficus* (or fig) has multiple, small seeds like its domestic equivalent and Crittenden (2009) describes the fruit as normally eaten whole.

Vangueria is described by Woodburn (1970) as available in small quantities in equally small locations. (Its limited presence in this study's dataset further confirms that description). Fig trees, growing along riverbanks in very tall trees, are also described by Woodburn (1970), although figs were not consumed in large quantities. However, Crittenden (2009) and Crittenden *et al.* (2013) depict significant consumption by children and adolescents. Marula fruits are available only in the Dunduiya region and a small part of Mangola (Berbesque & Marlowe, 2009).

Adansonia (or baobab fruit) contributes more kilocalories than any other species in the Hadza diet (Marlowe, 2010). The fruit tree contributes in other ways, too; hollows hold honey or rainwater and the fruit shells form baby rattles or drinking cups (Woodburn,

1970). Comprised of a hard outer shell (exocarp), the baobab fruit contains a white, chalky pulp surrounding hard seeds. Figure 1.2 displays four baobab fruit pods. Consumption of baobab takes many forms: broken pieces of unprocessed pulp, processed pulp flour, processed pulp and seeds, and even a baobab paste when mixed with water or juice from other berries.

Figure 1.2 Baobab Pods in Hadzaland. Four pods of the species *Adansonia digitata*. Photograph: Fitzpatrick, 2015.

Since baobab trees produce pods on different schedules, the pods are available for the majority of the year (Marlowe, 2010). Blurton Jones (2016) estimates that they are available for at least eight months in most years. Sometimes only the seeds themselves are foraged, from baboon or elephant excrement (Woodburn, 1970; Blurton Jones, 2016).

1.4.3.2 Tubers

After berries, tubers represent the second biggest contribution to the diet by women (Marlowe, 2010, p. 127). Tubers are called other names including roots, tuberous roots or underground storage organs (USOs). The enlarged plant organs are beneath the surface, storing energy or moisture for the plant. Cassava and sweet potatoes are domestic

examples. For the Hadza, at least 10 species of tubers are consumed (Marlowe, 2010). This study includes data from five: *//ekwa* (*Vigna frutescens*), *do'aiko* and *shakeako* (*Vigna macrorhyncha*), *makalita* (*Rhynchosia comosa* or *Eminia entennulifa*) and *shumuwako* (*Vatoraea pseudolablab*).

Vincent (1985), building on her PhD dissertation (Vincent, 1984), provides an excellent overview of the Hadza tubers and their ecology in the Mangola area. The tubers form along lateral shoots, connecting to a central rootstock (Vincent, 1985). Whereas *makalita* and *shumuwako* often have shallow enough roots to be dug by children (Blurton Jones, 2016), the *//ekwa* tubers may be 1.5 metres below the surface (Vincent, 1985). Appendix B includes further physical descriptions of the tuber species.

Tubers are available throughout the year, varying more by region than by season (Berbesque & Marlowe, 2009; Marlowe & Berbesque, 2009). They are most commonly found along rocky hillsides (Blurton Jones, 2016). Because they are the least preferred food type of men and women and the most continuously available, tubers are regarded as fallback foods (Marlowe & Berbesque, 2009).

1.4.3.3   Meat & Eggs

Women occasionally target small mammals, birds, eggs, tortoises and large land snails (Marlowe, 2010). Large game is not targeted (no observed instances in 263 follow days, see Chapter 3) and small game is the least regularly targeted of the five food types. Small game is usually acquired while women are out foraging for berries or tubers (except in the case of *Quelea* discussed shortly). For instance, just as a woman may be scanning the ground for an appropriate hammerstone (see tool use in Appendix E), so too may she be scanning the trees for nests on her walk to a berry patch. In the case of Figure 1.3, Hadza women had noticed a nest during a digging trip. One woman knocked down the nest with her digging stick while another woman collected eggs and a nestling.

Figure 1.3 Eggs Foraged by Hadza Women. Two eggs of the bare-faced go-away bird (*Corythaixoides personatus*). Photograph: Fitzpatrick, 2015.

The synchronised mass reproduction of *Quelea* is an exceptional case of meat and egg foraging by Hadza women, men and children.   The red-billed *Quelea* birds are remarkable for many reasons; they have the shortest incubation period for any bird, the largest colonies for any land bird, and a high degree of mass synchronisation (within 2 to 3 days) (Lack, 1968; Jaeger *et al.*, 1989). The *Quelea* nestlings and eggs are foraged by the Hadza for only two to three weeks during the rainy season (Crittenden, 2009; Marlowe, 2010; Blurton Jones, 2016). This study includes follows where women target *Quelea* chicks and eggs. While the migratory *Quelea* demonstrates clear seasonality, some small game do not vary seasonally (Berbesque & Marlowe, 2009).

1.4.3.4 Honey

Honey has the highest calorific value per kilogram of Hadza foods (Marlowe *et al.*, 2014) and is also the most preferred food of women and men alike (Berbesque & Marlowe, 2009). Both sexes have been observed targeting honey, but men acquire the vast majority (Marlowe, 2010; Marlowe *et al.*, 2014, Wood *et al.*, 2014). Marlowe *et al.* (2014) found that of 1,170 cases of honey acquisition, men alone were responsible for 89.6% (1,029 cases).

Women acquired 9.4% of the honey (110 cases), and both men and women (mostly husband and wife pairs) acquired 2.6% (31 cases).

Of the seven types of Hadza honey, women have been documented to target *kanoa* (*Trigona ruspolii*) most often, a honey from stingless bees living in hives located at or near eye-level (Marlowe *et al.*, 2014). To reach the hollow inside the *Commiphora* trees, the women usually need to borrow a husband's axe (Marlowe *et al.*, 2014), though women have been observed to use sharp rocks or sticks to retrieve honey (Colette Berbesque, pers comm).

Honey is available during a large portion of the year (Marlowe & Berbesque, 2009), but the greatest amount is foraged in the wet season, peaking from March to May (Marlowe *et al.*, 2014; Wood *et al.*, 2014).

1.4.4 Women's Daily Routine

A typical day is one in which "women and children set off to gather berries, roots or baobab fruit" (Obst, 1912, cited Blurton Jones *et al.*, 1994, p. 222). Between about 8:00 or 9:00 am, the women leave camp as a group to target tubers or fruits, depending on the season (Hawkes *et al.*, 1989). The women's foraging party consists of adult women, their nursing infants, some children, and sometimes teenage boys or an adult man (Hawkes *et al.*, 1989). The parties tend to travel 5.8 kilometres daily (*SD* = 1.7), a shorter distance than men travel on their hunting forays (daily mean = 11.4, *SD* = 2.1) (Pontzer *et al.*, 2012). While men and women are away from camp, elderly or juvenile caregivers supervise the remaining children in camp (Crittenden *et al.*, 2013). Depending on the resource targeted and its distance, the women may return to camp by mid-afternoon or later. On their route home or shortly after returning, women may gather firewood, collect water or collect grass for their huts (Woodburn, 1964). In the evening, foods are cooked and shared between the sexes.

Women seem to have a particular target in mind before they set off for the day (Blurton Jones & Marlowe, 2002). For fruit collecting trips, women target berry patches and fruit trees. They pick large amounts of small berries from their stems or whole branches to be picked from later. They collect larger fruits from the ground below the trees. These fruits may have fallen down naturally or been knocked or thrown down by women and/or men. For example, men occasionally shake the limbs of a baobab tree for women to collect the pods below (Marlowe, 2010). In other instances, women may throw branches or rocks to knock the baobab fruits from the trees (Berbesque, pers comm).

Figure 1.4 Hadza Woman Digging for Underground Tuber. Photograph: Fitzpatrick, 2015.

On digging trips, the women target tuber patches. Women spend less than six minutes searching for a plant to dig (Vincent, 1985). In selecting a plant, a woman taps the ground with her digging stick to listen for tubers (Hawkes *et al.*, 1989; Marlowe, 2010). If a boulder prevents digging (because of a rocky location), then women will work together to lift the rock away, using a digging stick as a lever (Marlowe, 2010; Blurton Jones, 2016). Figure 1.4 demonstrates a Hadza woman digging for an underground tuber. Once a woman pulls the tuber out of the ground, she must disconnect the tuber from any shoots, using a knife (see more on tool use in Appendix E).

1.4.5 Women's Lifetime Reproduction

Hadza women participate in the daily foraging activities from childhood into late adulthood. By age 12, girls start targeting tubers that are more difficult to acquire (Blurton Jones & Marlowe, 2002). By adolescence, they are able to make their own digging sticks

(Crittenden, 2016). At around 16 or 17 years, the girls will have their first menstruation (Marlowe, 2010). Their puberty ritual, the *maitoko*, is planned around the ripening of the *undushipi* berry (*Cordia sinensis*) (see Marlowe, 2010, p. 55; Power, 2015).

The average Hadza woman will have her first birth by age 18.95 (Marlowe, 2010; Blurton Jones, 2016). By that age (18 or 19), she will be fully proficient at acquiring all tuber species (Crittenden *et al.*, 2013). As she continues to forage across her reproductive years, the average woman will marry twice and give birth to six children, nursing five for approximately 2.5 years each (Marlowe, 2010; Blurton Jones, 2016). She may nurse longer if she does not become pregnant again (Woodburn, 1959).

When the Hadza woman is breastfeeding, she will take her infant on foraging trips (Crittenden & Marlowe, 2008). The average one year old Hadza infant weighs about 8 kg and the average two year old, 9.4 to 9.7 kg (Blurton Jones, 2016, p. 319). These additional weights will be carried by the mother while she forages outside of camp until the child is being weaned and left inside camp (Crittenden, 2016).

The average woman will give birth to her final child at age 37.8 and become a grandmother around that same time (Marlowe, 2010; Blurton Jones, 2016). By around age 43, she will cease menstruating and become post-menopausal (Phillip *et al.*, 1999). She will live another twenty years (28.8 years after last birth) and will remain very active during many of those years (Blurton Jones, 2016, p. 153).

1.5 The Research Question

Although there is a rich literature on the Hadza's foraging lifestyle, there is a lack of data on important aspects of women's lives, including their eating and sharing outside of camp and their lived experience of the reproductive timeline. Similarly, there is a paucity of data on women's provisioning outside of camp, despite the extensive literature and ongoing debates about men's provisioning. Most studies on the sexual division of labour, including those that examine data from the Hadza, focus on the foraging behaviours of men outside of camp, not of women.

Indeed, data on women's foraging outside of camp seldom feature in debates on the sexual division of labour. One reason for this lack of representation is simply the lack of data. No study documents how much forager women provision themselves and others outside of camp. Another reason is the perpetuation of a fundamental assumption: that women's foraging is constrained by reproduction. While this assumption persists, women's role in provisioning outside camp may continue to be excluded from present debates about the sexual division of labour.

This thesis seeks to investigate the soundness of the assumption that women's foraging outside of camp is constrained by reproduction. By examining new data from Hadza women, the thesis addresses the following research question:

How, if at all, does a woman's reproductive status change her foraging behaviour outside of camp?

To answer this question, the thesis analyses data on Hadza women's foraging outside of camp as well as data on the women's reproductive timeline. Chapter 2 describes the field methodology for collecting and preparing data. Analyses focus on three key objectives: establishing how Hadza women forage generally outside of camp; exploring the lived experience of the reproductive timeline; and testing whether reproductive status is perceived to affect and/or is observed to affect women's foraging behaviours.

To achieve the first objective, Chapter 3 documents how much women eat, forage and share outside of camp. Data analyses reveal the daily foraging behaviours for Hadza women outside of camp. For the second objective, Chapter 4 delves into the women's reproductive timeline, from menarche to post-menopause. Data are analysed both quantitatively and qualitatively to better understand women's experiences across different reproductive statuses. Chapter 5 addresses the third objective by documenting how reproductive status is perceived to affect and is observed to affect women's foraging behaviours. Data analyses test whether there are associations between women's reproductive status and women's foraging.

In documenting the results of these three objectives, the thesis applies a biocultural lens to the lifestyle of Hadza women. The thesis addresses the research question by engaging in a more holistic examination of the relationship between women's foraging and reproductive status. Chapter 6 presents a final discussion, including a synthesis of the results from the qualitative and quantitative analyses as well as broader implications of the study. Following the final chapter, the thesis provides extensive Appendices, from Appendix A on food weights to Appendix H on translated text. Each individual appendix is mentioned in the text where applicable.

2 Methodology

2.1 Introduction

All data analysed in the thesis were collected from fieldwork conducted with the Hadza in Hadzaland. Two types of data were collected: focal follow data and interview data. The follow data were collected by Frank Marlowe and his team during field trips between 2004 and 2006. I collected the interview data during my fieldwork in the late wet season of 2015. The methodologies for data collection and preparation are described in the following chapter.

2.2 Focal Follow Data

2.2.1 Data Collection

From 2004 to 2006, focal follow data were collected from 10 camps across 263 person/day follows. Frank Marlowe, along with his team of field assistants and researchers, Colette Berbesque, Alyssa Crittenden, Brian Wood, Claire Porter, Happy Msofe, Golden Ngumbuke, Daniel Ngumbuke and Ephraim Mutakyahwa, collected the women's follow data. Table 2.1 displays the three year period of data collection according to year, season, region, camp and follow day count. All four regions of Hadzaland were represented.

The data encompass both seasons of Hadzaland, wet and dry. More specific designations of Hadza seasons demarcate four seasons: early wet (December to February), late wet (March to May), early dry (June to August) and late dry (September to November). While data were collected during three of these four seasons, data are unavailable for early wet (with one exceptional follow in early December grouped into a majority of late dry follows).

Table 2.1 Women's Follows by Year, Season, Region & Camp

Year	Season	Region	Camp	Follow Count
2004	Early Dry	Tli'ika	Sangeli	11
	Early Dry	Tli'ika	Sanola	12
	Early Dry	Tli'ika	Kisanakwipi	30
2005	Late Wet	Siponga	Goandeka	57
	Late Wet	Tli'ika	Gangidape	52
	Early Dry	Dunduiya	Mayai/Wamkwimba	19
	Late Dry	Siponga	Siponga	17
	Late Dry	Siponga	Tuwa	8
2006	Late Wet	Tli'ika	Lelangidako	33
	Late Wet	Mangola	Olpiro	24
Total	3 Seasons	4 Regions	10 Camps	263 Follows

At each camp, Marlowe and his research team aimed to follow all women at least once. To do so, random sampling without replacement was used to select the focal individual. With the focal individual selected, a researcher (or field assistant) observed this woman from the time she departed camp (usually sometime after 8am, once the other women were ready) until she returned to camp (usually early to late afternoon).

During each foray, the researcher recorded behavioural observations. As he or she followed the focal individual, he or she adhered to standard methodological practices for participant observation: minimisation of intrusion and maximisation of space afforded to the individual. Although potential observer effects may arise from the presence of a researcher, the researcher took measures to minimise the risk of these effects, including walking silently, approximately five to ten metres behind, and avoiding disruptive actions that may directly or indirectly affect the woman's behaviours.

2.2.1.1 Women's Food Stuffs

Data were recorded on all food eaten and shared by the focal woman. Following the methods of Rothman *et al.* (2012), the researcher visually estimated food amounts. Section 2.2.2 establishes the format of these estimations for the various food categories and their conversions to kilograms.

In terms of food sharing, a gift event was recorded for every instance a woman gave or received food. Each gift event corresponds to a particular food item and the visual estimate of that food item. The visual estimations of food sharing relied on the same

methodology as food eaten. Besides estimates of food, other activities were recorded, including walking, resting and nursing.

Amounts of food eaten, gifts given and gifts received were based on estimates recorded during the follow. The amount of food brought back to camp was based on estimates recorded after the follow. Upon a woman's return to camp, her food was weighed via hanging spring scales. Food weights along with any container weights were recorded. Not every follow had a corresponding food weight measurement, however. Due to the availability of food return data, the sample size for follow days with corresponding food acquisition data is 198 follow days.

2.2.1.2 Women's Personal Data

During each camp visit from 2004 to 2006, the research team measured the height and weight of all follow women. Alongside these anthropometric measurements, details of the woman's spouse and number of living children were recorded. If the woman was noticeably pregnant or breastfeeding, such variables were also recorded.

2.2.2 Data Preparation

I received the original paper copies of the follows recorded from 2004 to 2006. I also received the original paper copies of anthropometry and interview data from each camp visit. I scanned all of the copies to create digital files for each page. From these digital copies, I manually entered the data into Microsoft Excel and organized the data with Microsoft Access.

Before data analysis could begin, three important steps remained. Firstly, the visual estimates of food stuffs needed to be converted into equivalent weight estimates. Secondly, the weight estimates required conversion to calorific estimates. Thirdly, the identity of each woman had to be matched with her respective anthropometry and interview records.

2.2.2.1 Weight of Food Stuffs

Previous analyses of Hadza food data systematically relied on food weighed in camp, with occasional estimates by Frank Marlowe based on experience only (Berbesque, pers comm). For total food foraged, this study too relied on food weighed upon return to camp. As for the other food variables, however, visual estimations were used. This methodology is less accurate than the ideal scenario of weighing all food eaten, processed and shared, but substantially more practical. Individually weighing those variables would not only be highly intrusive but also inherently bias-prone.

With the publication of Berbesque *et al.* (2016), estimates of food eaten outside of camp were analysed for the first time, and thereby, estimates outside of the standard food returns data. As with the study of Berbesque *et al.*, this study relies on visually estimated food amounts. These approximations included different units of food for different categories. Unlike the men's follows, however, many more units were used, encompassing varying tuber species and larger volumes of additional berry species.

Although Wood and Marlowe (2014) have (very usefully) published total mass estimates of various game species, the individual weights of female-targeted food items are lacking. While the lack of data is manageable if only weighed foods are examined, this serves as an impediment to examining out of camp foods that have not been weighed. Even if one were to employ a more intrusive eating study, any total eat counts would still require an estimate for various species' weights.

To determine the weights of the female-targeted species (and thereby the corresponding visual units), this study undertook an extensive literature review in addition to analysing food data previously collected from Hadza food returns. This study also determined the density of one tuber species to be used for volume to mass calculations.

All food weights were determined on a fresh, wet weight basis. The results of the literature review, analysis and density calculation are outlined for the following food categories:

Fruits (berries): For the berries, visual estimates of total berry handfuls were used. The fieldworker collected data on the average number of berries per handful per follow. For those follows which did not include an average number of berries per handful, an overall average was used for that berry during the same research period. The total number of berries was converted to kilograms according to estimates in Appendix B.

Berry seeds may be spit out or swallowed whole. When they are swallowed whole, they are not digested by the Hadza (Murray *et al.* 2001). Therefore, berry seeds were not included in nutritional analyses.

Fruits (non-berry fruits): The non-berry fruits and baobab were larger than the Hadza berries and thereby could be visually estimated in units of individual fruits. The fruits were converted to kilograms according to estimates in Appendix B.

Baobab: In the case of baobab, distinctions were made between units of pulp, seeds and processed flour of pulp and seeds. These baobab parts were converted to kilograms according to the weights determined in Appendix B. This study derived the average total weight for baobabs from previously collected food returns (see Appendix A).

Tubers: Visual estimates for tuber volume included height, length and width estimations. Visually intuitive units were recorded (e.g. golfball size for smaller tubers), in line with such unit types for honey (Wood & Marlowe, 2014). Some tubers were also designated as small, medium or large for a particular species. This study derived the average weights for various tuber species from previously collected food return data (see Appendix A). Since the tuber weights were positively skewed, the median values for tuber weights was used rather than mean values. For those tubers labelled small, medium or large in a particular species, the 25th percentile and 75th percentile weights were applied.

Because the majority of tuber visual estimations were volumetric, it was necessary to use an estimated density to convert to total mass. I calculated the dry weight density of a single tuber sample retrieved from the field by measuring its dry volume and dry weight. This density estimate was used to calculate the density of all tuber species, given their particular moisture contents.

Meat: For meat portions, visual estimations in grams were used by the researcher, with a few examples of visually intuitive units for smaller meat pieces. For four species of animals, three bird species and the elephant shrew, the whole animals were recorded as units. This study derived weight estimates from previously collected data (see Appendix A) and calculated the edible mass based on the subtraction of skeletal mass, fur/feather mass and gizzard mass.

Eggs: Like the units of whole animals, eggs featured as a simple unit of measurement. Only *Quelea quelea* eggs were recorded in the follows dataset and Table B.7 outlines the mass data for this particular egg.

Honey: Visually intuitive units were used for estimates of honey weights, as with the methods of Wood and Marlowe (2014). These units mostly included teaspoon and tablespoon estimates. Similarly to the treatment of tubers, it was necessary to estimate the density of honey given volumetric visual estimations. Honey density was calculated using measured weights and the recorded volumes of honey containers.

2.2.2.2 Nutritional Composition of Food Stuffs

The next task was to convert all kilograms of food to calorific values. Because all food estimates were wet weight estimates, nutritional values were calculated based on 100 grams of wet weight. For many nutritional studies, the standard presentation of data is per 100 grams of dry weight. Using the moisture content given by each study, the nutritional values were converted from dry weight to wet weight estimates.

In contrast to the paucity of data on the weights of female-targeted foods, there are nutritional data available for some Hadza foods. However, these studies too are limited. Only three published studies are available: Vincent (1985) and Schoeninger *et al.* (2001) on tubers, and Murray *et al.* (2001) on honey and fruits.

Additional nutritional data are available in the form of dissertations and unpublished data: Galvin *et al.* (nd) [accessed from the supplementary material of Blurton Jones (2016)], Crittenden (2009), and Migata (2011).

In the case of Schoeninger *et al.* (2001), both Crittenden (2009) and Blurton Jones (2016) offer serious objections to the tuber data. A helpful diagram provided by Blurton Jones (2016, p. 20) highlights the large discrepancy between the results of Schoeninger *et al.* (2001) and those of Galvin *et al.* (nd), Vincent (1985), and Crittenden (2009). In agreement with critiques from Blurton Jones (2016) and Crittenden (2009), this study did not include the tuber data from Schoeninger *et al.* (2001).

As with the food weight data, an extensive literature review was conducted to include additional nutritional information. This study used the available Hadza data where appropriate and also integrated nutritional estimates from other studies on the same species in Africa (with preference given for studies from Tanzania or other East African countries). All nutritional values were used according to the estimates determined in Appendix C.

2.2.2.3 Women's Personal Data

By reviewing the anthropometry and interview data recorded at the time of fieldwork, focal women were matched to their respective personal and family data files. Two estimations, however, required greater accuracy than could be obtained from the fieldwork records alone: age and pregnancy status. To determine estimates for these variables, the woman's name was cross-checked with the Hadza longitudinal dataset. This file builds on long-term census data systematized by Nicholas Blurton Jones and Frank Marlowe. The file has been maintained and updated by other researchers, including Colette Berbesque, Alyssa Crittenden and Brian Wood.

Through reference to the anthropometry and interview data from the field as well as the Hadza longitudinal dataset, the following variables were identified:

Age: Ages of follow women were determined with reference to the Hadza longitudinal dataset. Because this file originates from Blurton Jones' fieldwork in the 1980s and has continually been updated by Hadza researchers, the database includes very robust estimates for adults and children born since the 1980s. For adults born before this period, Marlowe (2010) and Blurton Jones (2016) applied similar methodologies for estimating

ages. Blurton Jones (2016, p. 71) describes his methodology of combining historical marker dates, census lists and relative ages. Photographs of the Hadza from Ludwig Kohl-Larsen and Dorothea Bleek in the 1930s were also used by Blurton Jones and Marlowe to estimate ages for older Hadza individuals.

BMI: Body mass index (BMI) was calculated from height measurements (in metres) and weight measurements (in kilograms).

Husband and number of children: During anthropometry data collection, women were asked about their current marital status and the number of children living and deceased. The total number of children was cross-checked with the census data in the Hadza longitudinal file, and husband status was cross-checked with the husband's reported marital status.

Pregnancy status: Any visibly pregnant woman was noted as such in the anthropometric data. The pregnancy status of a woman who was early stage or not visibly pregnant may not have been accurately recorded during data collection. To determine the pregnancy status of such women, children born in the years 2004 to 2007 were pooled from the Hadza longitudinal file. Their mothers were cross-checked from the focal follow women for the appropriate years. This also allowed for a determination of the sample size of pregnant women in their third trimester (see discussion in Section 5.10.6).

2.3 Interview Data

2.3.1 Data Collection

I conducted fieldwork with Frank Marlowe, Colette Berbesque and Ibrahim Mabulla in March and April of the late wet season of 2015. During the fieldwork, we visited nine Hadza camps. I conducted in-depth interviews with 58 Hadza women from these camps. Of the 58 women, aged 14 to 85 (median = 33 years), seven were pre-menarcheal and 14 were post-menopausal. Of the remaining 37 women, five were nursing and six were pregnant at the time of interviews.

During my stay in each camp, I was introduced to the Hadza by Marlowe and Berbesque. I approached the women in camp to ask for participation in my interviews. One-on-one interviews were conducted in a private setting (e.g. beneath a tree secluded from others). Before I began each interview, I explained the topics that I would be asking about in the interview. Verbal consent was given for participation in the interview. I also explained that I would like to record the interviews, and I provided a small demonstration of my voice recorder. With permission from the interviewee, I recorded our discussion.

Interviews were semi-structured and included questions regarding menarche, menstruation, pregnancy, breastfeeding and menopause. Family data were also recorded, including the woman's present marital status, her husband's name and the birth order and names of her children. Depending on the interviewee's reproductive status (e.g. post-menopausal or pregnant), I asked additional questions. Similarly, I asked a different set of questions to pre-menarcheal girls.

Figure 2.1 Interview with a Hadza Woman. Photograph: Fitzpatrick, 2015.

All interviews were conducted in Swahili. Most Hadza are fluent in Swahili as their second language, except for the oldest Hadza women. For four of the older women (above 70 years old), another Hadza woman in the same camp was present at the time of the interview to translate the Swahili questions into Hadzane.

Interview questions were checked and edited for clarity with the help of Ibrahim Mabulla, a native Tanzanian with fieldwork experience with the Hadza. Upon learning the Hadzane word for menstruation during my interviews in the first camp, I continually checked and applied this word in all other camps. Because no equivalent words were found for the English words of menarche and menopause, I also applied the Swahili phrases used by the Hadza women to describe these phenomena (see Section 4.4.1).

2.3.2 Data Preparation

All interviews were recorded, transcribed and translated into English. Based on the interviewee's name and other family data, I cross-checked her information with the Hadza longitudinal file to ascertain her age. Data were entered using Microsoft Excel, organized with Microsoft Access and analysed with RStudio software. Chapter 4 and Chapter 5 include quotations taken from the interviews and translated into English. For quotations of longer than five words, the original Swahili phrases are designated by codes (e.g. T1) and are available in Appendix H.

3 Foraging Outside of Camp

3.1 Introduction

Though foraging varies along a continuum from random searching to targeted searching (Kaplan & Hill, 1992), foragers usually depart from and return to a central place. This practice, called central-place foraging, typifies the food acquisition of most hunter-gatherers, including the Hadza (Marlowe, 2005a, 2006; Kelly, 2013). Because humans provision others with food at the communal place (as opposed to only sleeping there), they have been more aptly labelled central-place provisioners (Marlowe, 2006) and central-place sharers (Smith, 1985, 1992). Models for central-place foraging provide insights into hominin behaviour like food processing and transport (Winterhalder & Smith, 2000). For instance, using data from shellfish foraging in the Meriam, Bird (1997) derives important implications for how to interpret faunal assemblages and home bases in the archaeological record.

Behavioural observations of central-place foraging form the backdrop for studies of food sharing and the sexual division of labour. In studying food sharing and the division of labour in foragers' diets, anthropologists have predominately relied on data collected at the central place. Indeed, the pooling of food in a central place is directly conducive to anthropologists measuring what is eaten and what is shared. For example, Wood and Marlowe (2013) describe male provisioning in the Hadza by weighing both the initial amount of food a hunter returned to camp with and the individual amounts distributed per household in camp. These data from inside the camp, thereby, were used to directly test hypotheses on food sharing by males.

The tendency to rely on food data from inside the camp, however, has been to the exclusion of data from outside of camp. To describe accurately the food sharing and the division of labour in foragers requires the documentation of *all* food eaten and shared. The overwhelming majority of studies on food sharing, foraging diets, and sexual division of labour, however, have failed to document eating and sharing outside of camp. If studies have not captured the food habits outside of the central place, then the goals, costs and outcomes of food sharing and division of labour cannot be fully extrapolated.

The exclusion of out of camp eating could be substantially undercutting calorific estimates of the foraging diet. In a first of its kind study, Berbesque *et al*. (2016) documented out of camp eating for male foragers. They found that Hadza men consume approximately 90% of their average daily total energy expenditure (TEE) while outside of camp. This significant portion of TEE seriously calls into question long-held assumptions about the 'snacking' behaviour of foragers (see discussion below) and further informs the debate between provisioning and costly signalling models (see Section 1.3).

Even more so, the study's findings place a demand on further data from foragers. Because the study is the first to quantitatively document out of camp eating in male foragers, its results currently stand alone without context. Further data are needed to contextualise these findings: how much are the Hadza women eating outside of camp? The following chapter presents an answer to this question, analysing out of camp foraging in Hadza women. In doing so, this chapter presents the first quantitative analysis of out of camp eating in forager women.

3.2 Background

The forager diet has been studied across numerous disciplines, from studies of human behavioural ecology to studies of the gut microbiome. The diet has even featured in recent pop culture [see Pitt's (2016) review of the 'paleo diet' hype]. Like other aspects of the foraging lifestyle, foragers' diets are versatile and variable across populations, with no single population defining a 'forager diet' in and of itself. As omnivorous primates, humans are capable of subsisting on a range of food stuffs (see Harris & Ross, 1987). The variability of forager diets invokes not only differences across the calorific contributions of specific foodstuffs, but also differences across the contributions from the sexes, from different age groups, from different foraging strategies and from agricultural products.

At the Man the Hunter symposium (Lee & Devore, 1968), Lee presented the then surprising result that Ju/'hoansi[8] women returned with substantially more food than men: two to three times more (by weight). Since then, the comparison of male and female contributions to foraging diets has been documented in many populations. Kelly (2013) presents useful overviews across foraging groups, including contributions of male food procurement for 76 groups and contributions of hunting, gathering and fishing for 126 groups.

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[8] This name has replaced the use of the name !Kung as per the explanation provided by Lee (2013).

None of the diet breakdowns listed by Kelly (2013), however, includes an explicit, systematic account[9] of food eaten outside of camp. And in this respect, none of the proposed diets are wholly representative of the actual diet. A diet based on food returns alone cannot be wholly representative, unless every forager eats nothing outside of camp. Without the full account of food eaten outside of camp, it is difficult to assess the representativeness of the proposed diet. Even if a 'full' account of food eaten is not logistically possible, then at least some quantitative approximation or at least indication of food eaten will help to assess whether a diet based on in-camp data alone is accurate or representative.

Certainly, some studies may closely approximate the actual diet if minimal out of camp eating and sharing occurs. Equally though, some studies may be far from close approximations. The current paucity of quantitative data limits accounts of out of camp eating to either generalised statements or mere anecdotes. In their ethnography of the Batek, for example, Endicott and Endicott (2008) describe mothers in the forest who "might cook a few newly dug tubers if their children were particularly hungry" (p. 86) and hunters who "might butcher and cook the animal and eat a bit of the meat before returning to camp" (p. 74). Since the researchers explicitly state that their analyses do not include food consumed in the forest (2008, p. 72), these descriptions are not quantified. Rather, they only evoke the presumption of minimal eating.

An anecdote from the Yuquí foragers of Bolivia, on the other hand, evokes the presumption of more substantial eating outside of camp. Stearman (1991) describes one hunting trip with the Yuquí during which they 'snatched' and ate food while in pursuit of game. Her colleague, Kent Redford, mused that the Yuquí were "vacuuming the forest" (1991, p. 253). Stearman discerned that the Yuquí "snacking behaviour" may contribute significantly to total food consumption. Nevertheless, Stearman (1989) had only published on the amount of food brought back to the camp, not on the amount of food eaten outside of camp.

 'Snacking' has been a common catch-all for categorising out of camp eating. Despite its implicit connotation (less food than 'meal time'), its explicit vagueness[10] leaves a wider margin open to interpretation. Walker and Hewlett (1990) describe more snacking in pygmy women than pygmy men in central Africa, and Bogin (2011) suggests a link

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[9] Howell (2010) describes Lee (1969) attempting to document exact intake for only a few Ju/'ho-ansi. Other than this reference, there are no other known references of explicit documentation of out of camp eating.

[10] This vagueness parallels the impreciseness of the word 'some' when used to quantify out of camp eating. For instance, Hill *et al*. (1987) describe Ache men's eating: "some plant resources are picked up off the ground and eaten while continuing to forage" (p. 27).

between snacking in the Ju/'hoansi and a positive energy balance. In neither case, however, is snacking quantified. Additional mentions of 'snacking' include snacking on berries by Hadza women (Hawkes *et al.*, 1989), wild berries and plants as 'snack food' for the Agta (Headland, 1987), and snacking before the one main meal of the day in Australian Aboriginal hunter-gatherers (O'Dea *et al.*, 1991). In his summary of how foragers generally eat, Kelly (2013) writes of snacking behaviours:

> "Optimal-foraging models were intended to model the behaviour of animals that feed-as-they-go. But humans are better described as *central place foragers*. Although they may snack on some of the foods they collect in the field, foragers will transport a large portion back to a central location" (p. 65, original emphasis).

This notion of 'snacking' on 'some' foods is a far cry from the results of Berbesque *et al.* (2016). Although Kelly describes central-place foraging as distinct from 'feed-as-they-go', the latter strategy better describes the findings of Berbesque *et al.* From 146 person/day follows, they found that men on average consumed 2,405 kilocalories out of camp. Based on a mean TEE of 2,649 ± 395 kilocalories calculated for Hadza men (Pontzer *et al.* 2012), the kilocalories eaten outside of camp comprised 90.8% of total TEE on average.

It is unsurprising that studies have shied away from quantifying eating outside of camp. The central place has more favourable conditions; food returns can be weighed and sharing events are within eyesight. To weigh food eaten outside of camp would be trickier, more intrusive and more disruptive to foraging. Since, as Berbesque *et al.* (2016) readily point out, the anthropologist cannot be in two places at once, it is understandable that anthropologists have tended to rely on in-camp food returns.

Nevertheless, the substantial kilocalories eaten by Hadza men suggest that it is not sufficient for anthropologists to overlook out of camp eating. In the case of the Hadza, complementary data from women are needed to complete the picture of out of camp eating. Comparable data are available for children's eating outside of camp in Crittenden *et al.* (2013). These data demonstrate significant sex differences in consumption patterns of children. Adult sex differences have been found in food consumption by food type and eating frequency (Berbesque *et al.*, 2011), in food preferences (Berbesque & Marlowe, 2009), in dental wear patterns (Berbesque *et al.*, 2012), and in gut microbial composition (Schnorr *et al.*, 2014). As far as food returns, Marlowe (2010) found that Hadza women are responsible for 60% of all kilocalories brought to camp. In documenting women's eating out of camp, this study completes the full picture of eating out of camp for the Hadza, presenting a point of comparison between the sexes.

A previous study of Hadza women's foraging used indirect measures to estimate one part of total consumption outside of camp. Hawkes *et al*. (1989) assumed the amount of berries eaten based on picking rates and eating time, though noted that eating time was directly correlated with age (with older women spending less time eating). As for tubers, the study did not include estimates of eating; eating time was used only to calculate foraging time, not food estimates. Studies of other foraging groups have attempted indirect measures too. For instance, Howell (2010, p. 8) describes researchers using weight gain or weight loss as indirect measures of caloric consumption in the Ju/'hoansi.

The use of proxy measures has the potential to distort interpretations of women's foraging. At the most basic level, the proxy of food returns misrepresents the total amount consumed (unless all women eat nothing outside of camp). At a more nuanced level, however, there are ramifications for conclusions drawn about 'foraging efficiency' and its covariates. Consider, for instance, the finding that nursing Ache women are less efficient foragers (Hurtado *et al*., 1985, p. 24). The researchers used food returns as a proxy for foraging efficiency, assuming that lower returns equated to lower efficiency. The problem with the assumption of 'efficiency', however, is that returning with more food does not necessarily mean a nursing woman foraged more overall. She could have eaten more food outside of camp (thereby personally foraging more but returning with less) or she could have received more food from others outside of camp (thereby personally foraging less but returning with more).

A hypothetical scenario illustrates why it is problematic to equate food returns with foraging efficiency and to ignore food eaten and shared outside of camp. In a single camp during one season, Group A and Group B target the same foods. Both groups forage for the same amount of time. Food returns are measured in terms of kilocalories acquired. Group A returns to camp with more food than Group B. By the logic of most previous studies, Group A are more efficient foragers because they seemingly acquired more kilocalories in the same amount of time**.** Table 3.1 highlights the problem with this assumption, however. Group B may have actually acquired more total kilocalories, if they ate more than A, shared more than A, or did both outside of camp.

Table 3.1 demonstrates the alternative foraging possibilities by which increased food returns do not equate to increased foraging efficiency. Conclusions which are drawn about particular variables corresponding to foraging efficiency are firstly questionable if efficiency does not take into account food eaten and shared outside of camp (both aspects of total foraged). They are secondly questionable because the variable of interest (like nursing) may reflect a relationship to the amount eaten or shared rather than food brought back to camp. Without data from food outside of camp, this relationship cannot be properly investigated.

Table 3.1 Foraging Efficiency Possibilities for a Food Return Scenario

Food Return Scenario	Eating	Sharing	Foraging Efficiency Possibilities
A returns with more food than B.	A = B	A = B	A is more efficient than B.
	A > B	A > B	A is more efficient than B.
	A < B	A < B	A is equally **OR** less efficient than B.
	A > B	A < B	A is more **OR** equally **OR** less efficient than B.
	A < B	A > B	A is more **OR** equally **OR** less efficient than B.

Because studies have focused on in-camp eating, documentation of sharing has largely focused on in-camp sharing. There is a lack of understanding of all sharing which takes place *before* sharing at the central place. This form of sharing could have important ripple effects on sharing in camp. Since the Hadza men usually hunt alone (Marlowe, 2010), there is less opportunity for sharing (though they may occasionally encounter other Hadza). But for the Hadza women foraging in groups, their eating data may illustrate the vastly underreported sharing outside of camp.

Like sharing, satiation may also have important ripple effects on eating in camp. As Berbesque *et al*. (2016) highlight, decisions about sharing foods in camp are affected by the satiation of individuals returning to camp. In his descriptions of women's foraging, Woodburn (1968) writes, "only the food which remains after the women and children have satisfied their hunger is brought back to camp" (p. 51). Decisions about sharing may also be affected by what has already been shared outside of camp and by whom.

This study is the first to quantitatively document out of camp eating and sharing in forager women. The following chapter presents calorific accounts of both phenomena in Hadza women. Potential factors associated with eating, foraging and sharing outside of camp are also identified and examined. The results are then discussed with regards to previous results for Hadza men's out of camp foraging as well as the sexual division of labour.

3.3 Data Analysis

Data were entered using Microsoft Excel, organized with Microsoft Access and analysed with RStudio software.

When deciding which statistical tests to use, there are many important factors to consider, two of which are the independence of cases and normality. The repeat measures in the follows dataset violate the assumption of independence of cases. Data consist of 263 follow days for 93 women due to repeated measures. On average, each woman was observed for 2.4 follow days within a camp (SD = 1.8, range = 1 to 9, mode = 1). Of the 93 women, 14 are observed at two camps and one is observed at three camps.

Table 3.2 presents the frequency of repeat observation days (or person/days). Why some women were followed more than others is the result of various factors, including how long the researcher visited a particular camp and how many adult women were in camp. So if, for instance, the researcher visited a smaller camp for a longer period of time, then he or she may have randomly followed some women on multiple occasions. Another reason for repeat observations is that these data are taken across a three year period. As discussed in Chapter 1, the Hadza are highly mobile and camp composition changes. As a result, a woman who appeared in a certain camp in one year may be followed again in a different camp in a later year.

Table 3.2 Frequency of Repeat Observation Days across Women

No. of Observation Days	No. of Women
1	39
2	17
3	10
4	5
5	10
6	4
7	4
8	1
9	1
10	1
11	1
Total	93 Women

In addition to the non-independence of observations, the distribution of kilocalories consumed across the 263 person/days is non-normal (see Figure 3.1). This study does not exclude outliers on the basis that firstly, they are an undocumented yet integral part of

an overall eating strategy; secondly, the sample is already limited in its number of person/days, each of which required the arduous task of field data collection; and thirdly, exclusion of outliers does not resolve the issue of normality. For this last point, trials of varying levels of exclusion still resulted in high skewness. For example, applying the exclusion of 5 SD below or above the mean resulted in a skewness of 3.77. Additionally, applying an arbitrary cut-off of 10,000 kilocalories or 5,000 kilocalories resulted in skewness of 2.97 and 1.79, respectively. So while exclusion of the outliers changes the extent of the skewness, the shape of the data remains non-normal.

To address the issues with repeated measures and non-normality, linear mixed models (LMMs) and generalized linear mixed models (GLMMs) were used. Appendix G provides a further review on the use of mixed models in this study. The mixed models approach has the advantage of controlling for uneven repeated measures across subjects. GLMMs have the additional advantage of allowing for non-normal data and binary outcome variables. In both models, it is possible to distinguish between 'fixed' and 'random' effects and account for hierarchies within the dataset.

As Seltman (2015) explains, the use of multiple measurements per subject introduces correlated within-subject errors. Mixed models overcome the similarity in error structures by assigning random effects to act as random intercepts or slopes. For this study, woman and camp were selected as crossed random effects. Since every walk outside of camp represents a random realisation of all potential walks for that camp, the walks within a camp are more similar to each other. Likewise, every walk of a single woman represents a random realisation for all of her potential walks, and her walks are more similar to each other than those of a different woman.

Appendix G summarises the results of within-woman and between-women analyses to support the application of mixed models. If a woman's repeat measurements were found to be significantly different, then her follow days may be treated as independent observations. However, the results reveal no significant within-woman heterogeneity, supporting the application of mixed models and the assumption that a woman's walks are more similar to each other. Additionally, the results suggest no significant heterogeneity between women who are measured on multiple occasions. This finding supports the inclusion of unbalanced repeated measures, data which may be analysed by mixed models but not by repeated measures ANOVA.

The mixed models approach also enables the calculation of mean values while controlling for repeated measures. Mixed models were used to determine the average amount consumed, average gift given, average gift received and average amount foraged outside of camp. Regression diagnostics (e.g. checking residuals) were run for the models using quantile-quantile plots in R (qqPlot or qqnorm). When examining

models with explanatory variables (discussed below), model selection involved the use of R-squared values and Akaike information criterion (AIC) values. Although a model with more variables might be expected to have a higher R-squared, AIC penalizes the addition of explanatory variables.

The mixed models approach allows for the investigation of other factors, both continuous and categorical, that are potentially associated with eating, gifts and foraging. If traditional tests were used for either parametric or non-parametric data (e.g. Student's *t*-test or Spearman's rank correlation), then there would be no mechanism for controlling for repeat measures. These tests assume the independence of observations. Only the repeated measures ANOVA could be an appropriate substitute (for normally distributed, continuous data). But because the repeated measures are uneven across women and camps, this test is not useful for the women's dataset. The mixed models approach allows for not only determining the mean of the variables of interest (eating, gifts and foraging), but also those factors which may be significantly associated with them.

I identified the following factors for analysis: characteristics of the trip itself, of the environment, of the woman and of her family. These factors are summarised in Table 3.3. Trip characteristics include follow duration (in minutes) and distance travelled (in kilometres). Distance was measured by wearable GPS devices (Garmin 301 Forerunner devices). Environmental characteristics include year of follow, two season designation (wet or dry), four season designation (early or late wet and early or late dry) and Hadzaland region (Tli'ika, Siponga, Dunduiya or Mangola). Personal characteristics include age and BMI, measured from anthropometric data described in Chapter 2. Family characteristics include presence of husband and number of living children, measured from census data also described in Chapter 2. Data were available for all factors for all person/days except for distance travelled (n = 152 person/days, due to the GPS device malfunctioning, being taken off or being worn by another individual) and BMI (n = 241 person/days, due to missing weight or height measurements). The treatment of missing data by mixed models is described in Appendix G.

To determine the variable of 'foraging'[11], this study relies on a calculation (see Equation 1) which involves gifts and eating. Total foraging is calculated as:

Total Foraged = Food Eaten + Food Brought to Camp + Gifts Given – Gifts Received   (1)

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[11] The thesis applies an operational definition of 'to forage' as 'to acquire', whether by digging, picking or collecting food resources. This definition is used when amounts of foods are referred to or compared, as in 'kilocalories foraged'.

This calculation considers food foraged as food that has been acquired by the woman to consume immediately, to give as a gift to another individual, or to bring back to camp. This calculation does not consider food foraged as food that was received from someone else as a gift and which was either immediately consumed or brought back to camp. For instance, a woman who receives a gift of 300 kilocalories of tubers has not actually foraged for those extra 300 kilocalories. If she were to return to camp with those extra 300 kilocalories, a traditional study based on food returns alone might assume she herself foraged those kilocalories. This study, on the other hand, is able to distinguish what the woman individually gathers and consumes.

Foods consumed, given, received and foraged were also analysed in relation to food type. Five major food types have been identified and used in previous analyses of Hadza data: baobab, berries, honey, meat and tubers (e.g. Marlowe & Berbesque, 2009; Berbesque *et al.*, 2011). These food categories were applied, although meat comprised only small game for the women's sample. In line with Berbesque *et al.*'s (2016) use of definitions, small game here is applied as any game animal below 32 kg and large game is applied to any animal above that weight. As mentioned below, only one instance of large game eating occurs in the sample (warthog meat received as a gift).

Given that women's out of camp eating has not been analysed before and given the large number of potential explanatory variables, the analysis in this chapter is an exploratory analysis. Model averaging was used through the package MuMIn in R, by which all variables were run together in a single simulation for all possible combinations. Models are evaluated in the function based on AIC. The function also orders the relative importance of the variables in the summary output. Any variables with weights around 0.7 or above were tested individually. In contrast, the analyses in Chapter 5 are hypothesis-driven, using similar outcome variables to those of the present chapter but with more specific testing of individual reproductive variables.

Table 3.3 Summary of Potential Explanatory Variables for Eating, Gifts and Foraging

Category	Variable	Type	Description
Trip	Trip Duration	Continuous	Total duration of trip outside of camp in minutes
	Distance	Continuous	Total distance travelled outside of camp in kilometres
Environment	Year	Categorical	2004, 2005 or 2006
	Two Season	Categorical	Wet or dry
	Four Season	Categorical	Early or late wet; early or late dry
	Region	Categorical	Tli'ika, Siponga, Dunduiya or Mangola
Personal	Age	Continuous	Estimate from census data (Appendix D)
	BMI	Continuous	Estimate from anthropometric data (Appendix D)
Family	Husband	Dichotomous	Presence/absence of husband
	No. of Children	Continuous	Total number of living children

3.4 Results

3.4.1 Women's Eating

Ages ranged from 16 to 80 years old for the 93 women, with an average age of 36 and median of 34. Not controlling for repeat women, the average follow, equivalent to total time spent outside of camp, lasted for 299 minutes ($SD = 148$, median = 275, range = 27 to 704). Women travelled a mean distance of 7.22 kilometres per follow ($n = 152$, $SD =$

4.85, median = 6.43, range = 0.25 to 28.2), with an average group size of 8 (n = 214, SD = 5.12, median = 7, range = 2 to 30).

Kilocalorie consumption outside of camp demonstrated a wide range of variation. Total kilocalories consumed ranged from 0 to 22,704 kilocalories. Not controlling for repeat follows, the average number of kilocalories consumed was 1,488 kilocalories (SD = 3,011, median = 553). Figure 3.1 illustrates the distribution of kilocalories consumed per follow across the 263 person/days. There is evident positive skewing (skewness = 4.62). In fifteen observation days (across 14 women), no kilocalories were consumed outside of camp, and in five observation days (across 5 women), over 10,000 kilocalories were consumed.

The derived mean of 1,488 kilocalories is not wholly representative, however, because its computation treats all 263 observation days as independent. The observation days are not independent since they include repeat measurements in the same camp as well as repeat women. A more accurate estimation of the mean requires control for these repeated measures.

As mentioned previously, linear mixed models allow for such control of unbalanced repeated measures. For this study, the data distribution was first normalised using a log transformation[12]. A geometric mean of 326 kilocalories (95% CI: [174, 613]) per person/day was derived from the linear mixed effects model. Figure 3.2 displays the mean and confidence interval determined with the linear mixed effects model using the log-transformed distribution of kilocalories consumed. The log-transformed distribution is more visually useful because of the very large spread of total kilocalories. The placement of the geometric mean also demonstrates its representativeness across the total distribution.

Table 3.4 summarises the three measurements for calculating the average kilocalories consumed per person/day, including the new geometric mean, the traditional mean (not controlled for repeats) and the traditional median (not controlled for repeats).

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[12] The natural logarithm was applied throughout the study. To be noted, computation of geometric means returned the same value as the use of logarithm with base 10.
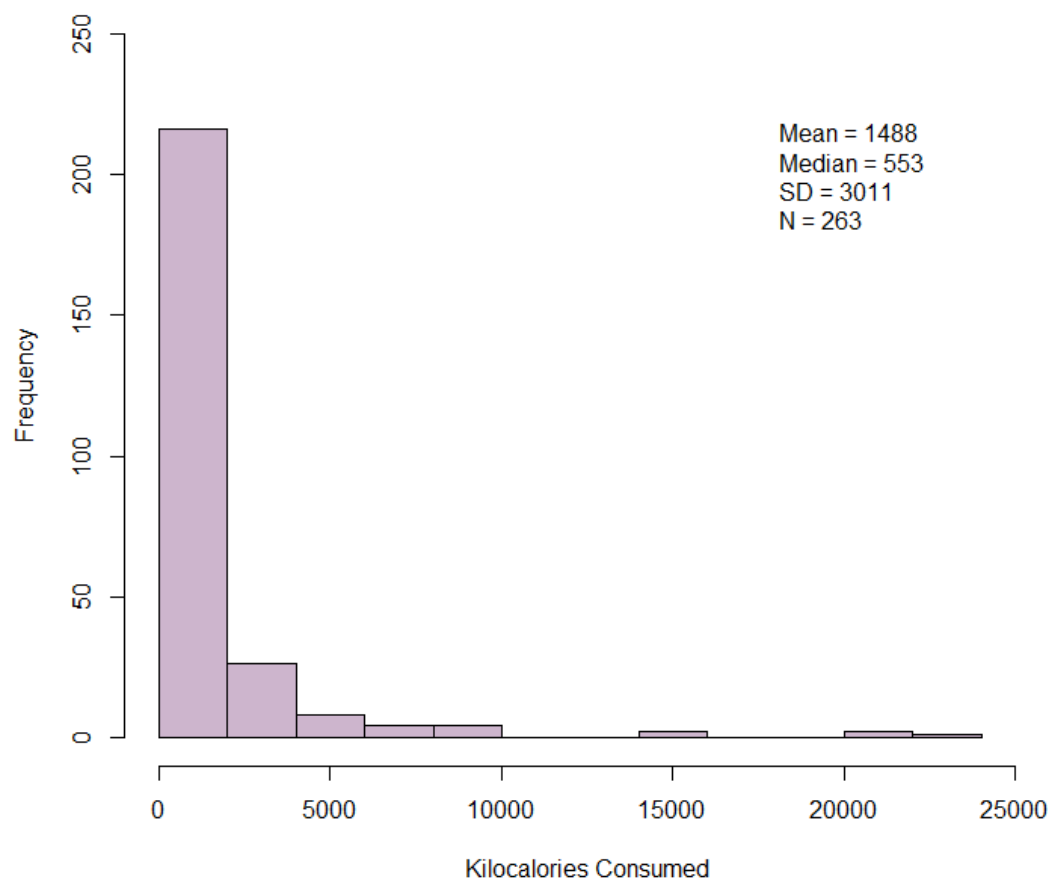
Figure 3.1 Total Kilocalories Consumed per Follow (*n* = 263).
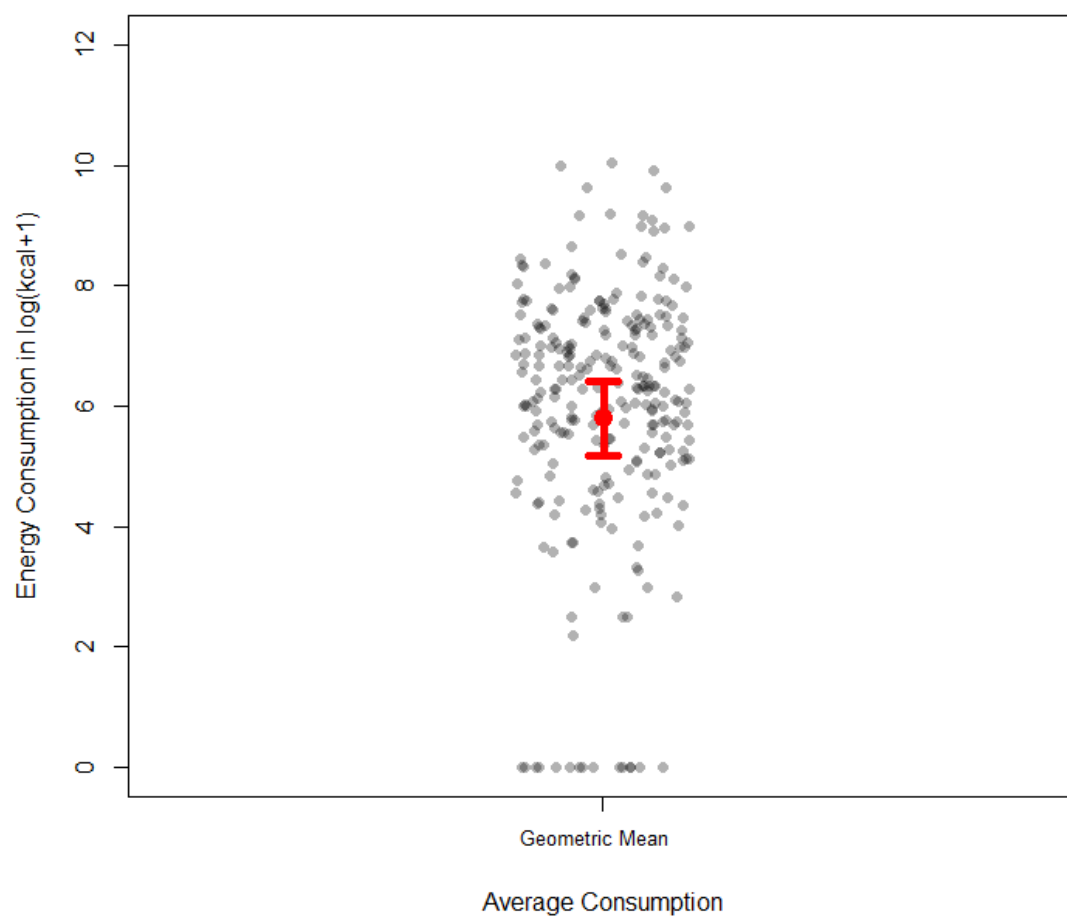
Figure **3.2** Average Energy Consumption per Follow (*n* = 263). The red error bar represents the 95% confidence interval.

Table 3.4 Estimating Average Kilocalories Consumed Outside of Camp Per Person/Day

	Mean	Median	Geometric Mean
	{uncontrolled for repeat measures}		*{controlled for repeat measures}*
Kilocalories per person/day	1,488	553	326

3.4.1.1 Explanatory Variables & Eating

On some person/days (*n* = 15), a woman did not consume any kilocalories. To explore possible explanations for why these women did not eat outside of camp, the explanatory variables identified in Section 3.3 were run in a model averaging simulation (R package MuMIn). The categorical variable of consumption was created and the GLMM was run with family set to binomial. None of the identified characteristics of the environment (year, two season designation and four season designation), of the woman (age and BMI) or of her family circumstances (presence of husband and number of living children) were significantly associated with whether or not a woman ate outside of camp.

Only trip duration (*n* = 263, *p* < .0001) and distance (*n* = 152, *p* < .05) were significantly associated with whether a woman ate anything outside of camp. The longer the trip lasted and the further the woman travelled, the more likely she was to consume food. Nevertheless, distance and trip duration are significantly correlated with each other (*n* = 152, *r* = 0.58, *t* = 8.73, df = 150, *p* < .0001). A model with trip duration alone was compared to a model with distance alone and a model with both variables. In a model with both variables, distance was no longer significant. The model with trip duration alone better explained variance with a higher R^2 and lower AIC (R^2 = 0.70). Trips on which women ate nothing had a median duration of 104 minutes. Every one hour increase in trip duration nearly tripled the odds of eating something (OR = 2.90, 95% CI: [2.23, 3.78]). Figure 3.3 demonstrates the increasing probability of consumption as trip duration increases.

3.4.1.2 Explanatory Variables & Total Eaten

The same exploratory variables were then tested in relation to how much a woman consumed per follow day outside of camp. The data were again normalised with log-transformation, the LMM was applied (in R, the GLMM function will default to LMM given a Gaussian distribution) and run in the model averaging simulation. None of the variables of the environment (year, season or region), of the woman (age or BMI) or of her

family circumstances (presence of husband or number of living children) were significantly associated with how much a woman consumed.

Only one variable was significantly associated with the total kilocalories eaten per person/day: trip duration (n = 263, linear mixed model, p < .0001, R^2 = 0.29). Trip duration had a large effect on consumption (d = 0. 65). Increases in follow length were associated with an exponential increase in the kilocalories a woman consumed. Figure 3.4 displays women's increasing consumption over time, with the logarithmic scale for easier visualisation of the total spread of data points. Table 3.5 summarises the significant associations found between explanatory variables and food eaten outside of camp.

Table 3.5 Summary of Significant Associations for Food Eaten

Category	Variable	Significance	Effect
Trip	Trip Duration	$p < .0001$ food eaten	Increased likelihood of eating food $R^2 = 0.70$, OR = 2.90
		$p < .0001$ amount eaten	Increased amount of food eaten $R^2 = 0.29$, $d = 0.65$
	Distance	*ns*	
Environment	Year	*ns*	
	Two Season	*ns*	
	Four Season	*ns*	
	Region	*ns*	
Personal	Age	*ns*	
	BMI	*ns*	
Family	Husband	*ns*	
	No. of Children	*ns*	

Figure 3.3 Probability of Eating over Time (*n* = 263).
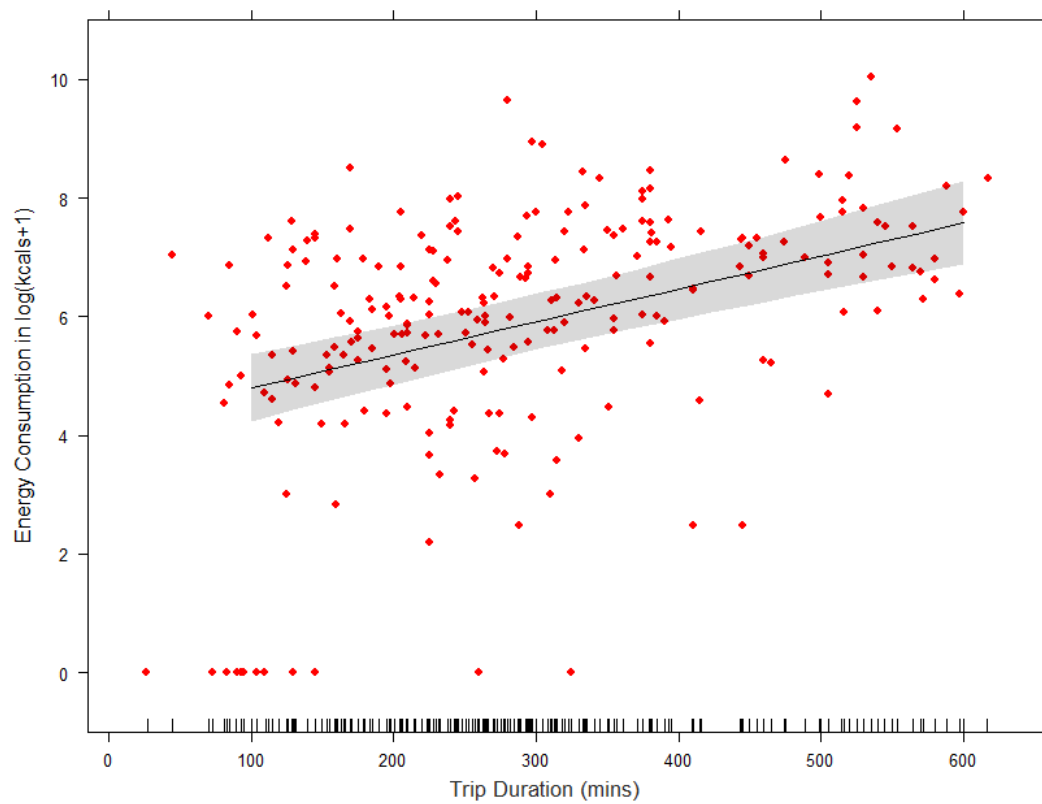
Figure 3.4 Kilocalorie Consumption over Time (*n* = 263).

3.4.2 Women's Gifts

Across all follows and not controlling for repeats, a total number of 480 individual gifts were given and 430 individual gifts received. There was a wide range of total kilocalories given per follow: 0 to 19,688 kilocalories (mean = 438, *SD* = 1,810, median = 0). There was an even wider range for total kilocalories received per follow: 0 to 34,791 kilocalories (mean = 754, *SD* = 3,515, median = 0). The kilocalorie distributions of total gifts given per follow and total gifts received per follow were both highly, positively skewed (skewness of 7.76 and 7.97, respectively). Figure 3.5 and Figure 3.6 demonstrate the distributions for total kilocalories given as gifts per person/day and total kilocalories received as gifts per person/day.

When applying a log transformation to the total distributions of gifts given and gifts received, normal distributions were achieved in the presence of gifts given and gifts received. However, there was an obvious non-normal distribution in those follows where no gifts were given or received. In more than half of the follows (55%), no gifts were given. Likewise, in more than half of the follows (57%), no gifts were received. Considering both simultaneously, 40% of follows had both no gifts given and no gifts received.

After excluding the follows where no gifts were given, the total kilocalorie distribution of gifts given was still positively skewed (skewness = 5.21). Of the follows with gifts given, the mean amount of total kilocalories given per person/day without control for repeats is 969 kilocalories (*SD* = 2,594, median = 202). The distribution was log-transformed to a normal distribution. As with total kilocalories consumed, a linear mixed model with woman and camp as crossed random effects was used to control for repeated measures and determine the geometric mean for gifts given. For those trips where gifts were given, the estimated geometric mean of kilocalories given per person/day is 136 kilocalories (95% CI: [56, 328]), as displayed in Figure 3.7.

The same analysis was applied to gifts received. Excluding trips where no gifts were received, the total kilocalorie distribution remained positively skewed (skewness = 5.19). For follows with gifts received, the mean amount of total kilocalories received per person/day, not controlled for repeat measures, is 1,742 kilocalories (*SD* = 5,178; median = 315). This distribution was log-transformed for normalization. A linear mixed model with woman and camp selected as crossed random effects revealed a geometric mean of 368 kilocalories (95% CI:[258, 527]). Figure 3.8 illustrates the estimated geometric mean within the log-transformed distribution. Table 3.6 contextualises the geometric means along with the traditional means and medians without control for repeated measures.

Table 3.6 Estimating Average Kilocalories of Total Gifts Per Person/Day

		Mean	Median	Geometric Mean
		{uncontrolled for repeat measures}		*{controlled for repeat measures}*
Total Gifts Given	Kilocalories per person/day	969	202	136
Total Gifts Received	Kilocalories per person/day	1,742	315	368

3.4.2.1 Explanatory Variables & Gifts

Explanatory factors were tested for associations with whether or not a woman gave any gifts and whether or not a woman received any gifts. GLMMs with family set to binomial and camp and woman as crossed random factors were applied. Categorical variables were created for gifts given and gifts received, and the model averaging simulation was run.

Gifts were significantly more likely to be given during longer trips ($p < .025$). (Though this is to be expected given that the longer the observation, the greater the likelihood of observing gift transfers.) Season (four season designation, $p < .01$) and year ($p = .005$) were also found to be significantly associated with whether or not gifts were given. Gifts were less likely to be given during the early dry season (Tukey post-hoc test, $p < .025$) and in 2004 (Tukey post-hoc test, $p < .0001$). Although there is no significant correlation between year and season ($n = 10$ camps, 3x3 contingency table, Fisher's exact test, $p = $ ns), the data from 2004 only includes follows from the early dry season. When included in a generalized linear mixed model with trip duration and year, season lost significance, suggesting that year was the more important factor and accounted for the significant association of the early dry season. A model of both year and trip duration had a lower AIC and higher R-squared compared to models of either variable alone ($R^2 = 0.20$). The year 2004 was associated with an 85% decrease in the likelihood of giving a gift (OR = 0.15, 95% CI: [0.10, 0.23]). Additionally, every one hour increase in trip duration increased the likelihood of giving a gift by 15% (OR = 1.15, 95% CI: [1.09, 1.21]).

Trip duration ($p < .0001$), year ($p < .01$) and season (four season designation) ($p < .025$) were also significantly associated with receiving gifts. A generalized linear mixed model with all three variables displayed a lower AIC and higher R-squared ($R^2 = 0.43$). Gifts were more likely to be received on longer trips ($p < .0001$) and less likely to be received in the year 2004 (Tukey post-hoc test, $p < .0001$) and the early dry season (Tukey post-hoc test, $p < .001$). The year 2004 was associated with a 94% decrease in the likelihood of receiving any gifts (OR = 0.06, 95% CI: [0.03, 0.11]), and the early dry season was associated with a 36% decrease in the likelihood of receiving gifts (OR = 0.64, 95% CI: [0.36, 1.16]). Every one hour increase in trip duration increased the likelihood of receiving a gift by 38% (OR = 1.38, 95% CI: [1.29, 1.48]).
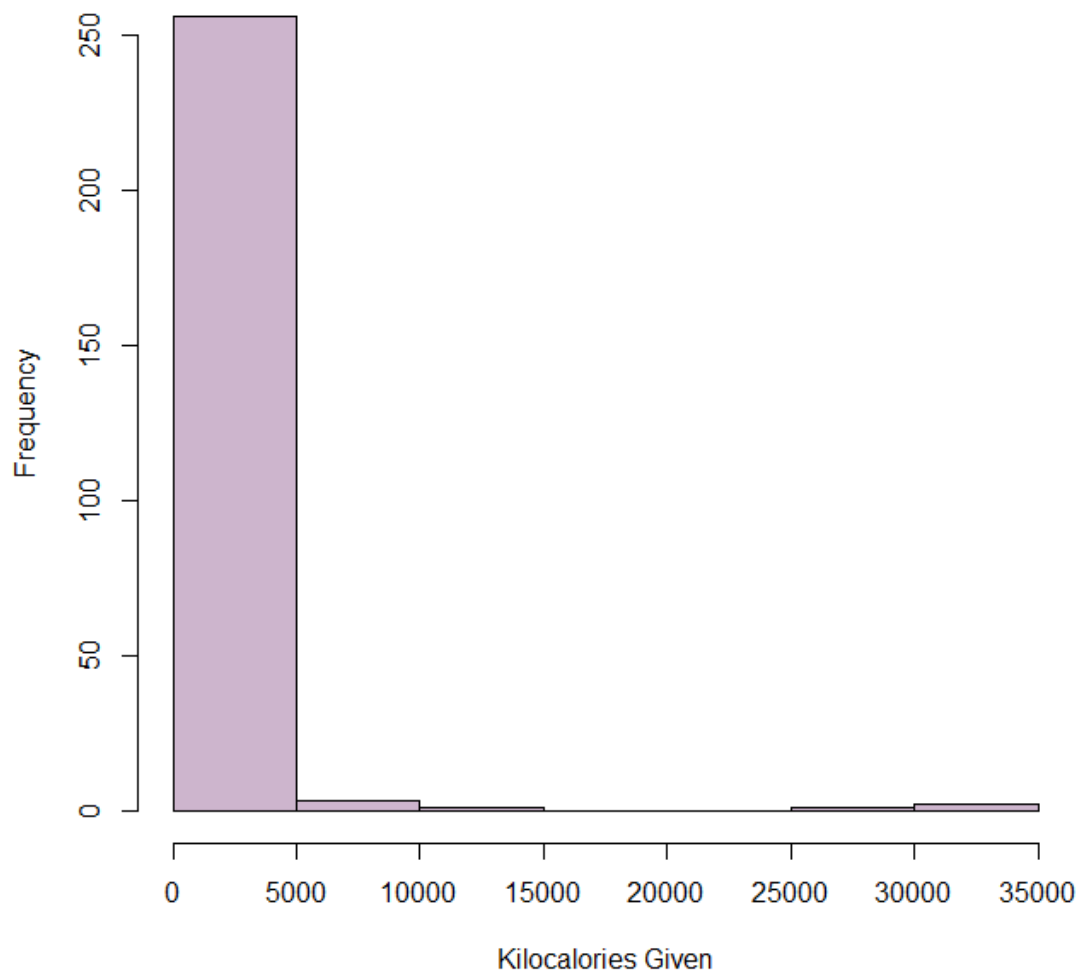
Figure 3.5 Total Kilocalories Given as Gifts per Follow ($n = 263$).
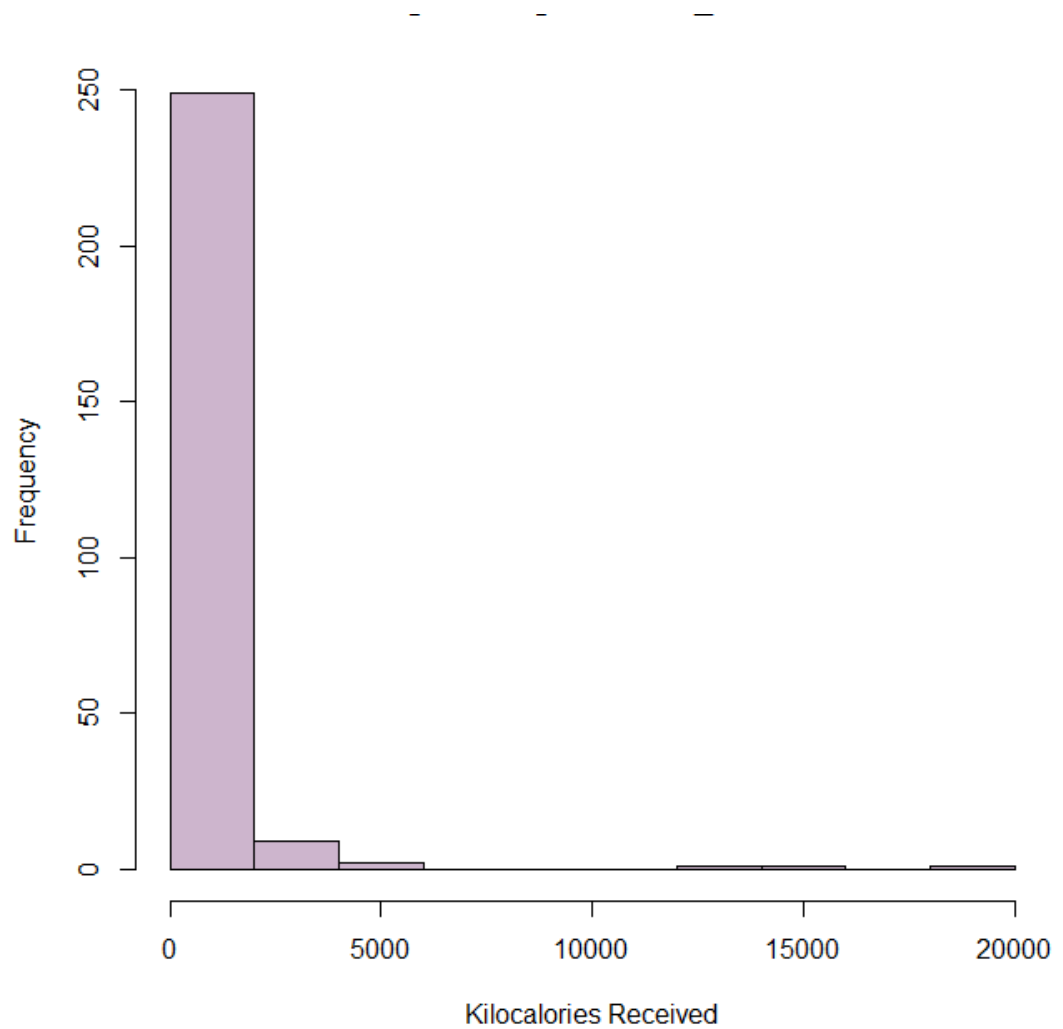
Figure 3.6 Total Kilocalories Received as Gifts per Follow (*n* = 263).
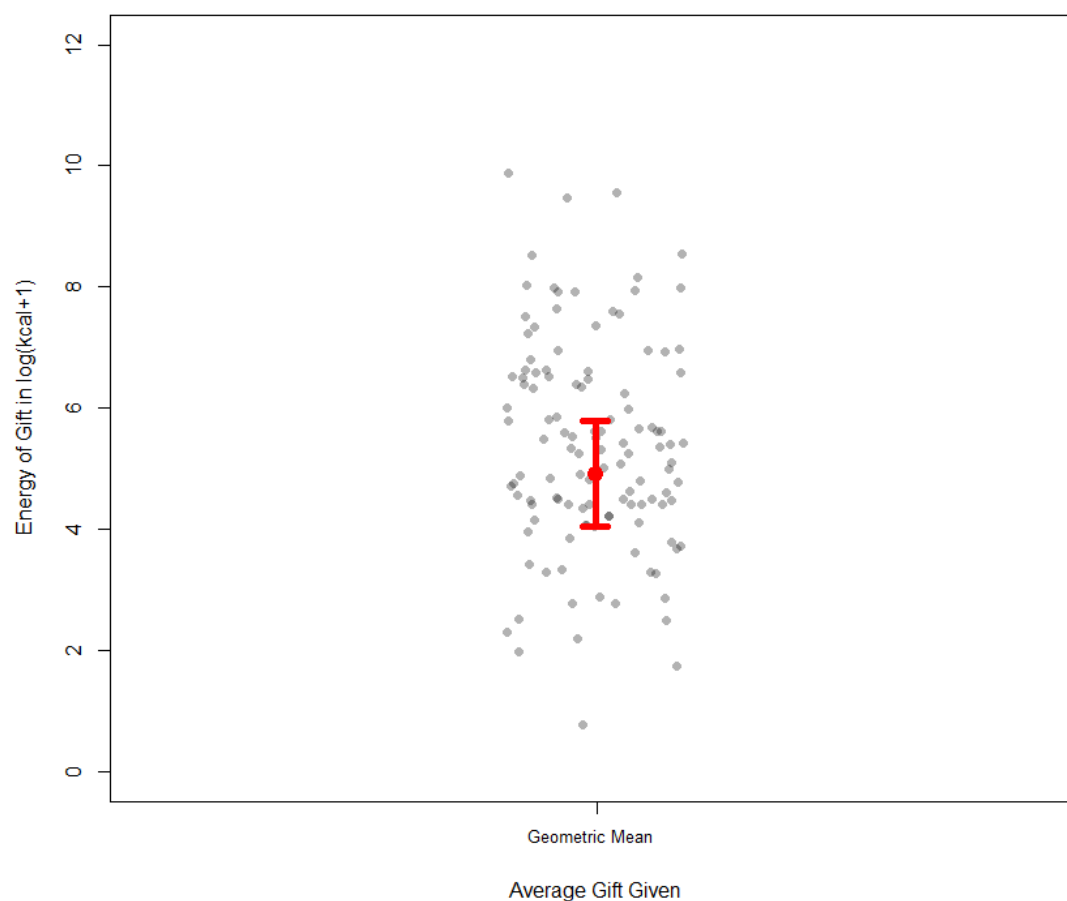
Figure 3.7 Average Energy of Total Gifts Given per Follow (*n* = 119). The sample
   size is per follow with at least one gift given. The red error bar represents
   the 95% confidence interval.
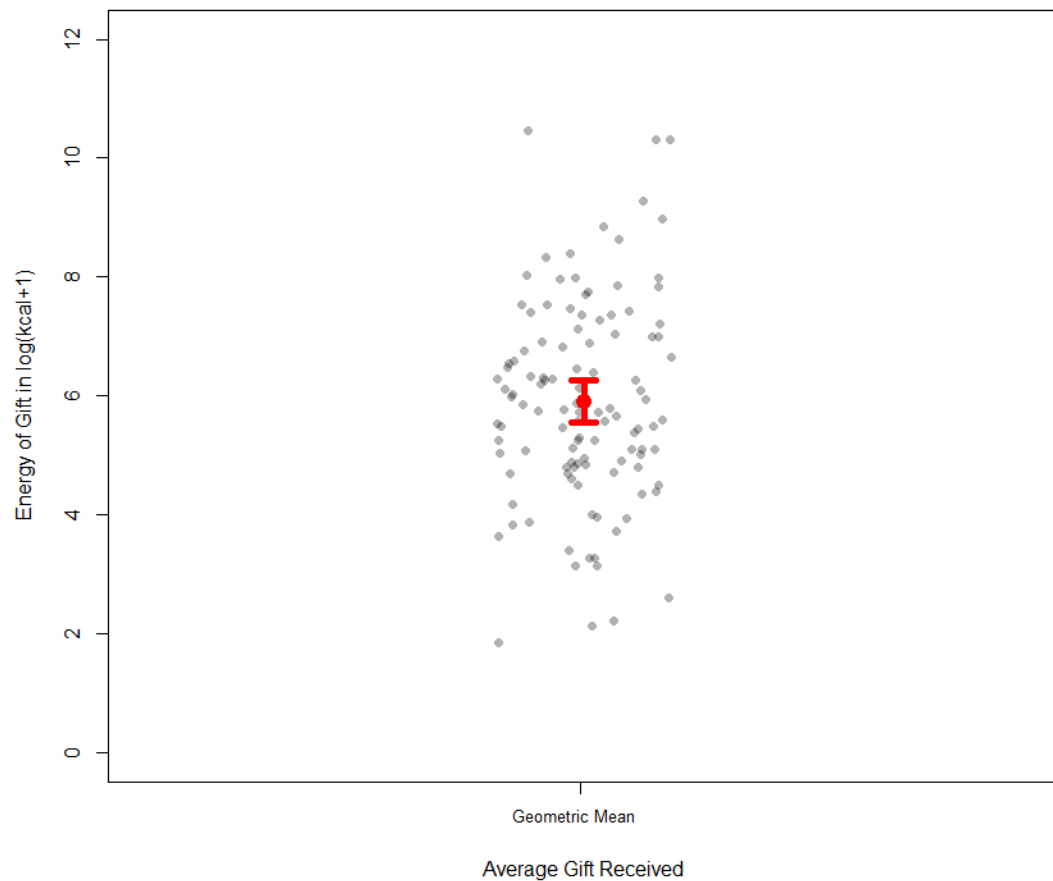
Figure 3.8 Average Energy of Total Gifts Received per Follow ($n = 115$). The sample size is per follow with at least one gift received. The red error bar represents the 95% confidence interval.

3.4.2.2   Explanatory Variables & Amount Given or Received

The total amounts of gifts given and gifts received were then examined with respect to explanatory variables. The explanatory variables were run in a model averaging simulation for a linear mixed model. Only year ($p < .005$) and trip length ($p < .0005$) were found to be significantly associated with the amount of total kilocalories given per woman ($n = 119$, limited to those follows with gifts given). Pairwise post-hoc testing revealed a significant difference between years 2004 and 2005 (Tukey post-hoc test, $p < .0001$), with less kilocalories given in 2004. Nevertheless, trip duration appears to be a more important factor. In comparing linear mixed models of trip duration alone, year alone, and both combined, a linear mixed model with trip duration had the highest R-squared ($R^2 = 0.45$). The longer the trip, the more total kilocalories given as gifts. The size of the effect was moderate ($d = 0.46$).

Similarly, only trip length was significantly associated with total kilocalories of gifts received ($n = 115$, limited to those follows with gifts received, $p < .025$). The effect size was moderate ($d = 0.33$), and the amount of variance explained by trip duration was very limited ($R^2 = 0.08$). Evidently, trip duration had a stronger effect on total kilocalories of gifts given than gifts received. Table 3.7 summarises the significant associations between explanatory variables and gifts given and Table 3.8, between explanatory variables and gifts received.

Additional tests were conducted to determine if total kilocalories of gifts given affected gifts received or vice versa (linear mixed models, $n = 119$ for gifts given and $n = 115$ for gifts received). Neither total kilocalories given nor total kilocalories received during a single trip were significantly associated with one another.

Table 3.7 Summary of Significant Associations for Gifts Given

Category	Variable	Significance	Effect
Trip	Trip Duration	$p < .0001$ gift given	Increased likelihood of giving $R^2 = 0.20$, OR = 1.15
		$p < .0005$ amount given	Increased total given $R^2 = 0.45$, $d = 0.46$
	Distance	*ns*	
Environment	Year	$p = .005$ gift given	Decreased likelihood of giving in 2004 $R^2 = 0.20$, OR = 0.15
	Two Season	*ns*	
	Four Season	*ns*	
	Region	*ns*	
Personal	Age	*ns*	
	BMI	*ns*	
Family	Husband	*ns*	
	No. of Children	*ns*	

Table 3.8 Summary of Significant Associations for Gifts Received

Category	Variable	Significance	Effect
Trip	Trip Duration	p < .0001 gift received	Increased likelihood of receiving $R^2 = 0.43$, OR = 1.38
		p < .025 amount received	Increased total received $R^2 = 0.08$, $d = 0.33$
	Distance	*ns*	
Environment	Year	*p* < .01 gift received	Decreased likelihood of receiving in 2004 $R^2 = 0.43$, OR = 0.06
	Two Season	*ns*	
	Four Season	*p* < .025 gift received	Decreased likelihood of receiving in early dry season $R^2 = 0.43$, OR = 0.64
	Region	*ns*	
Personal	Age	*ns*	
	BMI	*ns*	
Family	Husband	*ns*	
	No. of Children	*ns*	

3.4.3 Women's Foraging

The total amount foraged was calculated using Equation 1 defined in Section 3.3. Total foraged per person/day outside of camp ranged from 250 to 26,490 kilocalories (n = 198)[13]. All follows had at least some kilocalories foraged. Figure 3.9 displays the distribution of kilocalories foraged. This non-normal distribution has a skewness of 1.93 and kurtosis of 6.95. The average amount foraged per person/day, not controlling for repeat measurements, is 5,255 kilocalories (SD = 5,162, median = 3,216).

Once again, a linear mixed models approach was used to determine a geometric mean that would control for repeated measures. The same random effect structure was applied as in analyses for eating and gifts. The distribution was first normalised through a logarithmic transformation. The geometric average for amount foraged per person/day is 3,556 kilocalories (95% CI: [2,557, 4,946]). Figure 3.10 demonstrates the logarithmic distribution and the geometric mean. Table 3.9 summarises the mean, median and geometric mean estimates.

Table 3.9 Estimating Average Kilocalories Foraged Outside of Camp Per Person/Day

	Mean	Median	Geometric Mean
	{uncontrolled for repeat measures}		*{controlled for repeat measures}*
Kilocalories per person/day	5,255	3,216	3,556

3.4.3.1 Explanatory Variables & Foraging

The explanatory variables were analysed in relation to total foraged, following the same procedures as with total eaten and total gifts given and received. (Because all women foraged at least some kilocalories, no analyses were conducted to test associations between explanatory factors and whether or not a woman foraged.) Only one factor was found to be significantly associated with total foraged in the linear mixed models analysis. Women foraged significantly more on longer trips ($p < .0001$, R^2 = 0.43). The size of the effect was large (d = 0.81). As with total consumption over time, total foraged was

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[13] Although all follows had data for eating and gift giving/receiving, not all follows had measurements for foods returned to camp. The sample size is thereby reduced from the original 263 follow days to 198 follow days.

also associated with an exponential increase over time. Figure 3.11 illustrates the association between amount foraged and the duration of the trip. Table 3.10 summarises the significant associations between total foraged and explanatory variables.

3.4.3.2 Eating & Foraging Relationship

Having explored total eaten and total foraged separately in relation to other factors, these two variables were then examined in relation to each other. A variable of proportion eaten (a ratio of eat to forage) was created to analyse whether the amount a woman foraged overall was associated with how much she ate relative to how much she foraged. In a linear mixed model, absolute kilocalories foraged (controlled for time) was not significantly associated with the ratio of kilocalories eaten to kilocalories foraged (also controlled for time). In other words, no significant association was observed between the relative amount a woman ate and the absolute amount she foraged.

Absolute kilocalories foraged was significantly associated with absolute kilocalories eaten (linear mixed model, $p < .0001$, $R^2 = 0.46$). This was expected since total eaten is factored into the calculation of total foraged. When time was taken into account, the relationship remained positive and significant: kilocalories foraged per hour were significantly associated with kilocalories eaten per hour ($p < .0001$, $R^2 = 0.45$).
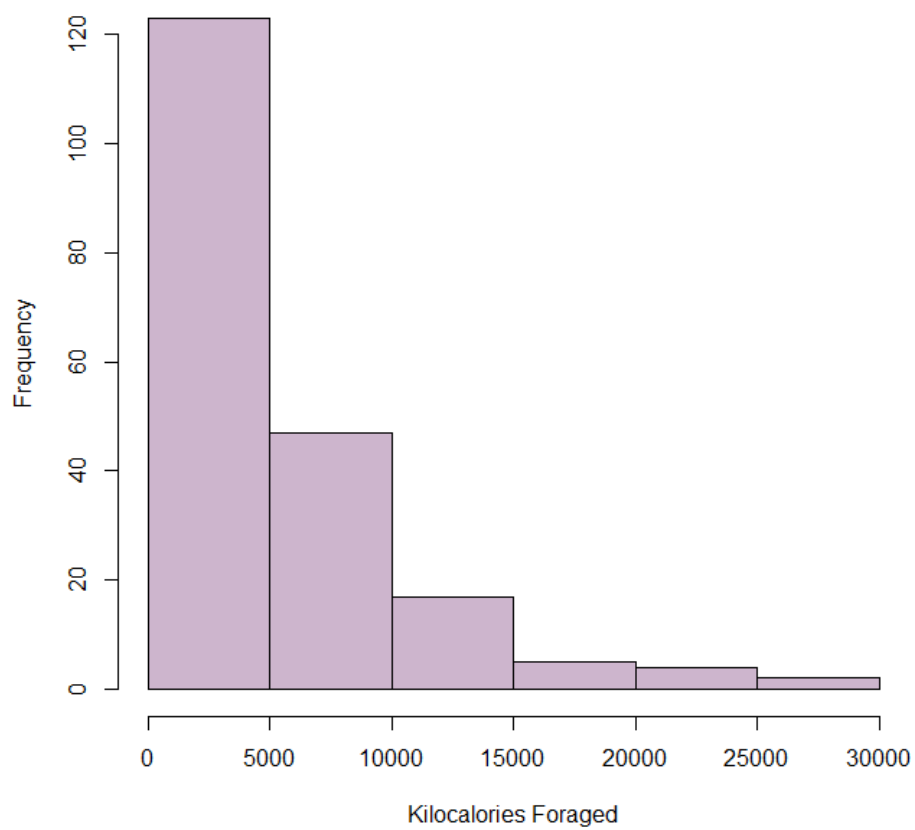
Figure 3.9 Total Kilocalories Foraged per Follow (*n* = 198).
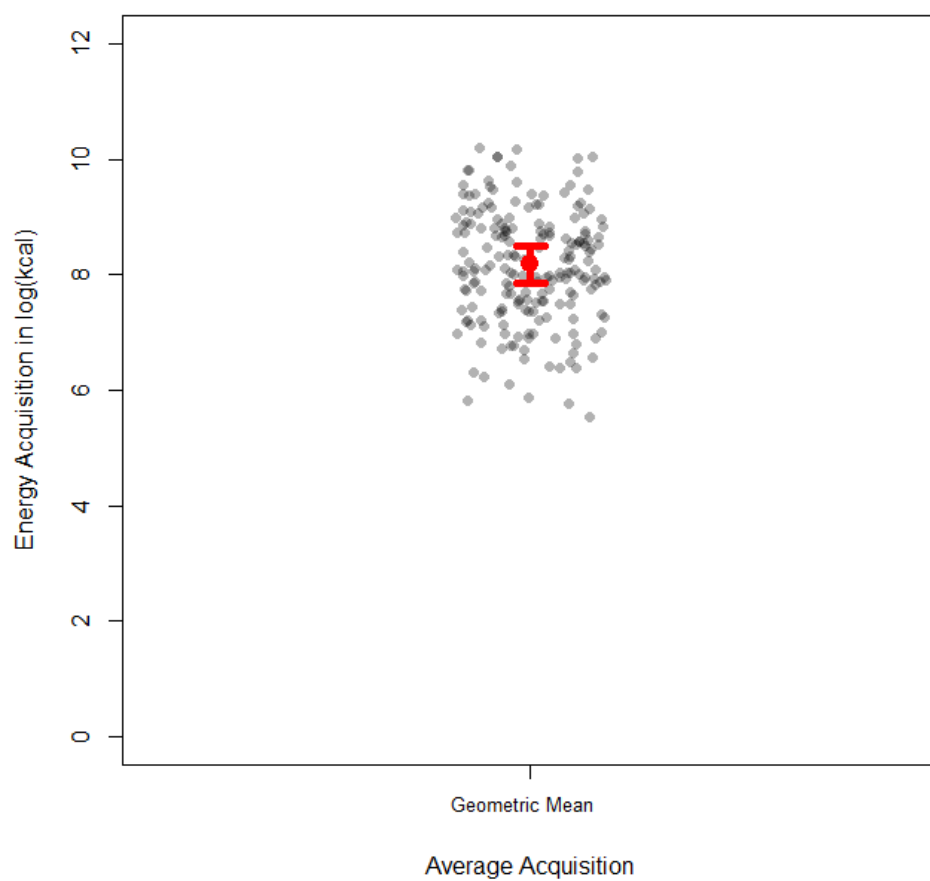
Figure 3.10 Average Energy Acquisition per Follow (*n* = 198). The red error bar
represents the 95% confidence interval.
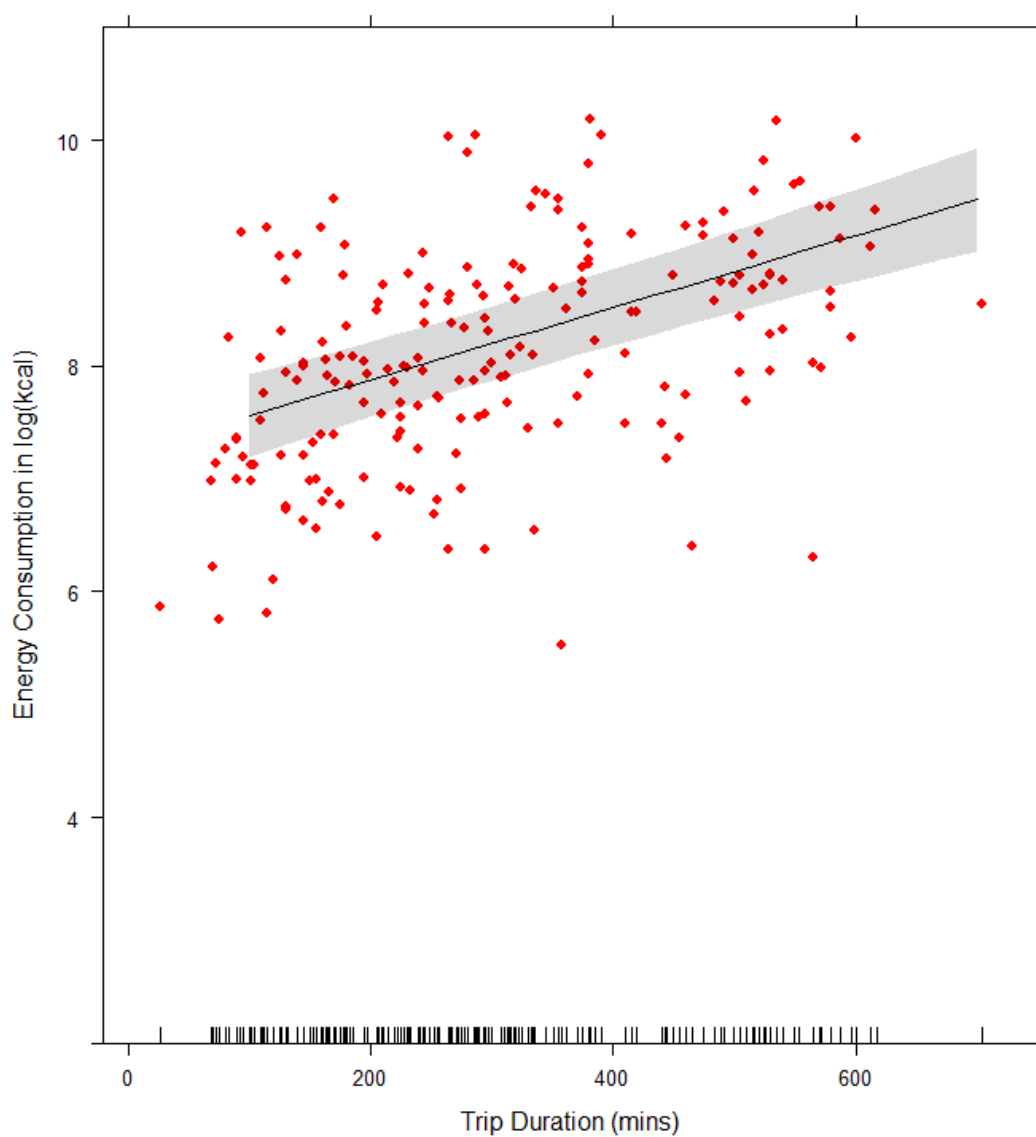
Figure 3.11 Kilocalories Foraged over Time (*n* = 198).

Table 3.10 Summary of Significant Associations for Food Foraged

Category	Variable	Significance	Effect
Trip	Trip Duration	$p < .0001$	Increased total foraged $R^2 = 0.43$, $d = 0.81$
	Distance	*ns*	
Environment	Year	*ns*	
	Two Season	*ns*	
	Four Season	*ns*	
	Region	*ns*	
Personal	Age	*ns*	
	BMI	*ns*	
Family	Husband	*ns*	
	No. of Children	*ns*	

3.4.4 Breakdown of Food Types

While the previous analyses presented an overall estimation of food eaten, food foraged and food given/received, the following section provides greater granularity with respect to food type. Eating, gifts and foraging are once again examined, but with respect to the five food types.

3.4.4.1 Frequency of Food Type Eaten & Acquired

In descending order of instances eaten outside of camp, the five most important food types were berries/fruits, tubers, honey, baobab and small game. Their relative frequency was consistent across both seasons. Figure 3.12 illustrates how frequently each food type was eaten during the dry and wet seasons.

Berries/fruits was the only food group consistently eaten outside of camp for all ten camps. Figure 3.13 demonstrates the breakdown of eating frequency across the ten camps. For the majority of camps ($n = 7$), berries/fruits were also the most frequently eaten in terms of total number of instances. For the remaining three camps, tubers surpassed berries/fruits as most frequently eaten.

Three other food types had minimal representation in the data sample: other vegetables (not tubers), large game, and agricultural products. In only one instance was a woman observed eating non-tuberous 'vegetables' (i.e. some grasses/herbs). Similarly, in only one instance was a woman observed eating large game: warthog meat, which she received as a gift. As for agricultural products, there were seven recorded instances. Six of these instances were all in the same camp, with three instances attributed to a single woman.

The same five food types were most frequent for foods acquired (agricultural products, vegetables and large game were not foraged by the women). The frequency distribution of food types acquired during both seasons is illustrated in Figure 3.14. Their distribution is similar to their distribution of foods eaten by season in Figure 3.12, with slight differences in baobab's ranking for both seasons and tuber's ranking for the wet season.

Across the two seasons, there is no significant difference for frequency of food types acquired ($n = 283$ instances of food types acquired , 2x5 contingency table of season by food type, Fisher's exact test, $p =$ ns). Figure 3.15 displays the frequency of food types acquired for the ten camps. Berries/fruits were again the only food types consistently foraged across all camps. Furthermore, berries/fruits were the most frequently acquired for the majority of camps ($n = 8$), with the remaining camps acquiring tubers more frequently.

Having considered the frequency of food types eaten and food types acquired, an additional frequency measure was considered: how often foods were eaten when they were acquired. Table 3.11 summarises the three different frequencies. Given the mismatch in the number of person/days with eating data and acquisition data, the total instances of eating data are drawn from 263 person/days while the total instances of acquired data are drawn from 198 person/days.

Table 3.11 Frequency of Food Types Eaten and Acquired across Follows

Food Type	No. of follows eaten (% of total follows)	No. of follows acquired (% of total follows)	Follows eaten / follows acquired (%)
Berries/Fruits	156 (59%)	111 (56%)	104 / 111 (94%)
Tubers	106 (40%)	99 (50%)	90 / 99 (91%)
Honey	35 (13%)	22 (11%)	20 / 22 (91%)
Baobab	25 (10%)	32 (16%)	**20 / 32 (63%)**
Small Game	18 (7%)	19 (10%)	14 / 19 (74%)

In terms of how often a food was acquired and eaten, baobab appears to be treated differently. It is eaten in the fewest instances that it is acquired (see highlighted value). This is also consistent with baobab's relative change in frequency between, for example, Figure 3.12 and Figure 3.14. Small game also has a small percentage, while the other food types are eaten at least 91% of the instances they are acquired.

A Fisher's exact test was used to determine whether baobab and small game were being treated differently outside of camp. Comparing the frequency of foods eaten and acquired and foods not eaten and acquired, there was a significant difference across the five food groups (n = 283 instances, 2x5 contingency table, Fisher's exact test, p < .0001). To determine if baobab and small game were both contributing to this difference, baobab counts were excluded and a new Fisher's exact test was run. The result was no longer significant (n = 251 instances, 2x4 contingency table, p = ns), suggesting that baobab is the only food type treated significantly differently for how often it is eaten relative to how often it is acquired.
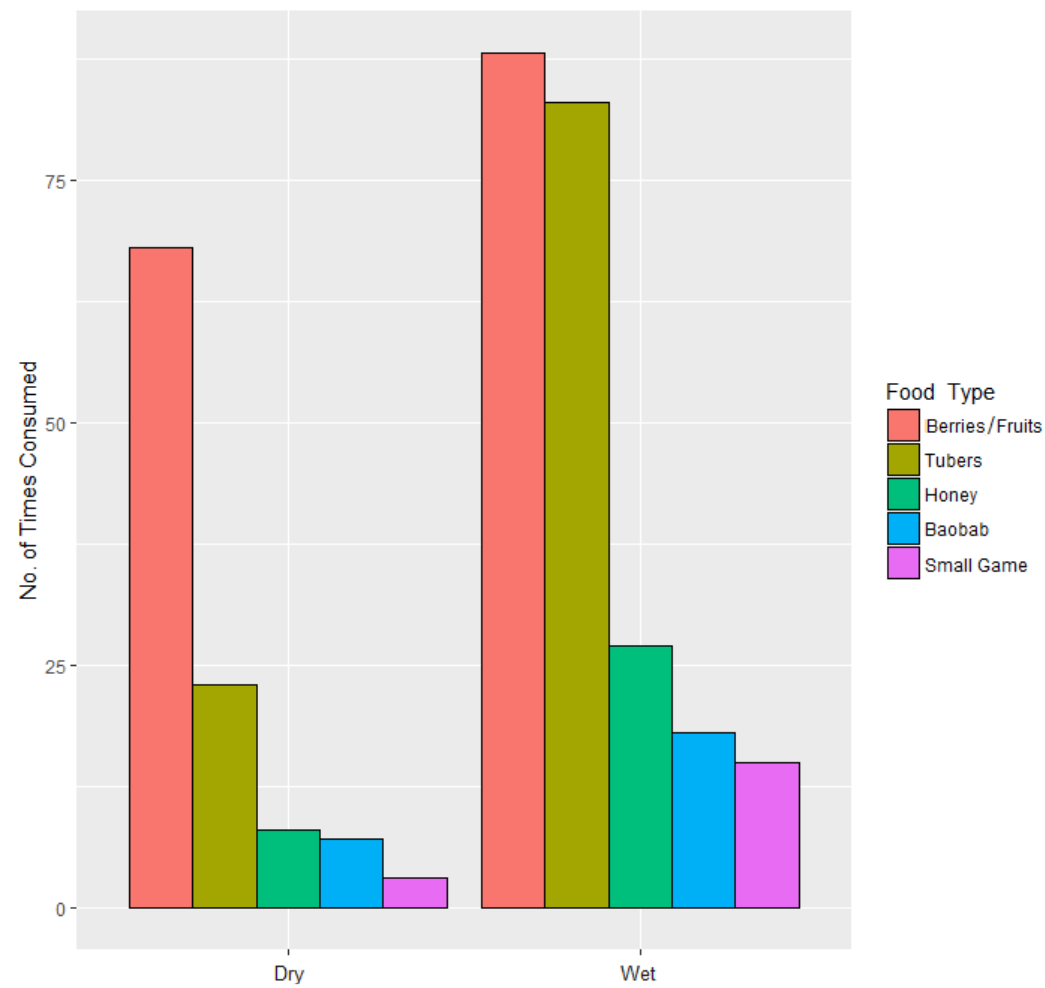
Figure 3.12 Frequency of Food Type Consumed by Season (*n* = 283).
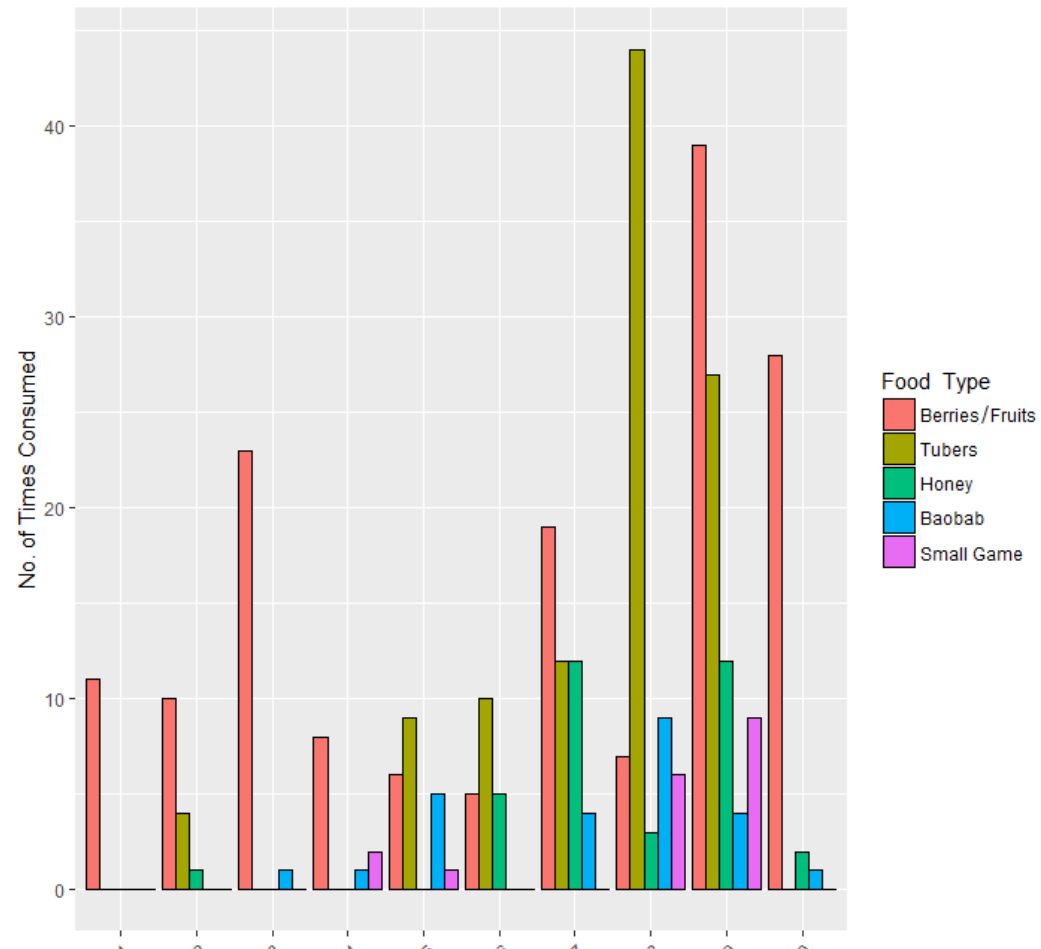
Figure 3.13 Frequency of Food Type Consumed by Camp (*n* = 283).
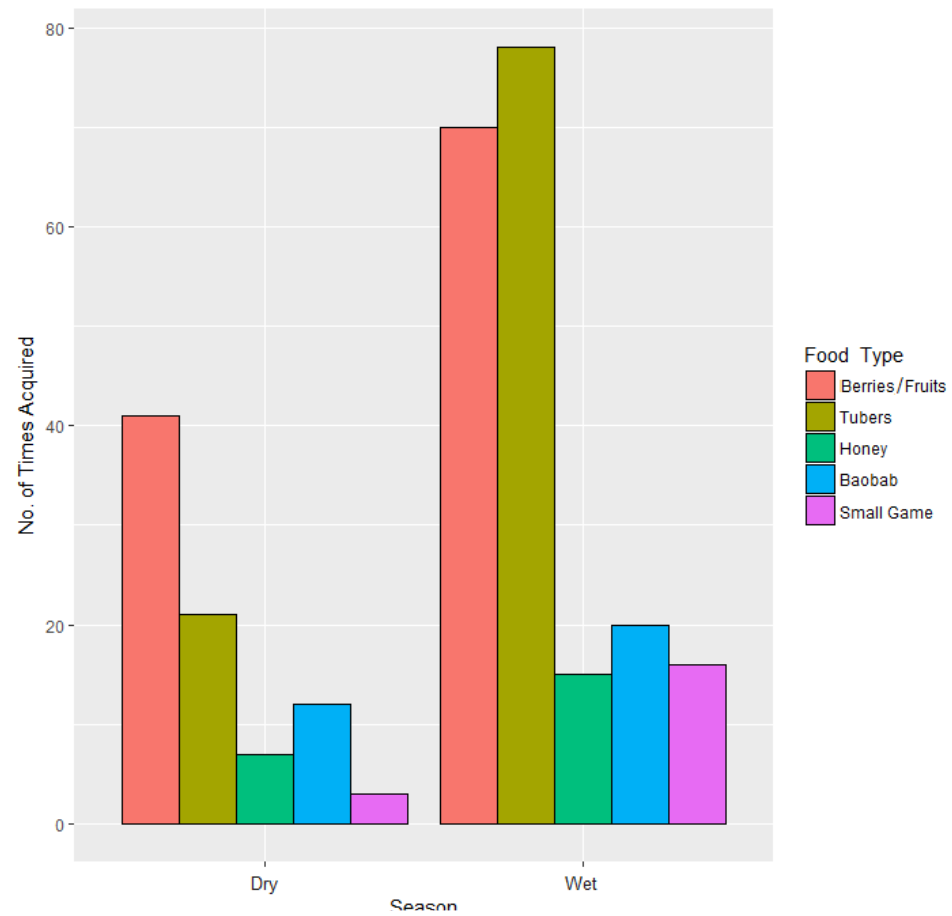
Figure 3.14 Frequency of Food Type Acquired by Season (*n* = 283).
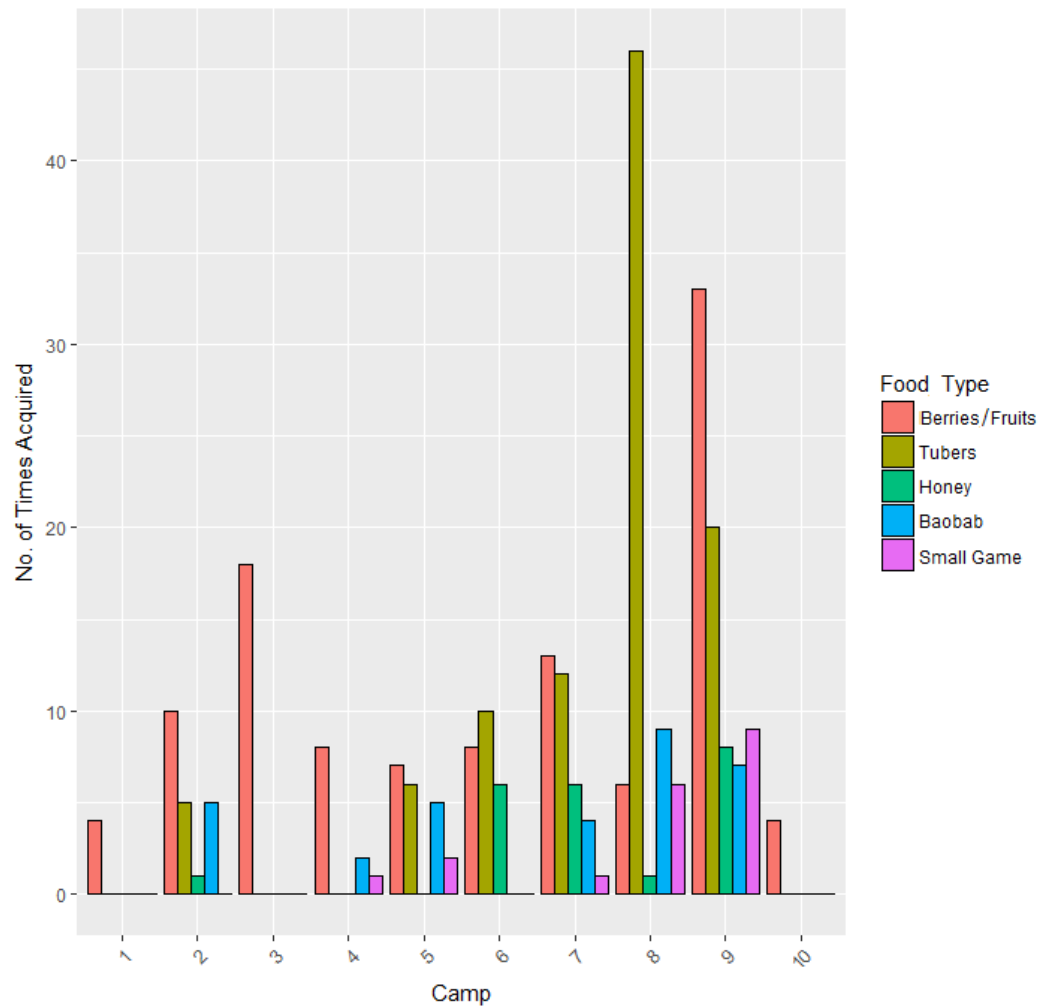
Figure 3.15 Frequency of Food Type Acquired by Camp (*n* = 283).

3.4.4.2 Kilocalories & Food Type

The food types were then examined in relation to caloric contributions. Each food type eaten and acquired had a wide range of kilocalories, with the two most calorific food types (baobab and honey) displaying the widest ranges. Table 3.12 presents the descriptive statistics for food types eaten and acquired. These descriptive statistics do not control for repeated measures across women and camps. The kilocalories eaten per hour and kilocalories acquired per hour are calculated from total kilocalories per person/day and total duration of observation hours per person/day (for that particular food type).

Table 3.12 Descriptive Statistics of Kilocalories Eaten and Acquired by Food Type

Food Type	Mean/Median *range* kcal eaten/follow	Mean/Median *range* kcal acquired/follow	SD kcal eaten/ SD kcal acquired	Mean/Median kcal eaten/hour	Mean/Median kcal acquired/hour
Berries/Fruits	251 / 41 *0 – 3,526*	1,988 / 86 *0 – 17,240*	452 / 3,244	92 / 60	768 / 527
Tubers	461 / 0 *0 – 15,110*	1,341 / 20 *0 – 18,342*	1,404 / 2,538	206 / 102	605 / 437
Honey	476 / 0 *0 – 21,915*	378 / 0 *0 – 21,502*	2,643 / 2,249	583 / 240	596 / 241
Baobab	194 / 0 *0 – 15,357*	973 / 0 *0 – 22,257*	1,114 / 3,343	430 / 210	1308 / 438
Small Game	59 / 0 *0 – 2,148*	576 / 0 *0 – 14,093*	279 / 2,237	121 / 89	837 / 749

3.4.4.3 Frequency of Food Type Given & Received

Tubers were the most frequently given and the most frequently received. Table 3.13 presents the frequency of gifts given and received for all five food types. In terms of relative frequencies, honey seems to be treated differently between gifts given and gifts received (see highlighted values). For the four other food types, the relative frequency is similar between given and received, with a difference ranging from 0% (small game) to a difference of 7% (berries/fruits). In other words, the other types were usually given as

often as they were received. For honey, however, the difference is a 16% change, with more honey received than given. McNemar's test, used to analyse significant differences in proportions which are not independent, was applied. This test confirmed that honey was received significantly more frequently than it was given (n = 234, 2 x 2 contingency table, McNemar's test, p < .0001).

Table 3.13 Frequency of Food Types for Gifts Given and Received

Food Type	No. of follows given (% of total follows given)	No. of follows received (% of total follows received)
Berries/Fruits	35 (29%)	25 (22%)
Tubers	69 (58%)	60 (52%)
Honey	**6 (5%)**	**24 (21%)**
Baobab	7 (6%)	13 (11%)
Small Game	13 (11%)	13 (11%)

3.4.4.4 Gifts Received

When gifts were received by a woman, she faced the choice of consuming all gifts, consuming some gifts and saving the rest for later or saving all gifts to bring back to camp. Food type was examined in relation to these decisions. Table 3.14 summarises the frequencies of each choice related to total gifts received across the food groups. Again, baobab seems to be treated much differently from the other food types: more of the baobab gifts are saved to be brought back to camp rather than consumed immediately. Berries/fruits appear to be treated similarly.

A 2x5 contingency table was created to compare food received and eaten wholly or partially to food received and not consumed across the food groups. The Fisher's exact test was significant (n = 135, p < .0001), suggesting that baobab and/or berries/fruits were treated differently. After removal of baobab, another Fisher's exact test was run and the result was again significant (n = 122, p < .01). Both baobab and berries/fruits (highlighted values) seem to be treated differently in terms of how often they are not consumed relative to how often they are received as gifts.

Table 3.14 Breakdown of Gifts Received by Food Type and Proportion of Immediate Consumption

Food Type	No. of follows received and fully consumed (% of follows received per food type)	No. of follows received and partially consumed (% of follows received per food type)	No. of follows received and not consumed (% of follows received per food type)
Berries/Fruits	8 (32%)	6 (24%)	**11 (44%)**
Tubers	**42 (70%)**	11 (18%)	7 (12%)
Honey	**19 (79%)**	2 (8%)	3 (13%)
Baobab	2 (15%)	2 (15%)	**9 (69%)**
Small Game	7 (54%)	3 (23%)	3 (23%)

In contrast to the treatment of berries/fruits and baobab, tubers and honey have relatively low percentages of not being consumed. Because Fisher's exact test reveals whether there are significant differences, not *where* those differences lie, the much lower percentages for tubers and honey may also be contributing to the significant finding across food groups. When examining only food consumed wholly, it appears that honey and tubers have relatively high percentages for whole consumption on the spot (fitting directly with the low percentages of not being consumed).

A 2x5 contingency table was set up to compare food received and eaten wholly to food partially eaten and food not consumed. This Fisher's exact test revealed again a significant difference across food groups ($n = 135$, $p < .0001$). Since this result could be reflective of baobab's different treatment (having such a lower percentage eaten wholly), baobab was removed and a 2x4 contingency table created. The result remained significant ($n = 122$, $p < .0001$), suggesting that tubers and honey are being treated significantly differently as foods consumed wholly on the spot.

3.4.4.5 Kilocalories & Gifts

Next, gifts were examined with respect to actual calorific amount. Table 3.15 summarises calorific data for gifts given and received. These values are not controlled for repeat measurements and are restricted to those follows where gifts were given ($n = 119$) and received ($n = 115$). With the exception of berries/fruits as gifts given, all other food types had wide ranges in total kilocalories given or total kilocalories received.

Table 3.15 Descriptive Statistics of Gifts Given and Received

Food Type	Mean/Median* *range* kcal given /follow	Mean/Median* *range* kcal received/follow	SD kcal given/ SD kcal received
Berries/Fruits	64 / 33 *1 – 276*	370 / 52 *4 – 2,816*	70 / 676
Tubers	730 / 275 *27 – 5,207*	1,104 / 203 *5 – 34,791*	1039 / 4,518
Honey	4,283 / 406 *67 – 19,688*	3,931 / 962 *5 – 30,016*	7,113 / 7,944
Baobab	4,291/ 657 *82 – 14,021*	866 / 492 *33 – 2,462*	5867 / 757
Small Game	465 / 227 *20 – 2,097*	310 / 76 *25 – 1,689*	614 / 489

*Mean and median calculated from only those follows where gifts were present.

Food types were examined to see whether the calorific amount a woman received was associated with the amount she consumed while outside of camp. Linear mixed models with the same structure as previous analyses were applied. For analysis of berries/fruits, there was no significant relationship between total kilocalories received and total eaten ($n = 25$). This is consistent with the majority of berries/fruits gifts not being eaten. Similarly, no relationship was found for baobab ($n = 13$), nor for small game ($n = 13$). The lack of a relationship for baobab is again consistent with the majority of baobab gifts not being consumed.

Both tubers ($n = 60$, $p < .0001$) and honey ($n = 24$, $p < .0001$) demonstrated significant positive relationships between total received and total eaten. The more kilocalories received of tubers and honey, the more that was consumed immediately on the spot. However, both food types had two substantially high outliers which may have been affecting the result. The top two outliers, based on two standard deviations from the mean, were excluded for tubers (34,791 and 7,859 kilocalories) and honey (20,016 and 28,803 kilocalories). With outliers removed, the relationship between total received and total eaten remained positive and significant (tubers: $n = 58$, $p < .0001$; honey: $n = 22$, $p < .0001$). Both models explained substantial variance for total kilocalories eaten of the gifts received (tubers: $R^2 =0.90$, honey: $R^2 =0.97$). Figure 3.16 and Figure 3.17 display the relationships for tubers and honey, respectively. The relationships have similar slopes: 0.93 for tubers

and 1.00 for honey. The women ate very close to or exactly the full amount they received for tubers and honey across the amounts received.

3.4.4.6 Kilocalories & Eat to Forage Ratio

The relationship between total eaten and total foraged was investigated by food type. Namely, to what extent amount foraged is associated with amount eaten and to what extent total foraged per hour is associated with total eaten per hour. Linear mixed models with the same structures were applied to the five food types.

Acquiring more kilocalories while foraging was associated with eating more kilocalories while out of camp. This relationship was positive and significant for all food types. Table 3.16 displays the slope of the relationships across the food types. The slope of the relationships was highest for honey and tubers at 0.63 and 0.46, respectively. The remaining food types had lower slopes (baobab: 0.17, small game: 0.10, and berries/fruits: 0.07). Though more food is eaten as food is foraged, baobab, small game and berries/fruits are eaten in the lowest proportions outside of camp.

When factoring in time, acquiring more kilocalories per hour foraged was significantly associated with eating more kilocalories per hour for each food type but honey. Table 3.16 summarises the different slopes across the food types. The slopes for baobab (0.12), small game (0.10), and berries/fruits (0.06) remained the same or very similar for the slopes of absolute foraged kilocalories to absolute consumed kilocalories. For tubers, on the other hand, the slope decreased to 0.27, so a smaller proportion of tubers are consumed in relation to total foraged if time is taken into consideration.

Table 3.16 Summary of Eat to Forage Ratios across Food Types

Food Type	Eat to Forage Ratio	Eat per Hour to Forage per Hour Ratio
Berries/Fruits ($n = 111$)	0.07 $p < .001$ $R^2 = 0.44$	0.06 $p < .0005$ $R^2 = 0.50$
Small Game ($n = 19$)	0.10 $p = .005$ $R^2 = 0.37$	0.10 $p = .002$ $R^2 = 0.44$
Baobab ($n = 32$)	0.17 $p < .025$ $R^2 = 0.96$	0.12 $p < .025$ $R^2 = 0.99$
Tubers ($n = 99$)	0.46 $p < .0001$ $R^2 = 0.79$	0.27 $p < .0001$ $R^2 = 0.33$
Honey ($n = 22$)	0.63 $p < .005$ $R^2 = 0.45$	*ns*
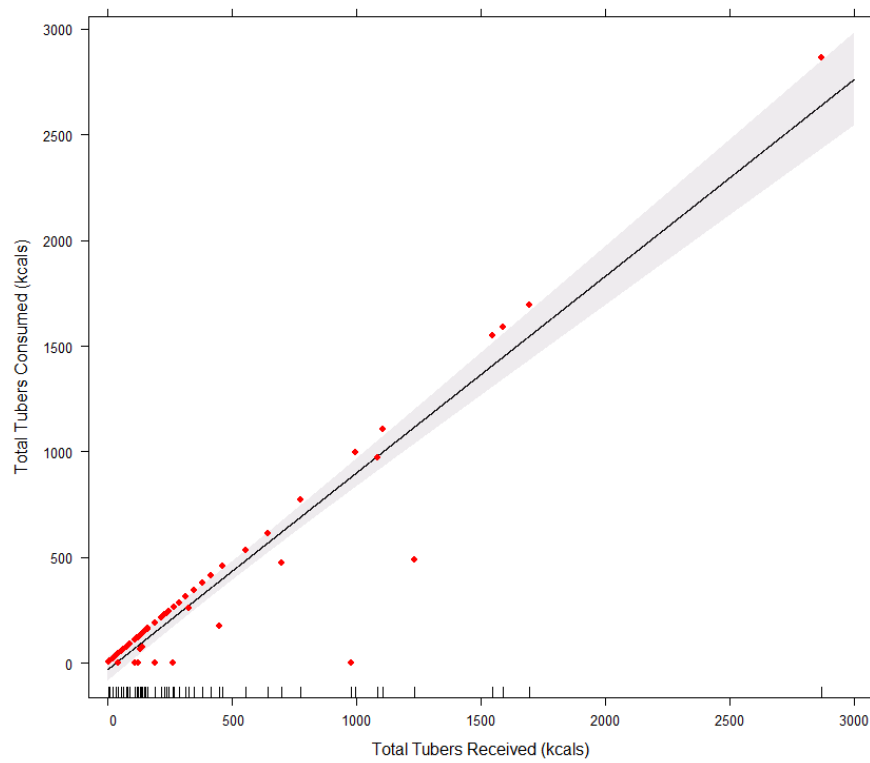
Figure 3.16 Kilocalorie Consumption of Tubers Relative to Amount Received as Gifts (*n* = 58).
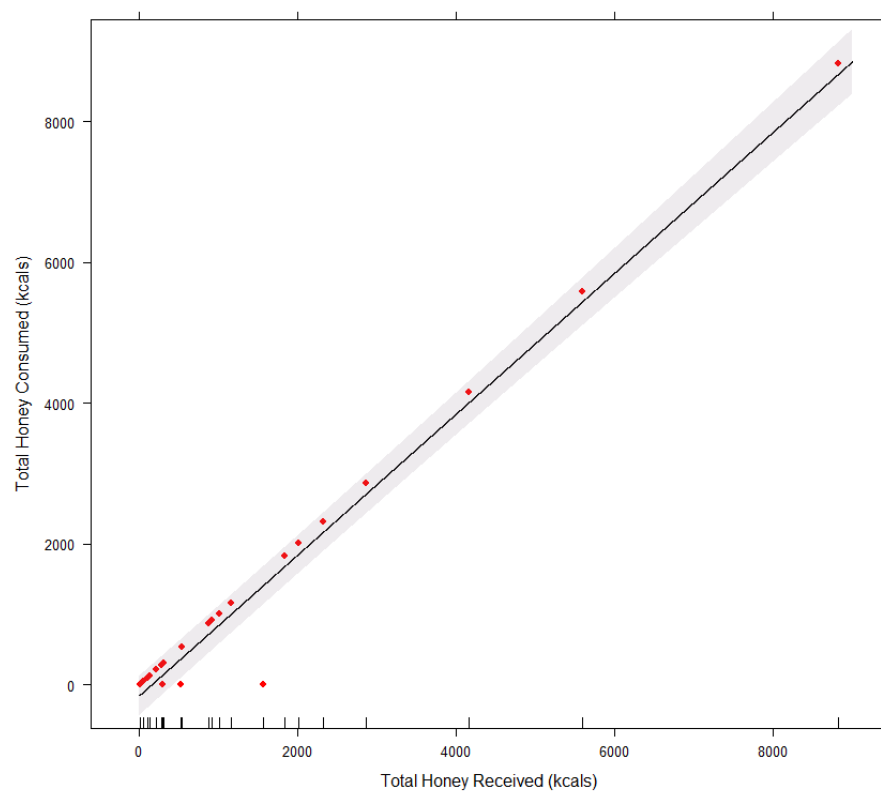
Figure 3.17 Kilocalorie Consumption of Honey Relative to Amount Received as Gifts (*n* = 22).

3.4.4.7   Honey & *Quelea*

Two food types were examined in further detail: honey and small game (specifically *Quelea*). Given the results of Berbesque *et al.* (2016), honey is a significant factor for men's out of camp eating. Additionally, *Quelea* chicks represent an unusual windfall in kilocalories due to *Quelea*'s mass reproductive synchrony (see description in Section 1.4.3). They also account for the majority of women's small game foraging: *Quelea* were foraged on 74% of all days with small game acquisition by women ($n = 19$). These two food sources were investigated in relation to eating, gifts and foraging. Two dichotomous factors were created, the presence/absence of honey and the presence/absence of *Quelea* chicks. The presence of honey defines those follows where honey was acquired or available (either through foraging or through sharing), and the presence of *Quelea* defines those follows where *Quelea* was acquired.

Quelea was significantly associated only with total foraged. Women foraged significantly more kilocalories in the presence of honey ($p < .025$) and significantly more kilocalories in follows with *Quelea* chicks ($p = .005$). In comparing linear mixed models with different combinations of honey, *Quelea* and trip duration, a model with all three variables had the lowest AIC and highest R-squared ($R^2 = 0.49$). Honey ($d = 0.25$) and *Quelea* ($d = 0.26$) had similarly small effect sizes. [Trip duration, in contrast, displayed a stronger effect ($d = 0.81$).] The median kilocalories foraged increased from 3,158 in the absence of honey to 4,972 in its presence. For *Quelea*, the median increased from 3,049 kilocalories in its absence to 7,665 kilocalories in its presence. To be noted, *Quelea* alone accounted for 92% of all kilocalories foraged on those person/days where *Quelea* was foraged ($n = 14$).

Honey ($n = 263$, $p < .0001$) was significantly associated with the total kilocalories eaten per person/day. A linear mixed model with both trip duration and honey had a lower AIC and higher R-squared than models with honey or trip duration alone ($R^2 = 0.37$). Honey had a medium effect on eating ($d = 0.44$), with a median of 1,614 kilocalories consumed in the presence of honey and a median of 426 kilocalories consumed in its absence.

That honey was significantly associated with more kilocalories eaten was not surprising, given its status as the most energy-rich resource. However, its presence on follow days might be obscuring other explanatory variables significantly associated with increased consumption. Model averaging was again applied, with a restricted sample of those person/days where honey was absent. Trip duration retained its significant association with total consumption ($n = 228$ with honey excluded, $p < .0001$, $R^2 = 0.32$). Region also emerged as a significantly associated factor, with Sipunga having significantly more

kilocalories than the other regions (n = 228 with honey excluded, p < .05). However, in a model with both trip duration and region, region lost its significance. Time thereby remained the most important predictor for consumption in the absence of honey.

As for gifts, honey was associated with an increased likelihood of receiving gifts. Women were more likely to receive gifts in the presence of honey (n = 263, generalized linear mixed model, p < .001). A model with year, honey and trip duration had the lowest AIC and highest R-squared (R^2 = 0.46). The presence of honey increased the likelihood of receiving gifts by fourfold (OR = 4.33, 95% CI: [2.50, 7.50]). Honey was also significantly associated with an increase in the total calorific amount of gifts received. A linear mixed model with trip duration and honey had a lower AIC and higher R-squared (R^2 = 0.15) than a model of trip duration alone. Honey had a moderate effect on total amount received (d = 0.42). The median amount of total gifts received in the absence of honey was 249 kilocalories per person/day compared to the median amount of 954 kilocalories received in its presence.

Honey was significantly associated with total foraged (as noted above) and was the only factor found to be significantly associated with the ratio of kilocalories eaten to kilocalories foraged. The presence of honey was significantly associated with higher ratios (p < .0005, R^2 = 0.21). The size of the effect was moderate (d = 0.35). The median proportion of kilocalories consumed was 46% of total foraged in the presence of honey and 15% of total foraged in its absence.

When follows with honey were excluded from analyses, however, two other factors were found to be significantly associated with the ratio of amount eaten to amount foraged. Trip duration and the presence of *Quelea* chicks were significantly associated with the ratio (n = 175). A linear mixed model of both trip duration (p < .0005) and chicks (p = .010) had the lowest AIC and a similar R-squared to honey (in context of full dataset) (R^2 = 0.22). Longer trips were associated with higher eat to forage ratios, whereas *Quelea* had the opposite effect: the presence of chicks produced lower eat to forage ratios. Trip duration (d = 0.39) and chicks (d = 0.30) both had moderate effects.

3.5 Discussion

3.5.1 Eating

Hadza women are eating fewer kilocalories outside of camp than men are eating. The geometric mean derived from this study of 326 kilocalories consumed per day is more than seven times lower than the mean reported for men, 2,405 kilocalories per day (Berbesque *et al.*, 2016). However, the two studies used different methodologies for deriving the mean estimate. The mean derived from Berbesque *et al.* did not explicitly control for repeated measures. This is potentially problematic given that the women's mean without control for repeats is 1,488 kilocalories and with control for repeats is 326 kilocalories: a fourfold difference.

The mean without control for repeats is less indicative of actual kilocalories consumed per day for two reasons: 1) the distribution of kilocalories per person/day is highly skewed, 2) the measurements of kilocalories per person/day are not independent. The mean is very sensitive to outliers and skewness. Both the eating data for women (skewness = 4.62) and for men [skewness = 2.69 (Berbesque *et al.*, 2016)] are highly, positively skewed (though women's data even more so than men's data). In such circumstances, the median is a more appropriate indication of the central tendency of data. Comparing medians alone, the median for women is 553 kilocalories per person/day and for men, 910 kilocalories per person/day (Berbesque *et al.*, 2016), still suggestive of a large difference between the sexes.

Measuring the central tendency of the eating data is complicated by the presence of repeated measurements. Both the men [observed 1.95 times on average (Berbesque *et al.*, 2016)] and women (observed 2.4 times on average) have repeated measures. Calculating the mean or median of such repeated measures, regardless of skewness, is not appropriate because certain individual's measurements are given more weight than others. To address these issues, this study applied a mixed model approach which allows for control of repeat camps and repeat individuals.

When Berbesque *et al.* (2016) calculated that men consume approximately 90% of their TEE outside of camp, they used a mean without control for repeats. However, if the median estimate is applied instead, then Hadza men consume approximately 34% of their TEE outside of camp. Given the women's TEE of 1,788 kilocalories (Pontzer *et al.*, 2015), Hadza women consume approximately 18% of their TEE outside of camp. Hadza men appear to consume nearly double the proportion of their TEE than women consume, though the men's estimates would be improved by control for repeated measures.

Since TEE was found to be 1,788 kilocalories per day and Hadza women were observed to eat 326 kilocalories outside of camp, then we can expect that women who are not gaining or losing weight are eating around 1,400 kilocalories in camp per day. Calorific data for women's in-camp eating are not yet published, but frequency data suggest that women eat significantly more frequently inside camp than men do (controlled for time in camp) (Berbesque *et al*., 2011). In camp, women consume significantly more of female-acquired and male-acquired foods than men consume; they eat more of all five food categories (Berbesque *et al.,* 2011). When husbands return to camp with food, their wives consume a larger proportion of husbands' foods than husbands consume (Wood & Marlowe, 2013). Wives also strongly influence the food's remaining distribution, having producer control for the majority of observed food distributions of husbands' acquired foods (Wood & Marlowe, 2013).

The present findings are in line with women consuming more in camp and less outside of camp than men. Still, we might also expect a high variance for the amount consumed in camp per day, given the high variance of women's eating outside of camp. So for those days of zero kilocalories eaten outside of camp (15 observation days, 6% of total days), women may eat around 1,788 kilocalories in camp, if they are not losing or gaining weight. But what about those days in which women eat far more than 1,788 kilocalories outside of camp? If we consider a cut-off of 1,800 kilocalories, then women consumed more than 100% of their TEE outside of camp on 52 observation days (20% of total days). If we further consider that an additional 3,500 kilocalories on top of 1,800 kilocalories roughly represents a one pound gain in weight (Hill *et al*., 2003), then women are eating enough outside of camp to gain at least one extra pound on 5% of total days (14 observation days).

Such high variance suggests that describing out of camp eating as 'snacking' behaviour is not useful. Firstly, it is unclear what calorific amount or range would constitute snacking. Secondly, even if snacking were determined to describe the mean 326 kilocalories for women, the large amount of variance suggests there is not a consistent 'snacking' strategy. Rather, the women's strategy encompasses variance. Such variance includes a range bounded by a lower 5% of days with nothing consumed to an upper 6% of days with enough consumed to gain a pound in weight (and even up to six pounds in weight for the highest consumption).

Since Hadza women maintain consistent BMIs across time, Sherry and Marlowe (2007) have argued that the Hadza demonstrate nutritional homogeneity. Their caloric intake seems to remain stable enough despite high variance in out of camp eating. Focusing on caloric measurements for a single day's TEE may be a limiting viewpoint. The women may be employing a strategy that works over a longer timeframe.

Surprisingly, only two of the identified factors helped to explain its variance. None of the environmental factors, none of the personal factors and none of the family factors were found to influence amount consumed outside of camp. Only time and presence of honey were significantly associated with amount eaten. Still, a model with both (controlled for repeat women and camps) explained less than half of total variance ($R^2 = 0.37$).

Numerous reasons may explain why some of the potential variables may not have been significantly associated with eating. The first possibility is that these variables simply do not explain much variance of eating outside of camp. Another possibility is that some variables were underrepresented in the dataset due to sampling procedures. Seasons and regions are governed by the fieldworkers' access and availability for data collection. The early wet season has no representation in this dataset and the regions of Mangola and Dunduiya only have one representative camp each. In these cases, error margins may be too wide to determine any significant differences due to smaller samples.

A third possibility is that some of these variables do not actually have much variance expressed in the population itself. For instance, husband presence is a dichotomous variable, and the majority of Hadza women are married [80-90% of women aged 20 to 40 (Blurton Jones, 2016)]. In the sample, only 16 women did not have husbands. BMI too seems to have low variance in the Hadza (Sherry & Marlowe, 2007), though Marlowe and Berbesque (2009) found significant differences for women by region and season. Nevertheless, variables like age and number of children are well-represented and have higher variance, yet still did not demonstrate significant associations. Berbesque *et al*. (2016) also found no significant association between age and men's eating outside of camp.

Time appears to be the most important predictor of whether or not a woman will eat outside of camp and how much she will eat. This is largely intuitive; the longer the foray, the hungrier someone may become and the more likely to consume food. Yet for men, there was no association[14] between length of foray and amount consumed outside of camp (Berbesque *et al*., 2016). This demarcates a clear difference between men's and women's eating patterns.

Honey, on the other hand, represented a similarity between their patterns. For men and women, honey was significantly associated with more eating. This is not surprising as

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[14] However, Berbesque *et al*. (2016) did not control for repeated measurements in this comparison. They used a Spearman's rank correlation which although not requiring normality, does assume that observations are independent. Since their observation days are not independent (likewise with the women's observation days), then this result should be taken with caution.

honey is the most calorific food stuff and the most energy-dense. Once acquired, honey represents the fastest route to consuming a large amount of kilocalories.

Honey also represents a key difference in out of camp and in-camp eating frequencies for women. The order of relative importance for food types differs between in camp and out of camp estimates. This study found that women eat (in order of decreasing frequency): berries/fruits, tubers, honey, baobab and small game. Berbesque *et al.* (2011), on the other hand, found different relative frequencies for women's eating inside camp (in order of decreasing frequency): berries, tubers, meat, baobab, and honey. While the top two food categories remained the same, honey and meat have switched places. For meat, this switch is understandable: the women are only occasionally foraging for small game and not foraging at all for large game. As a result, their access to game meat is highest once back in camp because men share their meat.

For honey, however, this switch seems more complex. Across all follow days, women embark on forays specifically targeting honey on only six days (three of which also involve acquisition of fruits or berries). Yet women are eating honey more frequently[15] outside of camp. As Berbesque *et al.* (2016) highlighted for men's eating, the consumption of honey is clearly underreported. If women are only occasionally targeting honey, then how are they eating it so frequently outside of camp? The answer appears to lie in the gifts shared outside of camp, particularly gifts from men. Of all the kilocalories consumed of honey across all follow days, the majority of kilocalories (60%) were received as gifts. The following section delves into a discussion on gifts.

3.5.2 Gifts

A large proportion of follows (40%) had neither gifts given nor received. Nevertheless, the majority of follows had at least some gifts given or some gifts received. For this reason alone, it is evident that, at least in the Hadza, ignoring gift exchanges outside of camp is ignoring a regular occurrence in women's foraging patterns. Moreover, ignoring gifts given or received could be ignoring a large caloric exchange, given the high variance in calorific ranges for both gift types.

When gifts were given or received, the women gave on average 136 kilocalories and received on average 368 kilocalories outside of camp. Honey may help explain the gap

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[15] Since we do not yet have calorific estimates of women's in-camp eating, it is unclear whether the absolute amount of honey consumed outside camp is greater than the absolute amount consumed in camp (despite their differences in frequencies). However, Marlowe (2010) estimated that honey comprised the lowest portion of women's in-camp diet: only 0.7%. (This estimate was based on food brought back to camp rather than direct observations of in-camp eating.)

between the two. Whereas both were significantly associated with time outside of camp (as with consumption), only the presence of honey was significantly associated with kilocalories received. Moreover, honey comprised a significantly higher proportion of gifts received than gifts given. Even though the number of individual gifts received (430) is lower than gifts given (480), the gifts received were more energy-dense due to the presence of honey.

Honey should not have an effect on the discrepancy between gifts given and gifts received, however, if the gift exchanges are a closed system involving only adult women. In such a system, we should expect similar estimates for gifts received and gifts given, regardless of the presence of honey. After all, one follow woman receiving a gift has an equivalent woman giving a gift. The gifts given and received should be a zero-sum game for follow women.

But the system is not closed: children join adult women outside of camp and sometimes men join too. Also, the Hadza women occasionally receive food stuffs from agriculturists (though only seven recorded instances of agricultural food stuffs in this dataset). It could be the case that the presence of honey is actually associated with another factor: the presence of men. In the follows dataset, men sometimes appeared to give gifts while the women were foraging. As a preliminary investigation, the number of gifts given to adult men and number of gifts received by adult men were calculated. Of the 480 individual gifts given, 4% (19 gifts) were given to adult men. In contrast, 28% (120 gifts) of the 430 individual gifts received were given by adult men. The majority (66%) of those individual gifts given by men were honey[16].

This presence of males opens up many new avenues for investigation, discussed further in Section 3.5.10. In general, the gift exchanges create a different landscape of foraging decisions for women. When men forage alone, they have a choice between eat now or save for later. With women, however, there are three options: eat now, give as a gift now or save for later. If the woman chooses to give a gift now, she opens up an array of new options not available to solo male foragers. She may decide various combinations of which people, how many people and how much food to give during the trip.

A woman's decision-making process of giving gifts outside of camp may be guided by kinship or reciprocity or even proximity to her position of foraging (ease of access). In this way, gifts outside of camp are not only a missing piece to the sexual division of labour, but also food sharing generally. Food transfers among foragers are important

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[16] It is possible men may be giving even more if original producers are analysed. For instance, a gift of honey may be marked as given by an aunt or a sister. But that gift may have originated from a man that joined the group.

ethnographic data for tests of reciprocal altruism, tolerated theft, and kin selection (e.g. Blurton Jones, 1987; Bliege Bird & Bird, 1997; Gurven *et al.*, 2000; Gurven, 2004a). A full picture of forager sharing patterns, and thereby tests of their adaptive functionality, necessitate the inclusion of all transfers, not only those inside camp.

Gurven (2004b) notes the biased focus on meat transfers from men and the rarity of examining gathered and other foods. This study has demonstrated that women's gifts outside of camp amount to at least 500 unaccounted for kilocalories. When considering models of reciprocal altruism, in particular, these missing kilocalories may be skewing perceived exchanges between individuals. If other forager women are sharing kilocalories outside of camp as in the Hadza, then there is the potential to miss substantial calorific data and insights into the totality of the sharing pattern.

With respect to food transfers outside of camp, this study investigated one aspect of the decision-making process for forager women: what happens when a woman receives certain food types. When women receive gifts of honey and tubers, they usually consume the entire quantity immediately. In contrast, they tend to consume none of the baobab or berries/fruits given to them. Why this difference occurs may be due to processing requirements. Honey and tubers (with the exception of certain species that require peeling) have little to no processing times after acquisition. Honey can be consumed by the handful and tubers can be consumed raw. Baobab, on the other hand, requires the lengthiest processing time, with cracking of the pod and pounding of the pulp and seeds. Based on a preliminary review, the majority (77%) of person/days with baobab gifts received (n = 13) included gifts in the form of unprocessed, whole baobab pods.

Individual berries/fruits, unless they are being pounded with water to form a sweet mush or pounded for their nuts (e.g. marula), also require little to no processing post-acquisition. However, if a woman has cut off *branches* of berries, then the berries still need to be picked off. A preliminary review of the berries/fruits gifts demonstrates that only 12% of person/days (n = 25) included gifts of berry branches. Otherwise, the gifts were given in handfuls or as whole fruits. Thereby, extra processing time does not explain why other berries/fruits, excluding baobab, are not immediately consumed. There may be other reasons why they are not immediately consumed, like the amount of berries/fruits already eaten prior to receiving the gifts.

There are additional reasons why honey and tubers may be consumed immediately, rather than saved for later. For honey, the decision may be logistical, dependent on access to appropriate containers. If a man has brought honey to a group of women collecting berries or digging for tubers, then he has a container for storing the thick liquid. The women, having anticipated only needing carrying devices for berries or tubers (e.g. baskets or cloths), may not each have a honey-proof container readily

available. In these cases, handfuls are taken from the man's container, so consumption is immediate.

As for tubers, there may be another phenomenon explaining why tubers are consumed immediately when received as gifts. Sometimes the women build a fire and roast tubers while still outside of camp. Hawkes *et al.* (1989) briefly describe this mid-afternoon roasting by women. No study has yet investigated what predicts this social eating outside of camp. Follow length is probably an important factor, but there are many other potential factors: the number and composition of people, how much the women have already foraged and the distance from camp. Maybe certain digging locations are associated with mid-afternoon meals. Evidently, this represents another interesting avenue for further investigation, especially as a social gathering within the larger social context of the Hadza women.

3.5.3 Foraging

The women are foraging an average of 3,556 kilocalories per day. This estimate is around 500 kilocalories greater than a previous estimate for adult Hadza women: 3,076 kilocalories [$n = 59$, Marlowe (2010)]. Marlowe's estimate was based only on food brought back to camp. This study is the first to compute a foraging estimate for women foragers that is different from food returns alone. Gifts given and received and eating were also factored into a calculation of how much a woman physically foraged herself.

By adding in these additional out of camp factors, the estimate for amount foraged has increased by about 15%. However, the difference may be even greater if tuber calculations and gifts received are considered. The original estimate of 3,076 is inflated due to a lack of knowledge of the edible percentages of tubers at the time. Schnorr *et al.* (2015) revealed that Hadza tuber species have much lower percentages of edibility than originally assumed. For instance, *//ekwa*, the tuber species most frequently consumed (Marlowe & Berbesque, 2009), is only 26% edible (Schnorr *et al.*, 2015), a factor not considered in past calculations. Additionally, no data had been published on the gifts women receive but do not forage themselves. The 3,076 kilocalories may also be inflated by kilocalories received as gifts.

Hadza women foraged significantly more on longer follows and in the presence of honey and *Quelea* chicks. Honey and *Quelea* may have had the same effect for different reasons, however. Honey is the most energy-dense resource, so foraging even a small amount entails higher returns. As for *Quelea*, the individual chicks are not especially calorific (see Appendix C), so a larger amount is needed to bring higher returns. Given the context of

the mass reproduction (see Section 1.4.3), easy access to larger amounts is possible, even for adolescents (Crittenden, 2009).

The presence of honey also significantly increased the overall ratio of food eaten to food foraged. In the absence of honey, longer trips and the presence of *Quelea* chicks affected the ratio. But *Quelea* had the opposite effect to honey; in the presence of *Quelea* chicks, women consumed less in relation to total foraged. In other words, when women were faced with their largest foraging opportunities for meat, they consumed a small percentage of their total foraged.

3.5.4 Men's and Women's Strategies by Food Type

3.5.4.1 Berries/Fruits

Men and women are both acquiring berries/fruits outside of camp, but not both bringing them back. Men eat almost all (99%) of the berries they acquire outside of camp (Berbesque *et al.*, 2016). Indeed, berries represented the food stuff with the highest amount eaten relative to amount acquired (Berbesque *et al.*, 2016). Women eat much less of the berries they acquire outside of camp. Berries represented the food stuff with the lowest amount eaten relative to amount acquired (slope of 0.06 for absolute eaten to absolute foraged).

Not only are men and women both acquiring berries, but they are both acquiring them in relatively high frequencies. For women, berries are acquired most frequently across all follow days, and for men, they are acquired the second most frequently (26%) (Berbesque *et al.*, 2016). Still, the absolute amounts they acquire are very different. Men consume a mean[17] of 21 kilocalories per hour while women consume a mean of 92 (median = 60 kilocalories) per hour. This fourfold difference remains consistent when median values per person/day are compared (restricted to those person/days where the food was eaten): men consume a median of 64 kilocalories per day while women consume a median of 256 kilocalories per day (*n* = 156 person/days). The women's range (0 to 3,526 kilocalories) is also more than 2.5 times greater than the men's range (2 to 1,388 kilocalories). [Though, to be noted, Berbesque *et al.* (2016) report the minimum non-zero values across food types.]

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[17] Berbesque *et al.* (2016) do not report median kilocalories per hour so comparisons are drawn to mean kilocalories per hour. These per hour comparisons are particularly important because Hadza men forage for more hours than women do (Pontzer *et al.*, 2015). Berbesque *et al.* (2016) observed Hadza men to forage for an average of 6.3 hours, and this study found that women foraged for an average of 5 hours per foray.

3.5.4.2 Tubers

Hadza men rarely target tubers (Marlowe & Berbesque, 2009). Berbesque *et al*. (2016) report only four instances of men eating tubers (which were given to them by women). They report no instances of tuber acquisition by men. However, Marlowe (2010) documents a small percentage of tubers for men's food returns. Interestingly, these two findings could represent the same phenomenon. Since women have been observed to give gifts of tubers outside of camp to men (Berbesque *et al*., 2016 and this study), then men may return with some tubers even though the men themselves did not acquire them outside of camp.

Women regularly target and consume tubers outside of camp. The proportion of tubers consumed in relation to foraged was the second highest of all food types (slope of 0.63 for absolute foraged to absolute eaten and slope of 0.27 for foraged per hour to eaten per hour). One source of variation yet to be considered (and a potential explanatory factor for the two different slopes) may be the midday meals of tubers. As mentioned previously, Hawkes *et al*. (1989) depict the Hadza women eating tubers around midday outside of camp. They write that more than one fire may be lit (depending on the group size) to cook and eat the tubers before women begin a second bout of digging. In the follows dataset of this study, there are multiple records of roasting tubers and building fires, observations that are consistent with the descriptions of Hawkes *et al*. (1989).

Women also consumed a large proportion of tubers when received as gifts. Again though, to what extent may midday meals represent an important factor in gifts? No study has yet investigated when, where or why these midday meals take place. These meals may be another way of socially binding the women (through exchanges of tuber gifts).

3.5.4.3 Baobab

Both men and women target and acquire baobab outside of camp. They also rank baobab in the same relative position of food preferences, third of the five food groups (Berbesque & Marlowe, 2009). Men and women differ, however, in the amount they choose to bring back to camp. When men acquire baobab, they eat a significant portion (63%) outside of camp (Berbesque *et al.*, 2016). Women eat a much smaller proportion outside of camp, around 12%. In terms of women's follow days, when baobab is acquired, it is consumed for significantly fewer days than any other food type.

Although men ate significantly more of the baobab they acquired, they acquired much less baobab overall, both in frequency and in absolute kilocalories. Men acquired baobab on only 5% of observed follow days (the same frequency for large game acquisition) (Berbesque *et al*., 2016). Women, on the other hand, acquired baobab on 16% of all follow

days (*n* = 198). Women's range of baobab calorific consumption was appreciably different from the men's range. Women's kilocalories ranged from 0 to 15,357 compared to men's, from 89 to 297 kilocalories. The mean kilocalories eaten per hour were also extremely different: women ate a mean of 430 (median = 210) kilocalories per hour compared to the men's average of 15 kilocalories per hour. When median kilocalories consumed per day are taken into account (restricted to those follows where baobab was consumed), the difference is not as large: men consumed a median of 134 kilocalories and women consumed a median of 1,058 kilocalories per person/day (*n* = 25). Nevertheless, the difference was still substantial – women ate nearly eight times as much baobab per person/day.

A simple explanation for the large calorific difference may be that women sometimes process the baobab outside of camp and men do not. If men are not processing the baobab outside of camp, then they are limited to the amount of kilocalories gleaned from baobab. The baobab seeds have significantly more kilocalories (see Appendix C) so when the seeds are processed, a meal of only seeds or seeds and pulp is more calorific than unprocessed pulp. How often the women process baobab outside of camp and why and when they choose to do so are further questions deserving of exploration.

3.5.4.4 Honey

Honey was acquired and consumed by both men and women. Women's honey consumption outside of camp appears to be influenced by men's sharing of honey (see earlier discussion in Section 3.5.2). The more kilocalories of honey men and women acquire, the more they consume. For women, the slope of this relationship was highest of all five food groups (0.63). When time was factored into the comparison, however, there was no significant relationship between foraged per hour and consumed per hour.

Men acquired honey more frequently (58% of follows, Berbesque *et al.*, 2016) than women (11% of follows). The amounts of kilocalories consumed are relatively similar (in comparison to other food types). The large range of kilocalories for men's consumption (97 to 20,776 kilocalories) overlaps entirely with the women's range (0 to 21,915). Their average consumption per hour did not differ greatly: men's mean of 614 kilocalories per hour compared to women's mean of 583 kilocalories per hour (median = 240 kilocalories). However, these averages were either skewed (which the median per hour for the women's data suggest) or men spent more time eating honey because the median values present a different picture. Men consumed a median of 2,398 kilocalories per person/day whereas women consumed a median of 1,457 kilocalories per person/day. As mentioned previously, men forage for more hours than women do, so time may be contributing to the relative sex differences between the median per foray and the mean per hour.

Honey accounted for the largest percentage of the men's diet out of camp (85%) (Berbesque *et al.*, 2016). Men were found to consume smaller proportions of honey, the more honey they acquired (Berbesque *et al.*, 2016). There was no similar finding for women. Still, overall, men consumed 84% of the honey they acquired (Berbesque *et al.*, 2016).

3.5.4.5 Meat

Women do not target large game outside of camp. The only instance of large game eating was warthog meat received as a gift. Women occasionally acquire small game [including *Quelea* chicks, eggs, other birds and leopard tortoise (*Geochelone pardalis*) in this study]. Men hunt large and small game, but the majority of their kills (79%) are small game. Men acquired small game more frequently (19% of follows, Berbesque *et al.*, 2016) than women did (10% of follows). Men also consumed more per hour and more per foray. Men consumed an average of 206 kilocalories per hour whereas women consumed an average of 121 kilocalories per hour (median = 89). On those follow/days where small game was consumed, men ate a median of 942 kilocalories, compared to women who ate a median of 745 kilocalories per person/day (n = 18). To be noted, the women's small game eating patterns are predominantly based on the calorific boon associated with *Quelea*.

When women and men decide the relative amount of meat to eat outside of camp, their strategies appear to be similar. Men eat a smaller proportion of meat relative to total acquired (Berbesque *et al.*, 2016), and women ate less *Quelea* (the largest source of meat in the dataset) in proportion to how much they acquired. It is interesting that women should eat a smaller proportion of meat, considering that they are generally receiving less meat than men. Although in-camp calorific consumption by women has been recorded, these estimates are not yet published and could reveal higher kilocalories for meat consumption by women.

From frequency estimates, meat consumption is lowest for women outside of camp and third (of five) for inside of camp (Berbesque *et al.*, 2011). If women are not eating as much meat proportionally as men, then why not consume more of the small game they acquire? One answer may be that the women seek to provision their children with small game. Though in-camp kilocalories will reveal the extent to which women consume small game they acquired, the currently available data suggest that women are consuming meat in lower proportions compared to the other food stuffs.

3.5.4.6 Overall

The relative consumption of honey and small game is similar for men and women. The absolute consumption, however, is different because men acquire more kilocalories of both. Berries/fruits and baobab are treated differently both in relative and absolute terms. Baobab may be treated differently because of the women's decision to sometimes process the pods outside of camp.

Berries/fruits represent an interesting difference because they are both frequently acquired by men and women but actual consumption differs greatly. Men almost never bring berries back to camp. Yet berries still represent the second most frequently acquired food stuff by men. When they do consume berries, they consume a mean 21 kilocalories per hour (Berbesque *et al.*, 2016). Since they only consume such a meagre amount per hour, why do men even bother picking berries? The answer may be a combination of convenience (location of berry patches and little to no processing time) and satiation.

The Hadza report that their hunger is more easily satiated when seeds are swallowed rather than spat out (Woodburn, 1964). If berries provide a feeling of fullness, then this could help explain why men target them frequently outside of camp. Even though they are not an efficient snack calorie-wise for men (only 21 kilocalories per hour), they may be efficient for the purposes of satiation.

Satiation may explain another interesting phenomenon. Men's two highest food types for immediate consumption (berries at 99% consumed and honey at 84% consumed) are also the lowest and highest calorific returns. Women's two highest foods consumed immediately (tubers and honey) are similarly their lowest and highest caloric returns. The consumption of tubers for women and berries for men may be a key mechanism to feelings of fullness. Woodburn (1964) writes that "the men, like the women, satisfy their hunger at the place where food is obtained" (p. 51). Similarly, Hawkes *et al.* (1989, p. 344) refer to appetites 'being satisfied' for women on digging trips. The volume of berries and of tubers may produce feelings of fullness, despite lower caloric contents.

3.5.5 Proximate & Ultimate Explanations

Hadza women eat fewer kilocalories than men outside of camp, both in absolute and relative terms. Women should be expected to eat less generally, given their smaller body sizes (Marlowe & Berbesque, 2009) and lower TEE (Pontzer *et al.*, 2012). But Hadza women appear to consume proportionally less than men outside of camp: women consume 18% of their TEE whereas men consume 34% of their TEE [derived from the median estimate of Berbesque *et al.* (2016)].

These differences in Hadza adults are anticipated by sex differences found in children (e.g. Hawkes *et al.*, 1995; Crittenden *et al.*, 2013). Boys consumed significantly more when foraging and brought back significantly fewer kilocalories (Crittenden *et al.*, 2013). Boys and girls also focused on different food stuffs. After baobab, boys focused on birds, honey and small mammals while girls focused on figs, tubers and berries (Crittenden *et al.*, 2013).

Why women are eating absolutely and relatively less while out of camp may have different proximate and ultimate explanations. In proximate terms, the women are consuming less than men while out of camp because they are eating foods with lower caloric values. Their two most frequent food stuffs eaten outside of camp are also the two least calorific: berries/fruits and tubers. On the other hand, the men's most consumed food stuff [accounting for 85% of total kilocalories (Berbesque *et al.*, 2016)] is the most calorific item in the diet: honey. Even if men and women consumed the same weight in foods, their choice of food stuffs entails very different caloric outputs. This then moves the question to why women eat more berries/fruits and tubers than men. Another proximate explanation is that women forage these food stuffs most often. Because berries/fruits and tubers are also the most frequently foraged by women, they have more opportunity to eat these foods outside of camp. When men are outside of camp, they do not forage for tubers and acquire the least amount, in terms of kilocalories per hour, for berries/fruits (Berbesque *et al.*, 2016).

An ultimate explanation (e.g. Mayr, 1961) may then seek to explain why women target tubers and berries/fruits. The traditional explanation invokes reproductive constraints. A Hadza woman may target tubers and berries/fruits because these are most compatible with childcare. Both are located in patches that are accessible to children's foraging. The food types targeted by Hadza women overlap with those targeted by young boys and girls (Blurton Jones *et al.*, 1994). Berries and fruits formed the majority (64%) of foods targeted by children (Crittenden *et al.*, 2013). Women's foraging for tubers and berries/fruits is also logistically compatible with nursing infants. Chapter 5 further investigates the relationship between women's foraging and childcare constraints.

In line with women facing reproductive constraints, Codding *et al.* (2011) have interpreted data from the sexual division of labour in terms of risk and energy trade-offs. Reviewing evidence from the Martu, Meriam and Ache, Codding *et al.* found that women tend to target low-risk resources, whether they are energetically high or low. Although a clear mechanism for determining 'riskiness' is needed[18], the Hadza women

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[18] Codding *et al.* (2011) use the coefficient of variation (CV) as a measurement of risk. Yet there is a question of standardisation. Should risk be considered with respect to overall risk of food stuffs

appear to follow a similar strategy. Tubers and berries/fruits are reliably available, especially tubers as a fallback food (Marlowe & Berbesque, 2009). Men, on the other hand, demonstrate preferences for foods in order of least reliability and highest variability: honey, meat, baobab, berries and tubers (Berbesque & Marlowe, 2009).

An important aspect of Codding *et al.*'s proposal is that it encapsulates both men's and women's foraging goals. The provisioning model, on the other hand, is not straightforward in delineating why women target certain food stuffs. The model seeks to explain why a difference exists generally, i.e. both parents in a nuclear family contribute through cooperative specialisation in varying foods. But there is not a clear indication of what determines who targets which food (besides recourse to assumed reproductive constraints). Similarly, the nutrient complementarity hypothesis (Hill, 1988; Kaplan & Hill, 1992), discussed further in Section 3.5.7, proposes the division of labor as a mechanism for balancing macronutrients. But as Bird (1999) suggests, the hypothesis fails to explain scenarios in which men and women target meat and to explain why obtaining protein should default to one sex over another.

The costly signalling model focuses almost exclusively on men's foraging goals. In particular, this ultimate explanation centres on big game meat. The model directly addresses neither women's foraging goals nor other important targets like honey (see discussion in Section 3.5.8). Furthermore, the model concentrates on a male strategy which constitutes a shorter time depth; small game acquisition by men and women constituted a larger portion of hominin evolution (e.g. Cordain *et al.*, 2001). Yet as Marlowe (2007) points out, "no one suggests [women] take this game to signify their quality rather than provision their households" (p. 188-189).

The following sections explore the ultimate explanations for the sexual division of labour in light of findings from the present study. The viewpoints of personal provisioning and nutrient complementarity are considered as well as the need for an increased emphasis on the role of honey. The final section highlights some future directions for further study.

3.5.6 Self-Provisioning

In their critique of evidence for the costly signalling model, Hill and Kaplan argue that Hawkes *et al.* (1993) should first address the causality of resource distribution before

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in that foraging economy or some other standard? For example, Codding *et al.* (2011) find that "while Aché women contribute more to two relatively higher variance resources than men (kurilla and larvae), the absolute level of risk for these resources is quite low, especially in comparison with the other populations" (p. 2504). The second question is to what degree other risk factors are not captured by CV. That is, the physical risks associated with activities like climbing.

addressing male foraging decisions (Hill and Kaplan, 1993). They lament that Hawkes *et al*. have taken for granted the distribution patterns of the men's resources as unavoidable. For example, they try to answer why men target a public good like big game without addressing why it is a public good in the first place.

The current study finds that there is still a more fundamental consideration that has been taken for granted. That is, how much does the forager eat for himself or herself? For anyone to be a successful provisioner of others, one must first be capable of provisioning oneself – otherwise, the provisioner cannot maintain his or her own survival. Therefore, there exists a question which is *a priori* to whether a hunter provisions or signals or whether sharing is based on reciprocal altruism or kin selection. How much does the forager eat as an individual? Another way to frame this question is – what percentage of the total acquired by a forager is *not* shared?

The provisioning model and the costly signalling model debate the motivations of men's provisioning without establishing how men firstly provision themselves. A critical motivation is, ultimately, how much the individual desires to consume first. In exploring this question across hunter-gatherer populations, there may be another layer to the sexual division of labour. Are there differences in how much forager men self-provision, even when they target similar food stuffs? This is especially important in groups where men usually hunt alone [e.g. the Hadza and the Martu (Bliege Bird *et al*., 2008)] and others are not witnesses to a man's decision of how much to eat.

The motivation for personal provisioning has direct ramifications for the hypothetical scenarios of the costly signalling model. The foundation for the costly signalling model (including the original iterations of the show-off hypothesis) has been built on the backbone of a singular hypothetical scenario: men could provide more kilocalories if they did *x* instead of *y*. Meriam men could achieve double the return rate if they collected shellfish instead of spearing small fish (Bird, 1999). Melanesian horticulturist men could provide more if they grew smaller yams instead of large, ceremonial yams that take twice as long to produce and are mostly inedible (Bliege Bird & Smith, 2005). Hadza men could produce more meat if they hunted and trapped small game instead of targeting large game (Hawkes *et al*., 1991). In all of these scenarios, there is a missing consideration. Could men *eat* more kilocalories if they did *x* instead of *y*? It is important to consider whether men would eat more relatively or absolutely or whether men would eat similarly in both foraging options. If men forage with a less efficient strategy [e.g. turtle hunting in the Meriam (Bliege Bird & Smith, 2005)], then men may disadvantage their capacity to provision themselves [e.g. Meriam turtle hunters usually keep no meat for themselves (Bliege Bird & Smith, 2005)].

Equally, women's self-provisioning must be considered in the context of costly signal-ling and provisioning models. Because these models often position women as recipients of men's foods, women's demand for kilocalories is presumed, rather than explicitly ex-amined. An accurate estimate of how much a woman requires for herself and her chil-dren necessitates data from outside of camp. How a woman provisions herself outside of camp has a knock-on effect for how she eats and shares inside of camp.

The extent to which a forager self-provisions will depend on his or her energetic de-mands. An individual's average demands depend on a number of factors, like body com-position, age, reproductive status and daily activity patterns (FAO, 2001). Kelly (2013, p. 71) summarises the daily caloric consumption in nine forager groups, ranging from 1,740 kilocalories in the Onge to 3,827 kilocalories in the Ache. Nevertheless, these estimates are predominantly based on food returns, not on systematic measurements of energy consumption and expenditure.

Besides energetic demands, self-provisioning may be related to resource availability (e.g. resource type and distribution), environmental conditions (e.g. season and locale) and other factors (e.g. foraging alone or with others). This study found that time and honey are important factors associated with women's eating outside of camp. Still, these factors explain less than half of the total variance; the extent to which women self-provision is highly variable.

This variability for women's out of camp eating produces an equivalent variability for in-camp eating. A Hadza woman's caloric demand inside of camp is not constant and on many days (20% of total follow days), a woman has already fulfilled her entire TEE through her own provisioning outside of camp. Studies on how men provision women need to consider the flux in women's self-provisioning.

Because women's caloric demands vary daily, aggregate food production data are lim-ited in their usefulness. Bliege Bird *et al.* (2009) succinctly summarise this conundrum for men's foraging: "50% average production by men could result either from consist-ently providing half of the production or from providing all or nothing half of the time" (p. 108). They found that the daily variance in Martu male contributions was very high: ranging from 0% to 100%.

There is still much to be gleaned from in-camp data, including how caloric demands are met by contributions from others and how much of the total foraged is given to children. Receiving food from others frees up even more of the kilocalories for women or men to share. Children also self-provision in the Hadza and other foraging groups, easing the burden of caloric demand from parents. For example, Mikea children are more efficient tuber foragers than Hadza children (Tucker & Young, 2005). They have been observed

to obtain a positive net production earlier than children from other groups, including the Ju/'hoansi, Ache and the Hadza (Tucker & Young, 2005). Such high contributions raise the issue of more consistently factoring in children's contributions to the overall diet.

3.5.7 Nutrient Complementarity

These data also have interesting implications for the nutrient complementarity hypothesis (Hill, 1988; Kaplan & Hill, 1992), which is one avenue of support for the provisioning model. This hypothesis proposes that men and women not only efficiently share the burden of energetic requirements, but they also share the burden of macronutrient requirements. They target different food stuffs to create a balanced intake of carbohydrates, proteins and lipids.

For Hadza women, there is the potential to benefit calorifically and nutritionally from the division of labour, given their consumption of only 326 kilocalories outside of camp. Depending on the consumption of husbands' foods and foods from other males, the women have the potential to satisfy macronutrient requirements from male-acquired foods. However, it is also possible for Hadza women to fulfil requirements from women's food stuffs. Based on the synthesis of nutritional data for foods consumed by Hadza women in this study (see Appendix C), women may easily meet carbohydrate requirements [of at least 55% of total kilocalories (Nishida & Nocito, 2007)]. A closer examination of protein and lipid requirements, the two macronutrients that male foods are usually proffered to provide (Hill, 1988), reveals that Hadza women may also meet these requirements from certain female-targeted food stuffs.

Averaging around 46 kilograms in weight (Marlowe, 2010), adult Hadza women require at least 30 grams of protein for daily maintenance [per WHO (2007) guidelines of 0.66 g/kg]. Reproductive-aged women are recommended a minimum intake of 20% of total energy from fats (and 30-35% as a maximum) (FAO, 2010). For Hadza women, minimum recommended daily lipid content amounts to around 358 kilocalories (based on TEE of 1,788), or around 40 grams of fat.

3.5.7.1 Nutritional Content of Berries/Fruits and Baobab

If women derived their entire TEE from some of the Hadza berry species, they could hypothetically satisfy lipid and protein requirements. For example, if a woman derived her entire TEE from a *Grewia* berry species like *Congolobe* [the most frequently acquired berry in this study across camps (*n* = 7 camps)], she would consume 65 grams of protein, more than double her recommended amount. She would also consume high amounts of

dietary iron (see Appendix D on iron content in *Grewia* species). If she received her entire TEE from a different berry species, like *Tafabe*, she would consume around 47 grams of lipids. Or, if she received her entire TEE from baobab pulp and seeds, she would consume around 99 grams of protein and 89 grams of lipids! From these hypothetical calculations, it is clear that the Hadza berries and fruits represent a strong potential source of protein and lipid amounts.

Baobab, in particular, is the strongest fruit source for macronutrients, with extremely high lipid and protein content (as well as Vitamin C, see Appendix D). The amount of protein in 100 grams of pulp and seeds (17 grams), or seeds alone (23 grams), is directly comparable to the amount found in 100 grams of fresh game meat. Furthermore, baobab is the food stuff that women are retrieving the most kilocalories per hour when foraged. The high calorific content is the result of the high lipids, proteins and carbohydrates.

Even if women could meet their own nutritional requirements from berries/fruits, it is possible they do not produce enough for their children's requirements as well. In this case, the nutrient complementarity hypothesis could be invoked to apply to men acquiring those other protein and lipid sources for children. However, since Hadza children are foraging berries and fruits (including baobab) (Crittenden *et al.*, 2013), then they too reap the benefits of the lipid and protein contents. Furthermore, a preliminary analysis reveals that Hadza women, when they target berries alone, may be foraging enough protein for themselves and children. Analysing a subsample of person/days on which only berries/fruits were foraged (n = 30 person/days), Hadza women foraged an average of 172 grams of protein (median = 176 grams). This presents a very different picture from the Ache women who were observed to forage almost no lipids or protein (Kaplan & Hill, 1992).

Another argument for nutrient complementarity may be that Hadza women do not supply enough "utilisable protein". This is calculated from the amount of amino acids and digestibility (WHO, 2007). Whereas meat suffices the dual requirement of easy digestibility and satisfying all essential amino acids, plant sources may be devoid of an essential amino acid and/or less digestible (Smil, 2002). Infants and children have higher amino acid requirements and pregnant and lactating women require more protein overall (WHO, 2007). For these individuals, protein from meat sources may represent an important source of additional requirements.

Even if plant protein is less easily digested than meat protein, the Hadza women acquire this protein more readily throughout the year. Berries/fruits were the only food stuff consistently foraged across all camps. Berries and baobab are also foraged in every month of the year (Marlowe & Berbesque, 2009). Although the early wet season was not represented in this study, berries are the largest proportion of the diet, by weight, in this

season (Marlowe & Berbesque, 2009). Women acquire berries more often than they acquire small game and men were observed to acquire berries on more days than small game or large game (Berbesque *et al.*, 2016). Berries/fruits and baobab could provide a more frequent flow of protein than meat.

Although the plant sources may reliably provide a strong source of protein, they appear to produce a substantially lower amount of lipids. A preliminary analysis was conducted on total lipid content for the same subsample of berries/fruits (n = 30 person/days). The Hadza women foraged an average of 12 grams of lipids (median = 10 grams). Despite *Tafabe* and baobab having higher lipid contents, the lower lipid content of species like *Undushipi* or *Mbilipe* (included in the subsample) do not produce comparable amounts of fat. In fact, the second most frequently acquired berry species in terms of number of camps acquired (n = 6 camps), *ngwilabe*, is the berry with the lowest lipid content of all berries/fruits. Unless women specifically target the berries/fruits with the higher lipid contents, they will not acquire sufficient amounts of fat for themselves and children. In such cases, women may be reliant on lipids supplied from male-targeted foods.

3.5.7.2 Nutritional Content of Tubers

Depending on the region and season, there are periods of time when tubers are foraged more frequently than berries/fruits. As in Marlowe and Berbesque (2009), this study found that tubers were more frequently acquired during the late wet season. There are also days during which women only dig for tubers. In this study, for example, the majority of days on which women acquired tubers (n = 99 person/days) were days on which women acquired only tubers and no other food stuff[19] (n = 62 person/days). Tubers are significantly lacking in proteins and lipids (see Appendix C). Although it may be assumed that tubers are better equipped to supply dietary carbohydrates or fiber, some Hadza berries and fruits actually have higher carbohydrate and/or fiber content than some of the tubers (per 100 grams of wet weight). Marlowe and Berbesque (2009) found that Hadza women had a lower percent body fat when more tubers were taken (and higher when more meat was taken), a result consistent with the low nutritional content of tubers.

When women acquire mostly tubers, they will face a large gap in lipids and proteins, unless they dig and consume very large sums of tubers. For instance, if a woman were

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[19] This estimate excludes any follow days where even small amounts of kilocalories were acquired from other food sources. If the estimate includes those follow days where less than 100 kilocalories were consumed from other foods (e.g. a few handfuls of berries), then tubers were nearly exclusively foraged on 70 person/days.

to acquire her TEE from *//ekwa* alone (the most frequently acquired tuber, per food returns), she would consume approximately 33 grams of protein and 18 grams of lipids. However, to do so, she would need to digest 2,157 grams of edible *//ekwa*. Given the edibility of only 26% of total mass (Schnorr *et al.*, 2015), she would have to consume a considerable amount of *//ekwa* to glean 2,157 edible grams: around 8,296 grams of total foraged *//ekwa*. Since *//ekwa* has such a low edibility, it is worth considering another tuber with a higher edibility component, like *makalita* (the second most frequently acquired tuber, per food returns) with 49% edible mass (Schnorr *et al.*, 2015). To hypothetically achieve her TEE by *makalita* alone, a woman must consume 3,275 edible grams, or 6,684 grams of total foraged *makalita*.

Tubers would need to be foraged in substantial quantities if women were to satisfy the caloric demands of themselves and children. Husbands or other men that were given tubers by women would also not glean much calorifically unless given substantial quantities as well. As for proteins and lipids, another preliminary analysis was conducted on a subsample of follow days where only tubers were foraged (*n* = 31 person/days). Women foraged an average of 22 grams of protein (median = 15 grams) and 11 grams of lipids (median = 9 grams). Despite women acquiring multiple kilograms of tubers, they received low returns of protein and lipids, values which are subsequently diminished as soon as women share any of the tubers with others.

An important application of the nutrient complementarity hypothesis is what Hadza men return to camp with on the days that women predominantly target tubers. Women are clearly in need of proteins and lipids for a large number of days – nearly one-quarter of all days sampled. Another consideration is how often women dig tubers on days where men cannot forage any other readily available food source. Such days would then represent a significant drought of protein and lipid supplies for the Hadza.

3.5.7.3 Overall

The lens of the nutrient complementarity hypothesis is useful for unwrapping kilocalories and examining macronutrient breakdowns. But just as Bliege Bird *et al.* (2009) highlighted the difficulty of using an aggregate number for male contributions to the diet, so too is there an inherent difficulty in using aggregate macronutrient contributions. For example, the Ache data used for the original hypothesis include an aggregated macronutrient breakdown for 'fruits', 'meat', 'roots' and other food groups (Hill, 1988). The Hadza data, however, demonstrate that individual berry or fruit values can create very different stories, especially if the frequency of the species is not taken into account. *Congolobe*, for instance, was the most frequently acquired berry across camps and also has 8.8 grams of protein per 100 grams of wet mass. If an aggregated number for protein in

berries had been used, then actual protein content would be estimated to be lower. Tubers too produce different breakdowns by species because of the large range of edibility by species type.

Comparisons with the Ache data demonstrate that such species differences may create larger differences between populations. For example, in the Ache data, fruits were all categorised as having 2% protein (Hill, 1988), a very different amount to some of the Hadza fruits, especially baobab. Conversely, Cordain *et al*. (2000) derived an aggregate estimate of 14% of protein in plant-based foods. They based their macronutrient estimates exclusively from Australian Aboriginal plant sources. In the Hadza plant sources for this study, no plant was found to have as high an amount of protein except baobab. As Cordain *et al*. (2000) point out, there are indeed variances in macronutrient composition of plant foods by season, latitude and locale.

An important next step to the nutrient complementarity hypothesis is to uncover another layer: the macronutrients of individual species. This is important for determining how Hadza men's foraging goals match the macronutrient demands of Hadza women and children. The Hadza women are in need of lipids during days when they do not forage meat, baobab and certain species of berries/fruit. They are also in need of lipids and proteins when they forage only for tubers. If women are to satisfy lipid requirements, then they need men's shared foods to have relatively higher lipid contents. Furthermore, they need men's shared foods to be available to their children, especially infants who require that 40-60% of their energy be derived from fats (FAO, 2010).

Meat is a valuable source of lipids. The fat content of meat has a greater variance than its protein content (e.g. Bohrer, 2017). Fat content within a species may vary according to age, gender and other factors, while fat content between species is largely determined by fat free mass (Cordain *et al*., 2001). For this reason, Cordain *et al*. (2001) argue that small game acquisition would not have provided sufficient quantities of fatty acids for encephalisation in the past. Their argument is also consistent with the reported phenomenon of "rabbit starvation" by which consuming too lean of protein without lipids (as in the combination of small game like rabbits) can lead to adverse side effects, even death (see review in WHO, 2007, p. 231-232).

There are exceptions in the Hadza diet, however. For instance, *Quelea* chicks have the second highest lipid content of all meat sources in the study (6 grams per 100 grams wet mass), even though they are the smallest game foraged in the sample. The macronutrient content of small game species is an additional element for the debates of costly signalling in Hadza men. Hawkes *et al*. (1991) argue that acquiring more small game would be a better strategy for husbands to provision based on kilocalories. While others reject the premise that Hadza men are big game specialists and do not already target small game

(e.g. Wood & Marlowe, 2013, 2014), an interesting consideration is whether the supposed 'extra' game Hadza men could acquire would amount to inconsequential or consequential amounts of lipids. Hawkes *et al*. (2014, p. 613) write that Hadza men trying to maximise meat returns for their households should "always" pursue small game instead of large game. But this conclusion ignores consideration of the quality of meat. Wives and children may be more in need of lipids, rather than kilocalories. Blanket statements about categories of 'small game' and 'large game' should be re-evaluated in terms of macronutrients. Low-lipid and high-lipid game meats may actually be a useful distinction that is not typically considered.

Besides consideration of species-specific fat content, these findings have also raised the issue of another area deserving of greater attention: the low nutritional value of tubers. So much attention has been given to why males hunt large game. The combination of high returns with a very low probability of success has intrigued many and inspired numerous explanations. Yet tubers are a similar conundrum, simply reversed. They are a combination of higher probability of success (in terms of availability during the year) and very low returns. Women's targeting of tubers is compatible with childcare constraints and low risk, reliable returns. But why, in groups like the Batek (Endicott & Endicott, 2008), would both men and women target tubers? This strategy is far from an efficient overlap in the sharing of macronutrients. The decision for males and females to both forage tubers also restricts their use of space. While foraging for berries or game meat, one has the opportunity to seize other food items. If men and women simultaneously target tubers [as Batek couples are observed to do (Endicott & Endicott, 2008)], then they are restricted to a more limited pool of resources.

Perhaps male participation in tuber digging may be necessitated by the unavailability of other foods. One of the redeeming qualities about tubers is their reliability. For example, they are the most continuously available in Hadzaland (Marlowe & Berbesque, 2009). But if males have the option to target other foods, indeed any other foods, then they could most likely produce more protein or lipids than the low amounts in tubers. In these instances, men and women could benefit more from an additional resource, even if more risk were involved. The instances in which men target tubers are also in contradiction to the findings of risk and reward from Codding *et al*. (2011). Males digging for tubers involves both low risk and low energetic reward, a strategy that more closely resembles their predicted strategy for females. Although exact nutritional values for the Batek tubers are not all available, at least one of the tuber species (*Dioscorea pentaphylla*) resembles the low nutritional contents of the Hadza tubers with only 72 kilocalories and 0.67 grams of fat per 100 grams of fresh weight (Rajyalakshmi & Geervani, 1994, cited

Maneenoon *et al*., 2008, p. 392). Men and women's simultaneous targeting of tubers with such low nutritional content is deserving of exploration.

3.5.8 Honey & Costly Signalling

Hadza men are not only provisioning themselves with honey outside of camp (Berbesque *et al*., 2016), but as this study has demonstrated, they are also provisioning women outside of camp. Honey and gift giving outside of camp are understudied components of forager food sharing. Even large game meat (though only one example in the follows data) may be shared with women outside the central place. If the provisioning model or the costly signalling model are restricted to in-camp data, then key food transfers are evidently missed outside the central place.

Honey is increasingly being recognised as an important food stuff in human evolution (e.g. Crittenden, 2011; Wrangham, 2011; Marlowe *et al*., 2014). As such, it is deserving of greater attention for its role in the sexual division of labour. The resource contributes substantially more kilocalories to the Hadza diet than recognised by in-camp eating alone. If total kilocalories are broken down across all women's follows (without controlling for repeats), then honey comprises the largest portion (33%) of out of camp eating by women. Honey is followed by tubers (32%), berries/fruits (17%), baobab (14%) and small game (7%). Although the measure of 33% may be biased by extreme values in honey consumption, it is still markedly different from the results of Marlowe (2010). He found that of the total kilocalories brought back to camp by women, honey constituted less than 1%.

Men's gifts of honey outside of camp help account for very high calorific consumption by women. Around one third of gifts received by women were given by adult men, the majority of which were gifts of honey. The vast majority of gifts (95%) were given to women of reproductive age (see results discussed in Section 5.10.8).

Honey has featured in the ongoing debates about the foraging goals of Hadza men. As Wood and Marlowe (2014) highlight, major proponents of the hypothesis have not tested honey – whether its acquisition, consumption or sharing. In their response to Gurven (2004b), Stevens and Cushman (2004) argue that honey, if traded for social deference, should be considered a case of costly signalling. This argument could also be extended to mating opportunities, an outcome commonly employed in costly signalling models.

Proponents of the costly signalling model have focused on the distribution of meat by men, to the exclusion of other foods. Hawkes and colleagues argue that Hadza men specialise in targeting the 'public good' of large game (e.g. Hawkes *et al*. 1991, 2001, 2014). As Wood *et al*. (2014) highlight, they code an activity like gathering honey as searching

time for large game. The treatment of men's other activities, like foraging for small game, collecting fruits and honey, is a point of contention between Wood and proponents of the provisioning model and Hawkes and colleagues. Wood *et al.* (2014) summarise the debate:

> "Hawkes *et al.* go to great lengths to argue that the Hadza men we observed were big game specialists, ignoring small game, and thus were lowering the rate at which they delivered food to their households in order to share more meat with others. Men's actual behavior, including their frequent pursuits of honey, small game, and fruit […] demonstrate that such a description doesn't match the reality we observed" (p. 628).

Wood and colleagues argue that Hadza men are not strictly big game specialists; they are also targeting small game, fruits and honey. Indeed, honey is that which men most frequently acquire and most frequently consume outside of camp (Berbesque *et al.*, 2016). Even Hawkes *et al.* (2014) documented honey as most frequently brought home by men.

There are many more intricacies[20] to the debate between Wood *et al.* (2014) and Hawkes *et al.* (2014), but one difference may help illuminate why Hawkes and colleagues deemphasise the importance of men's honey collection. Hawkes and colleagues' treatment of honey may be biased by their impressions from a single group of Hadza in 1985-1986. In following one group through five camps, Hawkes *et al.* (2001) wrote that "small parties of men, women, and children (often single families) took honey intermittently" (p. 682) and "[men] search specifically for honey, often in nuclear-family parties" (p. 683). The observation that honey collection was often done by nuclear family parties is inconsistent with Marlowe *et al.*'s (2014) findings from different groups across 24 camps as well as Berbesque *et al.*'s (2016) findings of men foraging and consuming honey by themselves. For example, Marlowe *et al.* (2014) document only one case of a husband and wife acquiring honey together; otherwise, the majority of acquisitions (1,031) are male and the minority are female (136). Thereby, one source for the different perceptions of the importance of honey may be the impressions Hawkes and colleagues received regarding honey foraging parties.

The results of this study add to the ongoing debate about Hadza men's foraging goals. Men were observed to approach a group of women and share gifts of honey. These men chose to devote time and effort to sharing honey outside the presence of all or most other adult men but within the presence of all or most adult females. Such a choice suggests that men are also being motivated to pursue honey for this type of sharing. They are

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[20] For instance, the researchers are not applying the same definition for small game. Hawkes *et al.* (2014) apply the cut-off of 5 kg whereas Wood *et al.* use the cut off of below 35 kg.

foregoing an opportunity to continue to pursue game during the daytime in order to bring honey spoils to a group of women. Men are prioritising honey acquisition and sharing, a choice that is consistent with an observation from Hawkes *et al.*'s (1991) original experiment. When Hadza men were being paid to target small game and asked to amass as much as possible, they still decided to spend time in other activities – "mainly honey collecting" (p. 86).

Honey is deserving of a comparative test for the provisioning and costly signalling models. The conditions for satisfying the stability of a costly signal include that signals impose a cost which is correlated with the quality the signaller advertises and that signallers and receivers benefit from the shared information (Bliege Bird & Smith, 2005). The distribution of honey by men while women are foraging in groups fulfils these conditions. Furthermore, men engage in "broadcast efficiency" (e.g. Smith & Bliege Bird, 2000; Bliege Bird & Smith, 2005), whereby they give gifts in front of an audience of most, if not all, adult female foragers, plus any children present or any other men that also joined the group. As Hawkes *et al.* (2001) also document, any visible honey is widely shared in the Hadza, a description which is consistent with honey as a 'public good'.

Honey is dangerous and costly to acquire, and its acquisition may signal the strength and risk-taking of the forager. Hadza men assume serious risks of injury and death when they climb tall trees for *ba'alako* honey (Marlowe & Berbesque, 2009). Men climb up to 15 metres to retrieve *ba'alako* (Marlowe *et al.*, 2014), the honey which has the highest calorific return, protein and lipid content of all honey types (see Appendix C). They also assume risks when they climb vines for accessing hives (Marlowe *et al.*, 2014). Past medical examinations of the Hadza reveal that falls account for a greater number of more serious injuries (29 cases) than injuries from wild animals (4 cases) (Bennett *et al.*, 1973; Blurton Jones, 2016).

Other hunter-gatherer populations climb trees primarily to acquire honey (Venkataraman *et al.*, 2013; Kraft *et al.*, 2014). Venkataraman *et al.* (2013) briefly review climbing for honey in the Mbuti, Efe and Aka. They write that tree climbing is energetically costly and inherently dangerous, accounting for 6.6% of deaths in Aka men (Hewlett *et al.*, 1986; Venkataraman *et al.*, 2013). Kraft *et al.* (2014) discuss the important fitness consequences of climbing for honey, in terms of high risk and high reward.

Due to this combination of high risk and high reward, honey is an important food for testing costly signalling. If Hadza women's food preferences are considered too, then honey is more important to women than meat. Of the five food types, honey is women's most preferred while meat is only fourth (Berbesque & Marlowe, 2009). Additionally, honey is most available when hunting is less productive (Marlowe *et al.*, 2014). This finding in particular raises the secondary issue: if men have not acquired meat then might

they produce a costly signal from an alternative resource? Considering that Hadza men only acquire large game meat very infrequently [comprising only 5% of foods in Wood and Marlowe (2014) and only 5% of forays in Berbesque *et al.* (2016)], then it is reasonable that if they are motivated to share via costly signalling then they may be motivated to do so via alternatives. Indeed, Bird (1999) wrote that "small game that is difficult to acquire and that would reliably distinguish one man from a competitor would be just as attractive as a source of prestige if an audience can be assured" (p. 72)—surely, then the difficult-to-acquire honey could be an equally attractive source for costly signalling.

Honey is also an important source for testing male foraging and sharing goals because of its prevalence across other hunter-gatherer populations. Foraging for honey is a predominantly male activity across warm-climate foragers (Marlowe *et al.*, 2014). The ubiquity of large game hunting has provoked explanations for why men tend to hunt, yet the pervasiveness of honey collection has not garnered equal attention for why men tend to gather honey. Marlowe *et al.* (2014) document seven groups where males exclusively acquire honey and four groups where males mostly acquire honey. There are additional groups not included in the Standard Cross-Cultural Sample (SCCS) where males predominantly forage for honey. For instance, Endicott and Endicott (2008, p. 90) observed no instances of Batek women foraging alone for honey, and they described men climbing the tallest trees and taking honey at night. In the Ache, men collect honey (Hill & Hurtado, 1996) and it is the food that is second most likely to be shared publicly, after big game (Kaplan *et al.*, 1985). Interestingly, Bird *et al.* (2009) document the increasing importance of honey collection from feral European bees in the Martu.

There are still many questions remaining for the observation of Hadza men giving honey outside of camp. For example, how often are men doing this? How many are kin and how many of the husbands are giving to their wives? These questions have important ramifications not only for costly signalling and provisioning hypotheses, but other models of food sharing like reciprocal altruism. Section 3.5.10 discusses future directions for subsequent studies.

3.5.9 Summary Points

- The average Hadza woman consumes over 300 kilocalories daily while outside of camp. The time she spends foraging is the strongest predictor of how much she will eat. Honey is also an important predictor of total consumption. Nevertheless, there is substantial variation in the amount consumed outside of camp, and these two variables explain less than half of the total variance.

- Women regularly transfer food while foraging outside of camp. Gifts given and gifts received account for around 500 kilocalories daily. As with women's eating, however, there is a wide distribution of total kilocalories given and received. When women receive gifts, their decision to consume the food now or save it for later differs by food type. Honey and tubers are usually consumed immediately.

- The average Hadza woman forages around 3,500 kilocalories per day. The more time she spends foraging, the more kilocalories she forages overall. On days where women forage honey and *Quelea* chicks, women forage significantly more kilocalories. The mass reproduction schedules of *Quelea* allow women to acquire a large number of chicks.

- Hadza women are capable of meeting daily macronutrient requirements for themselves and offspring from female-targeted foods. However, women need to obtain certain species at sufficient frequencies to meet macronutrient requirements. The Hadza nutritional data suggest that male-targeted foods which are high in lipids may be the most beneficial to women.

- Although women do not regularly target honey, this food source is an important component of their out of camp eating and sharing. Honey comprises the largest portion of the total kilocalories consumed by women outside of camp. Women also frequently receive gifts of honey from men. Honey satisfies the conditions for a costly signal and should be investigated with respect to the costly signalling model.

3.5.10 Future Directions

By documenting calorific data for eating and gifts outside of camp, this study has demonstrated that a lack of out of camp data translates to an average loss of 830 documented kilocalories per woman per day (the sum of the geometric means for gifts and eating). Given the large range in kilocalories, however, thousands of kilocalories could be missed in a single day, whether in gifts or in consumption alone. Future foraging studies should focus on incorporating out of camp calorific data, as a significant portion of eating and sharing occurs outside the central place. Models of forager food economies that rely only on central place data have serious potential for bias.

The gift exchanges that occur outside of camp require more attention from future studies. These exchanges may involve a mix of players from both sexes. A record of such gifts is especially important for studies on sharing and reciprocity. Long-term gift exchanges may be fulfilled outside the central place and still in the witness of others.

Which men show up to give gifts and when is another interesting aspect. Are there different behaviours for married and unmarried men? How does proximity feature into the gift exchanges?

This study's methodology of factoring gifts into total foraging also raises interesting questions. Adding gifts to total foraged is more straightforward: a woman who gives a gift of 500 kilocalories to another woman did indeed need to forage an additional 500 kilocalories. On the other hand, subtracting gifts received from total foraged questions to what extent a social foraging strategy may exist. This study subtracted gifts received because these were not physically foraged by the women themselves, but to what extent did the women position themselves, either by past gifts given or other social ties to receive these gifts?

The sociality of gift giving, in particular, may represent an important manifestation of cooperation between and among the sexes outside of camp. Future studies may seek to investigate interindividual differences in gift giving. For example, Chaudhary *et al*. (2016) documented a gift network among BaYaka foragers, finding significant variance between individuals. Greater 'relational wealth' (receiving gifts from more people) was significantly associated with higher BMI and age-related fertility in women. Overall, men displayed greater variance in relational wealth than women. Such results raise avenues for exploration in the Hadza, especially at the individual level of gift giving and receiving outside of camp.

4 The Hadza Woman's Menstrual Cycle

4.1 Introduction

The forager woman physically changes over time; she is the menstruating woman, the pregnant woman, the lactating woman and the post-menopausal woman. How a woman's reproductive life stages affect her foraging behaviour is an important consideration for foraging studies. Besides the 4% of Hadza women with primary sterility (Blurton Jones, 2016, p. 134), the average woman shifts between reproductive stages over the course of decades. Not only do women shift between these stages, they shift within these stages: from early to late pregnancy, from early breastfeeding to weaning. Changes within and between these reproductive stages may have different effects on foraging behaviours. These effects may be physical, as in differing energy requirements, or cultural, as in restrictive taboos about consumption of particular foods or participation in particular activities.

Before considering what effects reproductive status may have on foraging behaviour, the following chapter chronicles the reproductive timeline of Hadza women: from menarche to pregnancy to breastfeeding to post-menopause. A woman's changing reproductive status is explored from the viewpoint of menstruation. Menstrual patterns help delineate the physical parameters within the fertile span, like lactational amenorrhea and the timing of menopause. This chapter incorporates a biocultural perspective of menstruation (e.g. Sievert, 2006), from menses duration and pain to menstrual cleaning and the meaning of menstruation.

Menstrual data from the Hadza are of importance not only to studying foraging behaviour specifically but also to studying reproductive biology generally. Differences

in menstrual cycles are linked to cardiovascular disease (Solomon *et al.*, 2002), type 2 diabetes (Solomon *et al.*, 2001) and reproductive cancers (Cirillo *et al.*, 2016). Endometrial, ovarian and breast cancers, accounting for over 30% of all cancers diagnosed in women worldwide (Ferlay *et al.*, 2015), have been linked specifically to hormonal and cycle length differences (Pike *et al.*, 2004; Bernstein, 2006) as well as bleeding duration (Brinton *et al.*, 1992). Natural fertility data are a critical source of information for the future detection and prevention of such cancers (Strassmann, 1999). Hunter-gatherer data, in particular, present an important type of natural fertility data for placing cancers in an evolutionary context (Eaton *et al.*, 1994). Reports of cancers in hunter-gatherers are either non-existent or very low (Eaton *et al.*, 1994). Forager diets and energetics are also important considerations for investigating factors linked to reproductive health, cancer risk and other health issues (e.g. Raichlen *et al.*, 2017).

Differences in menstrual patterns have been significantly associated with women's fecundity (e.g. Kolstad *et al.*, 1999; Small *et al.*, 2006; Small *et al.*, 2010). As such, a better understanding of menstrual variation entails a better understanding of fecundity. In the foraging environment, variance in menstrual patterns may offer key insights into the selective pressures acting upon female fecundity and fertility. Given their natural fertility status as a non-contracepting population and their foraging lifestyle, the Hadza are a prime population for exploring menstrual pattern variation in the foraging environment.

4.2 Background

Despite estimates of menopause and reports of menstrual pain (dysmenorrhea) dating back to Ancient Greece (Amundsen & Diers, 1970; Voto & Essig, 1984), variation in menstrual patterns was not formally described by the medical community until the mid-20th century. In the 1960s, large-scale studies challenged the notion of a 'normal' 28 day cycle (Matsumoto *et al.*, 1962; Treloar *et al.*, 1967; Chiazze *et al.*, 1968), a notion which prevailed in clinical textbooks at the time and continues even today. These studies found a wider range of variation, e.g. Chiazze *et al.* found a mean of 29.1 days with SD of 7.46 days. During that same decade, radioimmunoassays were developed for luteinizing hormone (LH) and follicle-stimulating hormone (FSH), with a peak in LH linked to ovulation (Midgley & Jaffe, 1966; Odell & Swedloff, 1968). An increased understanding of hormonal activity helped formally establish the follicular phase (from the start of menstruation to before ovulation) and the luteal phase (from after ovulation to the start of menstruation). Cycle variation has been predominantly attributed to follicular phase variation (Lenton *et al.*, 1984; Wood, 1990; Vitzthum, 2009).

Despite the recognition of greater variation both within and between women (Harlow *et al.*, 2000; Gorrindo *et al.*, 2007), the majority of data continues to be derived from Western, contracepting populations. Henrich *et al.* (2010) critiques the overreliance on 'WEIRD' societies (Western, educated, industrialised, rich and democratic societies) for defining what is 'normal' in behavioural sciences. Others have echoed this call for integration of more diverse populations in physiological research (e.g. Yatsunenko *et al.*, 2012). With regards to menstrual data, Vitzthum *et al.*'s (2001) comments remain valid today: "despite its importance, relatively little is known about inter and intrapopulational variation in the broader category of vaginal bleeding, of which menstruation is but one manifestation" (p. 319).

A critical source for menstrual data is non-contracepting, natural fertility populations. However, only a small number of studies have reported on actual menstruation in natural fertility populations. Notable study populations have included the Gainj in Papua New Guinea (Johnson *et al.*, 1987), the Lese in Zaire (Bentley *et al.*, 1990), the Dogon in Mali (Strassmann, 1992), and the Aymara in Bolivia (Vitzthum *et al.*, 2001). Johnson *et al.* (1987) estimated the median cycle length of Gainj women to be about 40% longer than that of American women (age adjusted sample for comparison) and suggested this finding as a partial explanation for low reproductive output in the Gainj. Lower fecundity in Lese has also been attributed to differences in menstrual cycle length along with differences in energy balance (Ellison *et al.*, 1989). Indeed, energy balance has been a key focus of theoretical explanations for ovarian function variability (Ellison, 1990; Ellison, 2003), finding further support from studies of the Tamang in Nepal (Panter-Brick *et al.*, 1993; Panter-Brick & Ellison, 1994).

Strassmann's hormonal and interview data from Dogon women, obliged to sleep for five nights in menstrual huts, are important contributions to non-contracepting menstrual profiles (Strassmann, 1992; Strassmann, 1996a; Strassmann, 1999). She contrasted the Dogon, whose total fertility rate (TFR) is 8.6 (Strassmann, 1992), to one American woman with 3 live births [the only case from Treloar *et al.* (1967) with a full menstrual history]. The result was striking: the American woman experienced 355 menstrual cycles while the Dogon women experience about 100 each (Strassmann, 1999). Strassmann's estimate of 100 cycles is based on data collected over a two-year period, during which women aged 15-19 experienced a mean of 11 cycles, women aged 20-34 experienced a mean of 4 cycles and women aged 35 and above experienced a mean of 13 cycles. For the non-contracepting Dogon, more pregnancies and longer periods of lactation (particularly during the key reproductive years) equated to fewer cycles, which, in turn, potentially help explain lower incidence rates of breast cancer (Strassmann, 1999).

In terms of menstrual bleeding, the Aymara study is the most descriptive of the natural fertility studies (Vitzthum *et al.*, 2001). The mean reported menses length of 3.5 days for non-contracepting Aymara women was the second lowest of all published values [second only to 3.25 days of the Lese (Bentley *et al.*, 1990)]. The study reiterated the importance of natural fertility data for understanding breast cancer. In comparing published values for menstrual bleeding, Vitzthum *et al.* observed that the shortest menses were characterised by natural fertility populations with low ovarian hormone levels and low breast cancer risk (e.g. Andean women) while the longest menses characterised populations with high levels and high risk (e.g. American women). Though these connections have not been statistically tested, it is evident that further data on bleeding patterns are needed.

None of the aforementioned populations, however, are foraging populations; they are all horticulturalists. Thus, the already limited pool of menstruation studies for non-contracepting populations is further constrained by subsistence strategy. Menstrual information for foraging women is extremely lacking. Besides scant hormonal data on segments of menstrual patterns[21], information about menstruation is restricted to minor descriptive accounts in the context of larger studies. As examples, Hill and Hurtado (1996) and Howell (1979) mention generalizations about menstruation in their larger demographic works on the Ache and Ju/'hoansi, respectively. Shostak's (1981) account of the Ju/'hoansi woman Nisa is also a source for anecdotal menstrual information in the Ju/'hoansi, though limited by methodology and reliance on a single source. Endicott and Endicott (2008) too include some menstrual information in their ethnography of the Batek.

In his book, Marlowe (2010) recounts some generalizations about Hadza menstruation. [No generalizations are included in Blurton Jones (2016).] Marlowe writes, "Hadza women say they tend to bleed only for about 3 days rather than the 5 days typical in the United States. In addition, their bleeding is apparently less copious than is typical for American women, according to my female research assistants[22]" (Marlowe, 2010, p. 159).

While generalisations are helpful and trustworthy to the extent that the researchers exhibit great familiarity with the study population (having studied and interviewed individuals over a number of years), these generalisations are not clearly supported by

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[21] For instance, Ellison *et al.*'s (1986) preliminary study includes information on the luteal phase of the Efe, but raw data from 14 Efe women are grouped together with data from horticultural women, forming an 'Ituri sample'. Another study draws conclusions on corpus luteum function and suppression of female sex steroids on a limited sample in the Ju/'hoansi (van der Walt *et al.*, 1978).

[22] Alyssa Crittenden made this initial observation (Crittenden, pers comm).

statistical data. There is a gap in descriptive menstrual data, which are grounded in clearly demarcated sample sizes. For example, Endicott and Endicott write of the Batek, "some people said sexual intercourse was prohibited during menstruation" (2008, p. 29) while Howell recounts of the Ju/'hoansi, "many women report that they never resumed menstruation after the birth and lactational amenorrhea of the final child" (1979, p. 130). Quantitative evidence would help support and contextualise the variability and representativeness of these qualitative investigations.

More detailed studies do exist for menstruation in foragers; they are just limited to menarche and menopause. Studies have sought to establish the timing of first and last menstruation in various foraging populations [e.g. the Agta (Goodman *et al.*, 1985a) and the Pume (Kramer, 2008)]. The timing of these phenomena has been discussed in the context of theoretical frameworks, too. For instance, earlier ages at menarche and first birth have been linked to high mortality rates and faster growth (than expected for body size) in several foraging populations (Migliano, 2005; Migliano *et al.*, 2007; Walker *et al.*, 2006).

Estimates of menarche and menopause in the Hadza stem from only two sources: Marlowe's (2010) preliminary investigation and Phillips *et al.*'s (1991) unpublished hormonal analysis. Marlowe (2010) estimates average age at menarche as 16.5 years, though he does not report a sample size nor any other statistics. The results of Phillips *et al.*'s (1991) study were not officially published; however, in his supplementary materials, Blurton Jones (2016) includes a written account of Phillips *et al.*'s study. The researchers tested urine samples of 82 Hadza women (68 with known ages) for the presence of LH. They inferred menopausal status from elevated LH (though it is unclear how the LH levels were standardised for comparison). They determined a median age of menopause as 41.9 years, and after a 1.5 year correction for premenopausal LH peaks, they estimated Hadza women's median age of menopause at 43.4 years.

Menarche and menopause are also featured in cultural contexts. Menarche, especially its associated rituals, taboos and liminal status, has been written about extensively (e.g. Power & Watts, 1996; Lutkehaus & Roscoe, 2013; Brown, 2015). As mentioned previously, the *maitoko* is a Hadza puberty initiation ritual for girls corresponding with the ripening of *Cordia sinensis* [Marlowe, 2010; see Power (2015) for further descriptions]. Though no ritual is associated with menopause for the Hadza, menopause does have a wide literature of cultural perspectives, with Sievert (2006) offering a useful review.

In focusing mostly on menarche and menopause, however, the majority of the literature is limited in scope. Menarche and menopause represent only two processes within a lifetime of menstrual cycles. A gap exists for descriptive, cultural accounts of menses itself. As examples, few accounts exist on how and what foraging women learn about

menses and how they clean and what they use to clean during menses. Equally, a gap exists for biological accounts of menses, like how long women actually menstruate and whether or not they have menstrual pain (two factors that have the potential to influence foraging decisions). More accounts of menstruation and its associated practices are needed for foraging groups. This chapter helps fill the gap in menstrual accounts by presenting multiple aspects of menstruation in the Hadza. Both the biological and cultural aspects of Hadza menstruation are discussed with reference to data from the clinical setting and from other reports in foraging populations.

4.3 Data Analysis

The analysis in this chapter focuses on comparisons across the women's interview answers. Many answers were categorical (e.g. 'yes', 'no' or 'I don't know') and were analysed with the one-sample proportions test with continuity correction. This test allows for determining whether a majority answer given (e.g. 'yes') is statistically significant (given the sample size and proportion) as well as the confidence interval for that answer.

Menses length, menstrual blood loss and menstrual pain were all treated as categorical outcome variables. Probit regression and one-way ANOVAs were used to examine whether continuous variables like age or parity (controlled for age) were significantly associated with these variables. Barnard's exact test (for 2x2 contingency tables) and Fisher's exact test (for 2xr tables) were used to examine comparisons between categorical variables, including variables like post-menopausal status and camp.

Age at menarche and age at menopause were estimated by 'status quo' probit analysis, based on the presence or absence of menstruation. The input and age restrictions for these analyses are discussed in further detail in Section 4.4.2 and Section 4.4.14.

One outcome variable that was unable to be analysed is the length of the menstrual cycle. All women answered this question in a similar way, without a reference to week count or day count. This variable is discussed in more detail (see Section 4.4.4), as well as the use of time in Hadza women's answers (see Section 4.4.10).

4.4 **Results**

4.4.1 **Menstrual Words & Meaning**

The women were asked the word for menstruation in Hadzane. As one woman explained, "in Hadzane it is just *atama* and in Swahili, blood" (T1). *Atama*[23] was the word given by all women interviewed. Both the Swahili word for 'blood' (*damu*) and the Hadzane word for blood (*atama*) are used when speaking of menstruation. Swahili has another word for menstruation (*mwezi*) with two alternative (though linked) meanings: month and moon. For this reason, pointing to the sky or use of the Hadzane word for moon (*seta*) were necessary to distinguish moon from month.

Colloquial Swahili has still further phrases for menstruation, including *siku zangu* (literally, my days) and *hali* (literally, conditions). That some Hadza women used these phrases during interviews suggests that menstruation is at least talked about. (Section 4.4.14 discusses Hadza women talking about menstruation in the context of menopause.) Based on behavioural observations during the interview, it is likely that menstruation is typically discussed among women only. Some women would say *atama* much quieter than other words. Women would often scan for any people near our secluded interview spot, especially for any men.

The women were also asked about words for first menstruation or last menstruation. No equivalent words or phrases were reported[24]. Women used certain verbs from Swahili to describe menstruation (e.g. the Swahili word *kupata* for 'to get' menstruation and *kufunga*, meaning to close, used as 'to stop' menstruation). Words for menstrual pain too were asked about, but none reported. Women said they simply use the word 'pain'.

Besides the questions for specific words, women were additionally asked about the meaning of menstruation. While some answered they did not know, for example "I don't know where it comes from, you can't see" (T2), the most common answer for the meaning of menstruation was "child". One woman said, "The meaning of blood is a child, if the child enters, then you don't get menstruation" (T3). Others explained, "in Hadzane, blood means getting a child; if you don't get it for a month, then you know you have a child. If you pass two months, then you know you have a child" (T4) and "in

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[23] Hadza women also used the word '*atamako*', reflecting a combination of the Hadzane word '*atama*' with the Swahili suffix *-ko*. By attaching the locative suffix *–ko*, the Hadza women use the new word as describing a state of being in *atama*.

[24] This is consistent with other fieldwork observations (Camilla Power, pers comm).

Hadzane it means you come from your mother's womb, you are born and you will menstruate" (T5).

Women were also asked to speculate as to why they think that they menstruate. A frequent answer was "God's plan" or "God's ability". References to "God" (referred to with the Swahili word *mungu*) appeared elsewhere in the context of a mother's teachings: "I just saw I am bleeding, I thought I am sick over there, then mom checked and said, ah this is because of God" (T6). Knowledge about pregnancy is also related to God in Section 4.4.12.

4.4.2 Menarche

For those younger women who were not yet married and/or had no children, a separate set of pre-menarcheal questions were asked. These ascertained whether the girl knew about menstruation (if so, from whom?) and whether she had menstruated yet.

Presence or absence of menstruation was used for a 'status quo' probit analysis to estimate the age of menarche. Median age at menarche is 16.8 (n = 21; 95% CI [14.2, 18.3]). Two girls, aged 11 and 13, were included in this sample in addition to the 58 women interviewees. These girls were not asked directly because their mothers explained they were too young, had not menstruated and did not know about menstruation. Excluding these girls, the menarche sample ranged in age from 14.25 to 20.75. The higher cut-off of 20.75 was selected on the basis of a 19.75 year old reporting no menstruation.

Hadza women were asked whether they knew about menstruation before they reached menarche. There was no clear trend of pre-knowledge: 52.8% reported they knew and 45.3% reported they did not know, with 1.9% not remembering (n = 53). Of those who did not know about menstruation, several detailed telling their mothers immediately afterwards. For example, one woman explained, "when I bled and saw the blood, I asked myself what is this, I went to mom crying" (T7) and another, "my mom told me nothing; she left me the way I was. When I bled, I went to tell my mom, I got my menstruation; she said 'this is the way of women'" (T8). Another woman recounted the unexpectedness: "I saw I am bleeding and I thought while I was asleep, someone came and pierced me!"(T9).

Though a smaller sample of women were asked how they felt about menarche, all reported they were not happy (n = 11). This sentiment was reinforced by some calling menstruation "bad". One woman said, "I just started, I thought this is bad and I cried" (T10). Many women recalled pains associated with first menstruation: "I had stomach pains" and "I felt my body is heavy, aching" (T11). One woman recounted: "if the girl starts menstruation, (she) feels back and waist pains, you start getting sick, when you

sleep and (then) wake up, it's done! You get decorated with white beads, and for that you are now a grown-up girl" (T12).

For the Hadza, mothers are an important source of information about menstruation. When asked the open-ended question of who taught them about menstruation, a significant majority of Hadza women answered 'mother' (84.9%) compared to all other answers (n = 53, one-sample proportions test with continuity correction, $p < .001$, 95% CI [0.81, 0.97]). Table 4.1 summarises the percentages for all four answers provided.

Table 4.1 Reponses to Who Taught Hadza Women about Menstruation

Response	Percentage of Women (n=53)
Mother	84.9%
No One	9.4%
Sister	3.8%
I Don't Know	1.9%

Hadza women were then asked what their mothers taught them about menstruation. Three themes emerged: symptoms or signs before menstruation (inclusive of those who answered they knew about menstruation before it first occurred), the symbolism of growth and child-bearing, and washing during menstruation. For symptoms and signs, women gave a diverse range of answers, including "she told me, when you start the period, you will see the sign of your skin changing" (T13), "she told me when you start to mature, the breasts appear and then you get menstruation" (T14) and "she told me when the moonlight appears, I know menstruation will start" (T15). (Further references to the moon are discussed at length in Section 4.4.10.) Pain, too, was a particular sign mentioned: "she said if you feel these symptoms then menstruation is coming; you feel body pain and fatigue, then you know menstruation is coming today" (T16) and "if you have waist pains, you are ready my daughter for menstruation, you have grown up" (T17).

Being 'grown' and having children appeared as a second theme, with mothers explaining "that menstruation you have seen, you have matured" (T18) and "when you grow my child, you will get the menstruation, when you see the menstruation, you will see the baby" (T19). A third theme, though, encompassed the majority of answers; twenty-one women discussed learning to wash during menstruation. As examples, "she

told me 'do the cleaning'; to wash the blood with water"(T20), "she taught me to clean […] for not stinking" (T21), "she taught that, do this, wash the cloth, do this, wash the cloth" (T22), and "she told me, my child, when you get the menstruation, you have to go to clean and bathe; when you bleed, wash your cloths, fetch water and bring home" (T23). Additional comments were made about cloths, e.g. "she taught me a lot about menstruation; you put the cloths properly so that men should not see the blood" (T24), and soap, e.g. "she taught me to clean with the soap in the bush" (T25). Comments about soap included six women who specifically referred to the Hadza soap (discussed in Section 4.4.9).

4.4.3 Menses Length

Women were asked how long they usually menstruate, and all answers were given in terms of days. For post-menopausal and menstruating women, the mean reported menses length is 2.3 days (SD = 0.84), with a median of 2.5 days and range of 1 to 4 days (n = 38). Figure 4.1 summarises the frequencies of menstrual duration for menstruating and post-menopausal women. Excluding post-menopausal women's answers, the mean menses length is 2.4 days (SD = 0.73), with a median of 3.0 days and a range of 1 to 3 days (n = 29). Figure 4.2 summarises the distribution with post-menopausal answers excluded.

When asked how long they menstruate, Hadza women answered with a specific number of days. Some women explained the number of days in relation to bathing, and others in relation to resting, e.g. "I rest for two days, the third day it is already finished" (T26). Two even described in terms of day and night: "morning, evening and night (for) three days" (T27) and "morning time for two days".

Menses length was treated as a categorical variable, with three categories of 1 day, 2 days and 3+ days. Age was not significantly associated with the number of days reported, whether all women were considered (n = 38, one-way ANOVA, p = ns) or only pre-menopausal women (n = 29, one-way ANOVA, p = ns). Because the inclusion of post-menopausal women introduces potential recall bias, the Fisher's exact test was applied to compare the answers between menstruating women and post-menopausal women. There was no significant difference between their answers (n = 38, Fisher's exact test, p = ns).
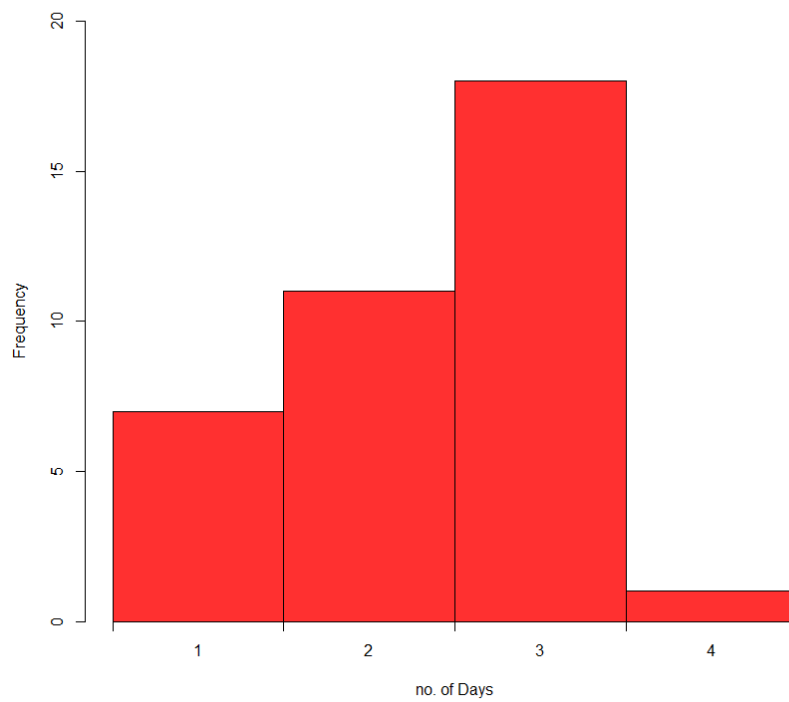
Figure 4.1 Reported Menses Length in Pre-menopausal & Post-menopausal Hadza Women (*n* = 38).
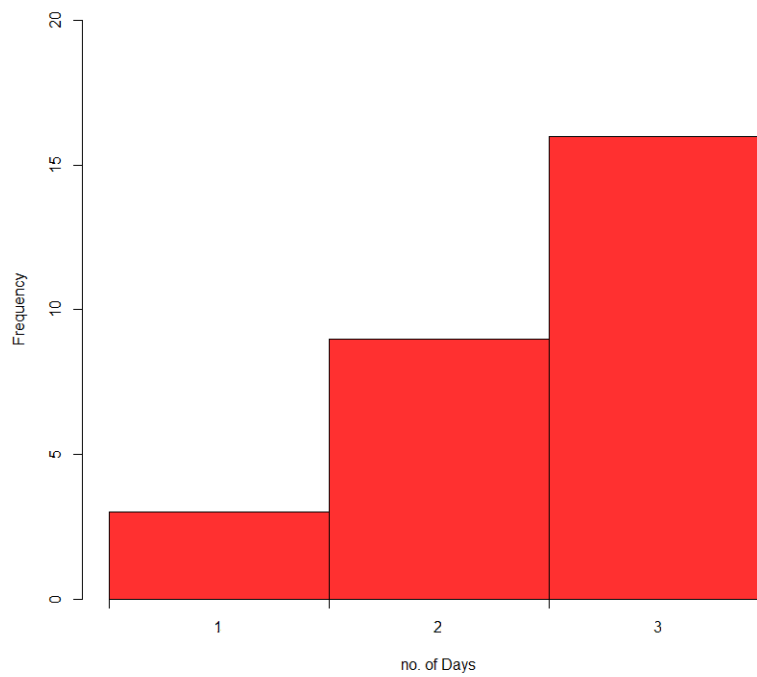
Figure 4.2 Reported Menses Length in Pre-menopausal Hadza Women (*n* = 29).

Interestingly, two women did not report any menstrual days because they described not having seen menstruation, despite both having children. One woman, a 25 year old with three children, explained "have yet to see menstruation". Because I had already asked questions about her children, I then said "but you have children" and asked again about menstruation. Her reply: "no, I am just getting pregnancy without having blood" (T28). Another woman, a 29 year old with seven children, described a similar scenario. She said, "when I was a girl, I didn't see blood, I just get a child, I don't have menstruation" (T29). Later she repeated, "not yet, I just get a child, I don't have menstruation" (T30).

4.4.4 Menstrual Frequency

Hadza women were asked when they get their period, after how much time. All women (n = 36) answered after one month. While the answers showed variation in wording, from "for every month" to "if you bleed in this month and it ends, the next period comes again in the following month" (T31) to "menstruation for just one month", the duration of one month did not differ. I also tested for menstrual irregularity, asking if periods came every two months or three months or less than one month. The women remained adamant about one month, explaining "no, no, one, one" and "it's impossible, a woman gets menstruation only after one month" (T32). The menstrual frequency of one month is consistent with the findings of Section 4.4.12, in which a missed period of one month signified pregnancy for many interviewees. How the Hadza women measure the time unit of one month is explored further in Section 4.4.10.

4.4.5 Menstrual Blood Loss

Women were asked the open question of how much they bleed. A significant majority of women answered 'a little' (85.3%) compared to a minority answering 'a lot' (14.7%) (n = 34, one-sample proportions test with continuity, $p < .001$, 95% CI [0.68, 0.94]). All of the 'a little' responses included one specific Swahili word (*kidogo* for small, or a little) while the 'a lot' responses incorporated one of two words (*nyingi* for many or a lot and *kubwa* for big). One woman even explained "a lot, stomped up to the feet" (T33). The perceived amount seemed to be consistent across days, with women confirming the same amount: "little in the first day, little in the second day and little in the third day" (T34). One woman, however, seemed to total all of the menses days in her response: "a lot, comes a little".

Probit regression was used to test whether age or parity (controlled for age) were significantly associated with reported blood loss. Neither variable was found to be significantly associated with blood loss (n = 34, p = ns, p = ns). Menses length was also

not significantly associated with menstrual blood loss (n = 34, Fisher's exact test, p = ns). Using a Barnard's exact test for analysing post-menopausal status, this variable too was not found to affect reported blood loss (Wald statistic = 1.21, p = ns).

4.4.6 Menstrual Pain

Hadza women reported both the presence and absence of menstrual pain. There was no significant difference between the two: 55.6% reported no pain and 44.4% reported pain (n = 27, one-sample proportions test with continuity correction, p = ns). Women described pain as occurring in the stomach or the waist. The number of days with pain typically paralleled the number of menstruation days. As discussed previously (Section 4.4.1), no specific word or phrase was used to describe the pain, just the Swahili word for pain and in one instance, the word for fire or heat, "you feel here a little heat in the waist" (T35). Some women offered their own adjectives to describe the pain, like "a little" or for another woman, "I get a sharp pain in the stomach" (T36). Menstrual pain was also a common theme associated with first menstruation (see Section 4.4.2). Hadza women appear to have a medicine for menstrual pain, with one woman explaining, "pain during menstruation? Yeah, they use a medicine from the bush" (T37).

Post-menopausal status was significantly associated with women's reports of menstrual pain. Currently menstruating women reported pain significantly more frequently than post-menopausal women, suggesting a potential recall bias (n = 27, Barnard's exact test, Wald statistic = 1.87, p < .05). Reports of pain were not significantly associated with menstrual blood loss (n = 23, Barnard's exact test, Wald statistic = 0.10, p = ns) nor with age (probit regression, p = ns), parity (controlled for age, probit regression, p = ns) or menses length (Fisher's exact test, p = ns). In fact, with the exception of the woman who reported a menses length of four days, the reports of pain were evenly divided across menses lengths. The number of women who reported pain exactly matched the number of women who reported no pain for menses lengths of one day, two days and three days.

Since post-menopausal status was associated with women's answers, responses from post-menopausal women were excluded. With post-menopausal women excluded, the majority of women (55%) reported menstrual pain. Once again, however, there was not a significant majority of women who reported menstrual pain (n = 20, one-sample proportions test with continuity correction, p = ns).

4.4.7 Menstrual Cleaning

Hadza women (n = 36) were asked what they use to clean during menstruation. The open question prompted three types of initial responses: water; water and soap; and water,

soap and cloth. During the interviews, the women often used hand gestures to depict the cleaning process. They would cup one hand, all fingers clasped together and curved, and motion the hand downwards along their lower body, showing where they would splash water. They also used hand motions to describe the soap and cloth (discussed further in Section 4.4.8 and Section 4.4.9).

Water was significantly chosen as the answer by 86.1% of women ($n = 36$, one-sample proportions test with continuity correction, $p < .001$; 95% CI [0.70, 0.95]). Of the 31 women who answered water, eleven specifically stated "water only". Table 4.2 displays the breakdown of answers.

Table 4.2 Hadza Women's Primary Reported Cleaning Method

Response	Percentage of Women (n = 36)
Water	86.1%
Water and Soap	11.1%
Water, Soap and Cloth	2.8%

After initial answers were given, I prompted for further elaboration, asking whether they use only what they listed or anything else. Ten of the women changed their initial answers, adding either soap, cloth or both to their first answer of water. There was no significant difference between those who said water after secondary prompting and the other answers. Table 4.3 summarises the four different types of answers given.

Table 4.3 Hadza Women's Secondary Reported Cleaning Method

Response	Percentage of Women (n = 36)
Water	55.6%
Water and Soap	27.8%
Water, Soap and Cloth	11.1%
Water and Cloth	5.6%

Changes in initial answers were accompanied by heavy reliance on the use of 'if'. Answers included "if you want", "if there is cloth", and "if there is soap". For this reason, Table 4.2 provides a comparative breakdown of cleaning methods to that of Table 4.3 based largely on conditional access to more resources.

Regardless of whether cloth or soap was added, all women use water. Women described fetching water then cleaning inside, as in "I clean at home inside so people will not see" (T38) and "I fetch water in a river, when I am back, I wash the blood" (T39) as well as describing washing outside of their home. Not enough women described where they clean (*n* = 8) to draw any significant inferences.

Because every woman answered water, I prompted with the question of what if there is no water. While one response questioned the basis of my question ("where will water go?") and another stated "if there is no water I go to fetch [it]" (T40), the remainder of responses aligned along three general themes: the ramifications of no water, help from others and alternatives to water.

The most frequent theme was the ramifications of the absence of water. The responses specifically focused on smell. Women explained "you clean yourself not to stink" (T41), "because if you don't clean, you smell bad" (T42), "you get rot", "you stink! You smell bad; people will notice the smell" (T43). One woman explained having to clean "the dirt". Women seemed particularly emphatic about these answers, some beginning with "no, no" before describing the smell or saying "water is necessary". One woman explained the situation more fully: "if there is no water, you will stink! At least if there is a small amount of water, to wash and to dry inside. After you are dried, you wear [cloths], men shouldn't see" (T44).

Help from others was another theme to emerge given an absence of water. Women explained "you ask someone to fetch water" (T45) or "if there is no water, my husband will go to fetch and bring water" (T46). Three types of people were specifically mentioned as bringing water to help: neighbours, mothers and husbands.

Besides receiving water from others, two alternatives to water were proposed: urine and cloth. As examples, one woman described the use of "urine if there is no water, women just use their own urine" (T47) while another laughed before simply answering "urine". Another woman proposed "if you don't have water, you can use cloths" (T48). The following section delves more specifically into descriptions of such cloths.

4.4.8 Menstrual Cloths

The Hadza women who mentioned cloths mostly used the Swahili word for cloth (*kitambaa*) while some used the Swahili word *kanga* which is a specific type of traditional patterned cloth in East Africa. Cloths were mentioned both as part of the cleaning process and as a preventative measure during menstruation.

For the cleaning process, some women gesticulated a wiping motion with their hands or a piece of cloth they were wearing. As for preventative measures, some women

explained "you use a cloth to prevent bleeding" (T49) and "I put on two *kanga* and wear them for the blood not to come out" (T50). Another woman described the addition of the Hadza's *pokoroshobo* (Hadzane word for animal skin): "I put a piece of cloth and then I take Hadza's *pokoroshobo* and tie it up. Then I wear a *kanga*" (T51).

When asked if they used different cloths during menstruation, women agreed, describing "menstruation cloths" ("*kitambaa kwa atama*" or "*kitambaa kuzuia atama*"). They described cleaning the menstruation cloths when cleaning themselves, as in "during menstruation we bathe and wash the cloths" (T52) and "you bathe with soap and wash cloths with soap" (T53). What type of soap these women were referring to is discussed further in the next section.

4.4.9 Menstrual Soap

In their descriptions of menstrual cleaning, some Hadza mentioned reliance on soap (see Table 4.2 and Table 4.3). Again, its use involved conditional language: "if there is no soap, you will wash only by water" (T54), "I clean when I have soap but I wash without soap if I don't have it" (T55) and "if there is a little soap, you clean with soap" (T56). When asked where the soap was from, two of the women answered "the shops" and "the village", while other women described "*sabuni ya wahadzabe*", or soap of the Hadza. I asked the women to describe what that soap was, how they made it and how they used it.

At one of the nine camps, the interviews were conducted under a large baobab tree and some baobab seeds were scattered around us. The women described "soap made from this tree", "with this", "like these" and gesticulated the pounding of the baobab pods. As they were describing menstrual cleaning, women described "just water and baobab", "you grind (and) foam appears" and "we take the soap of the fruits; you put the fruits into water and produce foam. When a little foam is produced then you take your cloths and wash" (T57). Some women clarified that it was just a little soap. For instance one described "just a bit of soap and apply oil[25] when done" (T58). After washing oneself and washing the cloth with the soap, one woman described "I clean with water, I put the cloth out in the sun and dry" (T59).

4.4.10 Menstruation & the Moon

The use of 'month' and 'days' in the Hadza women's answers prompted the addition of three time-related questions: how many days are in a week, how many days are in a

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[25] *Mafuta* refers to oil or animal fat.

month, and how many weeks are in a month. Because these questions were a later addition to the interviews, their sample size was smaller (*n* = 22). No woman answered thirty or thirty-one days in a month (no woman even answered above eight) and no woman answered four weeks in a month (answers varied from one to eight). For days in a week, only five women answered seven. (However, one of these women answered seven for all three questions.) Half of the women answered "I don't know" or did not respond to at least one of the three questions. It is worth noting too that Hadza women were quicker to laugh when posed with these questions than other menstrual questions that occasionally elicited laughter.

Though no Hadza woman could list the number of days or weeks in a month in accordance with the Gregorian calendar, women (*n* = 24) confirmed that they look at the moon to know one month has passed and to know menstruation is coming. In answering the question of how often they menstruate (see Section 4.4.4), some Hadza women had already mentioned the moon. For instance, some answers referenced the moonlight (*mbaramwezi*), like "after the moonlight has disappeared" and "they know after the moonlight". For the sake of clarity with word use (see Section 4.4.1) and for prompting further elaboration, three questions were asked (as well as interspersed with the follow-up of 'how?'): do you look at the sky to know one month has passed?; do you look at the moon to know one month has passed?; and do you know menstruation is coming because of the moon? Some answers to the first question anticipated the next questions, e.g. "I look at the sky because if I see the moonlight reaches here, possibly I will see menstruation" (T60).

The Hadza women appear to constantly monitor the waxing and waning of the moon as well as its position in the sky[26]. Women, for example, said "every day I just look at the moon" (T61) and "I look at the moon every day. The moons says if I am going to or not going to menstruate" (T62). One woman gave an example of describing when "the moon is in the middle" (T63). Three women used hand gestures to demonstrate the moon's movements across the sky, with one saying "if it has passed this way or risen like this" (T64) and another saying "if it passes over there". Two women from different camps

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[26] Other anecdotal evidence from my fieldwork implies that Hadza are generally tracking the moon's movements. During a long conversation with an adult male, he talked about the Hadza watching the moon and knowing time from the moon. In another anecdote, I was playing with four or five Hadza children during the daytime. I asked them questions like 'where is this?' and they would point to the answers. At one point, I asked 'where is the moon?' The children all pointed to a direction and location in the sky behind them, even though the moon was not visible.

even traced arcs into the dirt with their fingers. The arcs matched the sweeping motions of those with hand gestures.

Women's responses also included repetitive phrasing, like "I look at the moon when it is appearing, disappearing, appearing, disappearing, I look" (T65). Different Swahili verbs were used to describe the moon disappearing (including verbs directly translated to dying, finishing and sinking). Counting the months to determine pregnancy (see Section 4.4.12) was also related to the moon and repetitive phrasing: "You look at the moon, yes. You look to know that the time (literally: age) menstruation is cut off. You are sitting, watching. A month passes without menstruation, a month passes without menstruation, a month passes without menstruation. If two months without menstruation you know that you are pregnant" (T66). Another referenced the moonlight: "after the moonlight ends, I will know the month has passed without menstruation then I know I am pregnant" (T67). A different woman described looking at the moon in relation to sex, "I look at the moon. I look, if a man is doing this, I look at the moon then" (T68).

4.4.11 Menstruation & Sex

The Hadza women were asked about the timing of sex, in relation to menarche, marriage and menstruation. A significant majority of Hadza women (68.6%) reported having sex before menarche ($n = 35$, one-sample proportions test with continuity correction, $p < .05$; 95% CI [0.51, 0.83]), as well as a significant majority (77.1%) reporting sex before marriage ($n = 35$, one-sample proportions test with continuity correction, $p < .005$; 95% CI [0.59, 0.89]). Table 4.4 and Table 4.5 summarise the answers for sex before menarche and before marriage, respectively.

Table 4.4 Hadza Women's Reports of Sex before Menarche

Response	Percentage of Women (n = 35)[1]
Yes	68.6%
No	28.6%
I Don't Know	2.9%

[1] Individual values have been rounded, and the rounded values do not total 100%.

Table 4.5 Hadza Women's Reports of Sex before Marriage

Response	Percentage of Women (n = 35)
Yes	77.1%
No	22.9%

As for sex in relation to menstruation, no Hadza woman said she had sex during menstruation. Women explained "if you are in menstruation you deny sex" (T69), "after finishing bleeding", and "if I am bleeding, I do not have sex with a man; menstruation is bad" (T70). When asked how long after menstruation they would have sex, women gave varied answers. For instance, some did not use any time units, saying "after menstruation", while others explained one day after menstruation, like "after bathing on the fourth day, we meet" (T71) and others even said "after one week". It is highly unlikely that exactly seven days was intended by 'one week', given the findings of Section 4.4.10.

4.4.12 Pregnancy

Six of the women interviewed were pregnant. They were asked additional questions about their pregnancies: how long they had been pregnant, when they knew they were pregnant, and when they told their husbands they were pregnant. Their self-reported pregnancy durations ranged from one month to nine (including two, three, five and six months). Four of the women knew they were pregnant after one month while two (the youngest of the group, 17 and 19 years old) did not know until later in the pregnancy. The 19 year old explained, "I didn't know; I was told by my mom that I am pregnant"

(T72). The four oldest women told their husbands they were pregnant after one month, while the 17 year old waited until after 3 months. One woman recalled, "my husband said we have become pregnant" (T73).

Besides the specific questions addressed to the pregnant women, Hadza women were asked more generally how they know that they are pregnant. The most common answer was menstruation, as in "I know, you will see the blood has stopped; I know I am pregnant" (T74) and "I will know because if you are pregnant, you do not bleed" (T75). Other answers, however, were limited to "I don't know" and "I just know". One woman elaborated: "I will know; I am able to know, how did it get in? So I will know" (T76). Table 4.6 summarises the different types of answers given.

Table 4.6 Responses to How Hadza Women Know They are Pregnant

Response	*Percentage of Women (n = 36)*
Menstruation	50.0%
I don't know	16.7%
I just know	13.9%
Belly size	11.1%
Other	8.3%

The 'belly size' answers described witnessing the belly grow, e.g. "the belly getting bigger"". One woman said "I know as the body shines and gains weight" (T77). Other descriptions included references to breast size, "I know I am pregnant if the breasts become very big" (T78) and to bathing, "when I see the bodies of women" (T79). References were also included to God: "only God knows, I just see the belly is big" (T80) and "I don't know, God knows".

After women were asked how they know about pregnancy, I asked more specifically whether they count months without menstruation to know they are pregnant. Though the "I don't know" group of respondents remained the same, a significant majority of women (83.3%) said they do count the months ($n = 36$, one-sample proportions test with continuity correction, $p < .001$; 95% CI [0.67, 0.93]).   Table 4.7 outlines the three responses.

Table 4.7 Responses to Whether Hadza Women Count Months
without Menstruation for Knowledge of Pregnancy

Response	Percentage of Women (n=36)[1]
Yes	83.3%
I don't know	16.7%
No	8.3%

[1] Individual values have been rounded, and these rounded values do not total 100%.

Based on the full answers of the "I don't know" group, these women seemed to take issue with the term 'counting'. As examples, "I don't know (how) to count because Hadza are not educated" (T81), "I don't know; I was not educated" (T82) and "they don't count, they don't know how to count, we don't count" (T83). The fixation appeared to be on counting itself rather than knowing about menstruation months.

Nevertheless, the majority of women agreed with the description of counting. As one explained, "they are counting, one month, two months, three months without menstruation" (T84). Of the women's answers, fifteen answered a specific number of months without menstruation to know they were pregnant: eight answered after one month, four after two months and three after three or four months. The one month answers included "if one month has passed without blood then you know, the child is already in the belly" (T85) and "if one month it has stopped then I know I am pregnant" (T86). Two months respondents described "if two months have passed, I say there is pregnancy" (T87) and "Hadza women know about the menstruation cycle; if one month has passed and the second month without getting menstruation, there is a baby" (T88). Even one woman described the notion of forgetting: "if you forget getting menstruation for two months, then you know you are pregnant" (T89). Others detailed more than two months: "you look if three or four months passed without menstruation then you know have a child in the stomach" (T90) and "I will watch the moon, if three months have passed, I know the pregnancy is inside" (T91).

By counting their cycles, Hadza women have greater awareness of the timing of pregnancy. One woman even said, "I know the day of getting pregnancy" (T92). Others explained, "I am having menstruation for one day, I am entering into pregnancy after I finish the menstruation" (T93) and "I can say today I'm going to bleed but I don't […] I ask myself why have I not bled today? I wait for this month to end (and) I say I got a child" (T94).

There is also an awareness about pregnancy requiring menstruation. For instance, one woman said "when I was in maturity age, I couldn't have the chance to be pregnant" (T95) and another, "you must get menstruation first, after you see menstruation then you can be pregnant" (T96). But why menstruation is needed is mostly speculated in reference to God (see Section 4.4.1). However, one woman explained menstruation in the context of pregnancy as "if you sleep with a man, that blood goes to mix with the man's blood and it becomes a child" (T97).

4.4.13 Breastfeeding

As with pregnancy, Hadza women recognised breastfeeding as a time without menstruation. Five of the interview women were currently breastfeeding. When asked whether they get menstruation while breastfeeding, all answered no. The point at which menstruation resumed was relayed in terms of the child's age. As examples, "when the child starts to sit down and walk, then I get menstruation" (T98) and "you can't get menstruation early (literally: quickly) until the child gets bigger, then you have menstruation" (T99). Another woman explained, "if I have a child, I don't get menstruation, but if the child gets older like this one[27], then I start my menstruation" (T100).

4.4.14 Menopause

Fourteen of the interview women reported that they had stopped menstruation completely. No word or phrase was reported for menopause. As with menarcheal age, a 'status quo' probit analysis was conducted to estimate menopausal age. The first analysis was restricted to interviewed women, between the ages of 36 and 52 (n = 16). The slope for the probit sigmoid curve was not significant so no median age or confidence intervals could be calculated.

The second probit analysis added women to the sample size who had been named as post-menopausal. Both post-menopausal women and menstruating women were asked to name other women in camp whom they knew no longer menstruated. They were then asked to name other women outside of camp whom they knew no longer menstruated. Twenty-one new names were given and cross-checked with the Hadza longitudinal data on year of birth and age estimates (see Chapter 2). Seven women could not be matched to specific records (either due to missing information or an unrecorded Hadzane name). Restricting the age range from 36 to 52, the median age of menopause for the new sample

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[27] The child appeared to be around 1.5 years old.

is 42.8 (n = 22, probit analysis, 95% CI [38.3, 46.3]). This median age is less indicative of actual age at menopause because of the inclusion of named post-menopausal women.

The post-menopausal women were asked about reported symptoms of menopause: hot flushes, menstrual irregularity, pain during sex, and vaginal dryness. No woman reported hot flushes (the symptom was described with different phrases in the case of misunderstanding) and no woman reported menstrual irregularity (also described by multiple phrases). Reports of pain during sex were mixed: six of the fourteen reported pain. Vaginal dryness was reported by ten of the women, but this majority was not significant (n = 14, one-sample proportions test with continuity correction, p = ns). From my perspective, the 'yes' answers were particularly emphatic for this question. The women were animated, they repeated 'yes' more than once and they added adjectives like "very, very dry" and "completely dry".

During my interview of the first post-menopausal woman, she explained that her menstruation did not return after she finished breastfeeding her last child. This question, of whether menstruation returned after finishing breastfeeding of the final child, was then asked to all other post-menopausal women. Because I had ascertained a history of parity at the start of interviews, I could specifically reference the final child's name. No woman (n = 14) reported having menstruation again after completing breastfeeding her final child.

When asked how they felt about menopause, all post-menopausal women reported they were happy. All said that women talk about menstruation and about ceasing menstruation. As one post-menopausal woman explained, "they say 'we are done with menstruation'. They are happy; they are old" (T101).

Currently menstruating women were asked additional questions about post-menopausal women. Some were asked whether women resumed menstruation after they finished breastfeeding their final child, all said no (n = 20). Similarly, when asked whether older women without menstruation could still get pregnant, all said no. As one explained, "she can't; she absolutely can't". Another explained, "if you are an old grown woman, you cannot get menstruation again. They have ceased completely; they cannot get back menstruation" (T102). This demonstrated again a recognised relationship between pregnancy and menstruation (see Section 4.4.12).

4.5 Discussion

A vastly understudied part of the foraging lifestyle is menstruation, from its physical characteristics to its material culture. The present Hadza data are limited by their interview methodology, lacking hormonal or observational confirmation of reported

phenomena. Nevertheless, the reported data are unique in their contribution to menstruation in foraging women. They establish the first quantitative characterization of multiple facets of menstruation, including menses duration, menses pain, and menopausal symptoms, for any foraging population. Although the Hadza view time differently, only the units of 'days' and 'months' (tracked as lunar months) are applied in this discussion. The implications of the interview data and directions for future studies are discussed below.

4.5.1 The Hadza Menstrual Cycle

The Hadza's mean menses duration of 2.3 days (and 2.4 days, excluding post-menopausal recall) are the shortest menses reported for any population (Vitzthum *et al.*, 2001; WHO, 1981). If the median (3 days) or mode (also 3 days) are considered instead, then the Hadza still have the shortest menses reported of any population. Even the range of reported menses lengths is striking: only one woman (a post-menopausal woman) said four days and no other women reported four or above. In their multicultural study, the WHO (1981) found 4.0 days as the lowest mean value (Mexico; India, low caste group), while in an updated review, Vitzthum *et al.* (2001) found the lowest mean to be 3.25 days (Lese horticulturalists). Not only have the Hadza reported the shortest durations, but their reported menses are less than half of the 5 to 6 day average reported in medical and nursing textbooks (Fehring *et al.*, 2006). In fact, their reported menses length is so short that the entire range of reported lengths lies outside the range defined as 'normal' (e.g. 4.5 to 8 days in Fraser *et al.*, 2007).

The menses estimates are limited by recall interview data. Since women were asked for how long they bleed 'usually', there is potential for bias, like whether women thought across their lifetime or only back to their most recent menstruation. Nevertheless, the WHO (1981) multicultural study found that recall for menses length displays the highest accuracy compared to all other menstrual cycle estimates. While 85% of women were precise to the exact day, 97% of women were accurate to within one day. Furthermore, a review of studies of variability in menstruation has found that women's menses only rarely differs by one or two days (Vitzthum, 2009).

It is difficult to speculate on why the Hadza have such short menses at this point. Not only are further data lacking, but the causes of variation in the duration of menses generally remain unknown (Vitzthum, 2009). There are implications for this finding, however. Firstly, there is further support for turning to hunter-gatherer data for studying the link between reproductive cancers and menstrual history. The Hadza have both the shortest menses and no reproductive cancers reported. (However, the absence of cancer reports does not discount the possibility of reproductive cancers still being

present.) Secondly, this study establishes newfound acknowledgement for a menses duration which is not within a 'normal' range yet is still associated with women being fertile. Of the 21% of women ($n = 38$) who reported a menses length of only one day, all but one have at least one living child. The singular exception was pregnant at the time of interview.

The shorter menses length does not necessarily translate into a shorter cycle length. Because the Hadza women report no temporal account of cycle length outside of 'one month', it is difficult to determine actual cycle length. Indeed, direct observation would be necessary. Though the Hadza did not quantify 'one month' in terms of days or weeks, they did explain tracking time through lunar cycles. The Hadza track their cycles by the moonlight (suggesting waxing and waning) and the moon's position in the sky. Such tracking is consistent with reports of the Ju/'hoansi (Howell, 1979; Shostak, 1981; Howell, 2010), as well as the Pume foragers using "moon counts" (Kramer, 2008, p. 342). The average lunar month is 29.5 days and its variance across months is limited to seven hours (NASA, 2012). The moon has eight phases during the lunar month, each lasting approximately three and a half days. Because of the consistency of lunar cycles, the women's knowledge of lunar changes, and their insistence on 'one month', it is probable that women's cycle lengths are within a range inclusive of 29 days. Determining the actual variance in cycle length, however, requires observational data.

Despite the unknown variance in cycle length, cycles themselves appear to be frequent. Given their descriptions and many acknowledging pregnancy after only one month, the Hadza appear to have regular, monthly menstruation. That is not to suggest that women have consistent cycle length across time, but to suggest that the Hadza may not face periods of amenorrhea (outside of pregnancy and breastfeeding) as has been described for other foragers.

Descriptions of other foragers are consistent with reports of irregular or infrequent menstruation (e.g. Howell, 1979; Hill & Hurtado, 1996). Irregular menstruation is characterised by periods of 'secondary amenorrhea', or the absence of menstruation for longer than six months after menarche (Practice Committee of the American Society for Reproductive Medicine, 2004). In the Ache, for instance, Hill and Hurtado (1996) depict infrequent menstruation:

> "their menstrual cycles are irregular even when they are young, and missed cycles for several months do not necessarily indicate that a woman has ceased cycling permanently. Several women in their thirties and early forties went through periods of time longer than a year without menstruating" (p. 235).

Howell (1979) reports similar periods of amenorrhea in the Ju/'hoansi: "amenorrhea – cessation of menstrual periods, sometimes for long periods – is common" (p. 179). Although the sample sizes are not available for either the Ache or Ju/'hoansi descriptions, this Hadza sample reported no such irregularity.

The finding of regularity in the Hadza remains tentative in the absence of observational data. Furthermore, in the absence of biological samples, the regularity of *ovulatory* cycles, the more important indicator of fecundity, remains unknown. Interestingly, though, the apparent regularity and post-menopausal women's denial of irregularity may be speculatively linked to Blurton Jones' (2016) findings for interbirth intervals. Unlike other non-contracepting women whose closed interbirth intervals become longer as they age (Wood, 1990), including Ju/'hoansi women (Howell, 1979) and Ache women (Hill & Hurtado, 1996), Hadza women's birth spacing does not significantly increase over time (Blurton Jones, 2016). It is possible that the more stable birth intervals are associated with or caused by the menstrual regularity, since infrequent menstruation can indicate ovulatory dysfunction and problems with fertility (Speroff & Fritz, 2005, p. 1026).

As for menstrual pain, this is the first quantitative report of dysmenorrhea in a foraging population. Reports of the prevalence of dysmenorrhea across women vary widely: from 25% of all women to 90% of adolescent girls (Coco, 1999; Durain, 2004). That 55% of Hadza women (post-menopausal women excluded, $n = 20$) reported pain is noteworthy insofar as this symptom exists in the foraging population. Dysmenorrhea in the Hadza is also important to the extent that such pain may influence foraging behaviour, given its association with work absenteeism in other contexts (Andersch & Milsom, 1982; Dawood, 1988). This is discussed at greater length in the next chapter.

In terms of blood loss, a significant majority reported their loss as 'a little'. But it is unclear what 'a little' refers to without a relative comparison. Are those reporting 'a lot' comparing to what they know of others' menstrual bleeding? Are they thinking of the blood loss they might see in game meat? This study is very limited in suggesting any quantitative estimates of menstrual blood loss. The traditional methods for measuring loss are not applicable to the Hadza (see discussion in Appendix F) precisely because of their dependency on sanitary products. Nevertheless, the descriptions of 'a little' and 'very little' are important starting points for understanding total menstrual blood loss in the Hadza. Insofar as the women chose these descriptions from the open-ended question of 'how much' demonstrates the initial reference point for how Hadza women perceive blood loss.

4.5.2 Menarche & Menopause

The estimated age at menarche of 16.8 years is close to the estimate of 16.5 years from Marlowe (2010). The sample size used here is larger than that of the sample size used for Marlowe's estimate [Marlowe, pers comm; sample size not reported in Marlowe (2010)]. The estimated age at menopause of 42.8 is also close to the estimate of 43.4 from Phillip *et* al. (1999); both estimates round to 43 years. However, the reported estimate has limited validity to the extent that it contains reported names of women who were not directly interviewed. Because women said they talk about ceasing menstruation, it is not unreasonable to assume that at least some of the reported women are actually post-menopausal. Since it is still possible that some reported women were mistakenly labelled, the estimated age must be used with caution. Nevertheless, the resultant estimate is at least an indication of the age Hadza women perceive other women to be post-menopausal. Furthermore, the rounded estimate is in agreement with the only other study of menopause in the Hadza.

Menarcheal age is highly variable across societies, and substantial evidence exists for a secular trend in decreasing ages. Populations around the world display such decreases, including Cameroon (Pasquet *et al.*, 1999), the Gambia (Prentice *et al.*, 2010), Japan (Hoel *et al.*, 1983), India (Khanna & Kapoor, 2004), Mexico (Malina *et al.*, 2004), Portugal (Padez & Rocha, 2003), Spain (Cabanes *et al.*, 2009), Sri Lanka (Jayasekara & Goonewardene, 1987), Taiwan (Chang & Chen, 2008) and the United States (McDowell *et al.*, 2007). The Gambia data demonstrate one of the most rapid declines, with a decrease in median menarcheal age from 16.06 in 1989 to 14.90 in 2008 (Prentice *et al.*, 2010).

Even within foraging groups and other small-scale societies, menarcheal timing is variable, ranging from 12.6 in Hiwi foragers to 18.4 in Gainj and Asai farmers (see Walker *et al.*, 2006, p. 300). The Hadza menarcheal age appears to fall toward the higher end of the forager range. For example, across the mean ages of menarche reported in Kelly (2013, p. 195), the calculated median age is 15.85 years (*n* = 8). The Hadza estimate is around one year above this median and is closest to the estimate of 16.6 for the Ju/'hoansi (Howell, 2010).

The Hadza's estimated age of menopause at 43 years is much lower than the estimate of 51 years for Western women (McKinlay *et al.*, 1992; Gold *et al.*, 2001). This age is also lower than the reported median range of 49 to 52 years across 11 countries (Morabia & Costanza, 1998). But is the estimate comparatively lower in the context of natural fertility, non-industrialized populations? Unfortunately, data from such populations are lacking, a fact which other researchers have lamented in the past (e.g. McKinlay, 1996). (Forager data instead have focused on reported age at final birth.) For those data which are available, the Hadza's estimated menopause is not substantially lower, e.g. falling

between the estimate of 42 years for Mayan subsistence farmers (Beyene, 1986) and 44 years for Agta foragers (Goodman *et al.*, 1985a). Marlowe and Berbesque (2012) estimate the mean age as 45 years across hunter-gatherer groups.

Interindividual and interpopulational differences in the timing of menarche and menopause have been associated with genetic and environmental factors. Menarcheal age and menopausal age are highly heritable traits (e.g. Murabito *et al.*, 2005; Towne *et al.*, 2005). Although over 100 genetic loci have been identified for the timing of menarche (Perry *et al.*, 2014), these loci describe only a small fraction of the trait's heritability (He & Murabito, 2014). The results of genome-wide association studies suggest no genetic correlation between menarche and menopause, indicative of different regulatory pathways (He *et al.*, 2009).

As Kuzawa and Bragg (2012) summarise, pubertal timing appears to be extremely sensitive to environmental influences. Yet, there exists a lack of consensus about the non-genetic factors explaining the variability of menarcheal timing (Yermachenko & Dvornyk, 2014). Those factors with greater consensus for menarcheal timing are related to energy balance: higher BMI is mostly associated with early menarche and higher physical activity with later menarche (see review in Yermachenko & Dvornyk, 2014). Indeed, in their comparison across 58 countries, Thomas *et al*. (2001) conclude that age at menarche is related more so to energy balance than nutritional status alone.

Likewise, menopausal timing is also lacking consensus for those environmental factors which affect its variability. Menopausal timing appears to be predominantly explained by genetic factors (de Bruin *et al.*, 2001), with early menopause associated with genetic variants (Murray *et al.*, 2011; Perry *et al.*, 2013). Environmental factors associated with early onset of menopause (before age 45) are inconsistent. For example, higher fertility has been associated with earlier menopause (e.g. Thomas *et al.*, 2001) and with later menopause (e.g. Gold *et al.*, 2001). The most consistent and robust risk factor for earlier menopause is cigarette smoking; yet even this predictor only explains a difference of about one year (Pelosi *et al.*, 2015).

Investigations into the environmental factors associated with menopausal timing in foraging groups are lacking. This is unsurprising given the general paucity of menopausal data in foragers. Investigations into menarche, on the other hand, have revealed significant predictors of menarcheal timing in foragers. Adult body size, applied as a proxy for energetic availability, is significantly associated with menarcheal age in foragers and small-scale societies (Walker *et al.*, 2006). The probability of survivorship to age 15 and life expectancy at age 15, treated as indicators of environmental hazards, are also significantly associated with age at menarche (Walker *et al.*, 2006; Migliano & Guillon, 2012). Life expectancy at 15 appears to be the stronger

predictor, since the probability of survivorship to 15 was not significant in the slightly larger sample of Migliano and Guillon (2012).

The ages at menarche and menopause are also important in relation to understanding adolescent subfecundity and as Wood (1994) suggests, 'senescent subfecundity'. The delay between menarche and first ovulation produces a period of subfecundity, ranging from several months to approximately two years (Foster *et al.*, 1986). For the Hadza, the gap between menarche at 16.8 and first birth at 19 is indicative of subfecundity if sexual intercourse occurs during that timeframe. This study suggests that sexual intercourse does occur within that timeframe, based on a significant majority of women having sex before menarche and before marriage. Hill and Hurtado (1996, p. 69) report too that 'most' Ache girls have sex before menarche, and in the Ju/'hoansi, the majority of girls are married before menarche (Howell, 1979, p. 174), with at least some having sex before menstruation (Shostak, 1981). Although the exact coital frequency is unknown for the Hadza, it is clear that many Hadza women have engaged in sexual activity before starting menstruation.

As for senescent subfecundity, menstrual characteristics at later reproductive ages, like anovulation and longer, more variable cycles, may reduce fecundability (Wood, 1994). The Hadza did not report irregular or longer cycle lengths at later ages. Similar to the timespan after menarche, however, the time before menopause may have anovulatory cycles which require biological data from the Hadza. Even though post-menopausal women did not report irregular cycles, it is possible that ovulation itself was irregular.

The finding that Hadza women do not resume menstruation after completing nursing their final child complicates estimates of menopause. Ellison describes this phenomenon:

> "[In] many natural fertility societies lactation following the birth of a final child may easily last several years and menses may never resume. When menopause occurred in such an interval of extended amenorrhea is anybody's guess" (2001, p. 245).

In other words, the definition of menopause as 12 months of amenorrhea after the final period (WHO, 1996) is not straightforward for women who are undergoing amenorrhea due to pregnancy or lactation. The arbitrariness of 12 months becomes more apparent for natural fertility populations. To my knowledge[28], the phenomenon of never resuming menstruation has been described only in one other foraging population. Howell writes of the Ju/'hoansi:

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[28] Peter Ellison also notes that evidence for this phenomenon stems mostly from subsistence agricultural populations (Ellison, pers comm).

> "Many women report that they never resumed menstruation after the birth and lactational amenorrhea of the final child, which is one of the reasons why menopause is so difficult to date exactly. Others, especially those who had the final child early, menstruated for many years afterward" (Howell, 1979, p. 130-131).

The validity of the Hadza women's claim, and the Ju/'hoansi women, can only be determined by actual observation. It is possible that in viewing time differently the Hadza view the last child in relative terms. Knowledge of a 'final child' is predicated on an awareness that the woman will not conceive again. But the resoluteness with which women declared they were post-menopausal and the lack of irregular cycling supposes that there could indeed be a definitive cut-off in the return of menstruation.

Why cycling does not resume remains unclear, especially given the dearth of descriptions for this phenomenon. Ellison (2001) hypothesizes that even though follicular depletion has not reached its final limit, estrogen production may have fallen below a particular threshold. Interestingly, Pollycove *et al.* (2011) liken the physiological changes associated with menopause to those of lactation. After childbirth, a mother's estrogen levels immediately drop. As Pollycove *et al.* (2011) explain, lactation is "the only low-estrogen condition associated with successful reproductive effort" (p. 337). They document significant similarities in the metabolic changes during the low estrogen states of lactation and post-menopause.

As for the symptoms of menopause, this is the first study to quantitatively investigate such symptoms in foragers. The Hadza did not report any hot flushes or any menstrual irregularity. There is considerable variation in the prevalence of vasomotor symptoms (hot flushes and night sweats) and their duration before, during and after menopause (Politi *et al.*, 2008). Recent studies have linked genetic variants involved in estrogen release and estrogen metabolism to vasomotor symptoms (Moyer *et al.*, 2016; Crandall *et al.*, 2017; Prague *et al.*, 2017). The association between some of the identified single-nucleotide polymorphisms (SNPs) and vasomotor symptoms differs significantly by ethnic group (Ning *et al.*, 2005; Moyer *et al.*, 2016; Crandall *et al.*, 2017). These findings suggest that genetic variation could partially explain the absence of hot flushes in the Hadza. For the other menopausal symptoms, there were reports of pain during intercourse and of vaginal dryness. These two symptoms are more prevalent in post-menopausal women (Rosen *et al.*, 1993) and are linked to each other, since decreased lubrication interferes with sexual comfort (Gelfand, 2000).

4.5.3 Menstruation & Pregnancy

Hadza women know that menstruation is absent during pregnancy and at least part of the duration of breastfeeding (lactational amenorrhea is discussed in Section 4.5.5). It is unclear to what extent women learn about the connection between menstruation and pregnancy intuitively over time or from other Hadza women. For example, one of the pregnant women explained that her mother had to inform her she was pregnant. This raises an interesting issue in the teaching of fertility signals. Teachings from mothers may function as an important role in this respect.

The women recognise that to become pregnant, they must have menstruation. They recognise this firstly as a general dependency. That is, they say that a girl must reach menarche first, and they say that a breastfeeding woman must resume menses before she can become pregnant again. They also appear to recognise the link as a specific dependency. They seem to think that pregnancy depends on sex occurring after menses. In studying conception beliefs in the Hadza, Marlowe (2004) asked the Hadza when a woman is able to become pregnant. The majority of people answered right after menstruation. Marlowe (2010) found that sexual intercourse is "generally avoided" during menses (p. 175). This study supports both findings, that Hadza women avoid sex during menstruation and that they engage in sexual activity after menstruation. As in Marlowe (2004), the answer for 'how long' after menstruation women engage in sex varies among women and the answer of 'one week' should not be interpreted as seven days.

Because the women recognise a general dependency between pregnancy and menstruation and because they watch the moon, they are able to use the presence or absence of menses as signals of their ability to become pregnant. If Hadza men are also aware of the connection and are also tracking women's menstruation, then they too may be aware of fertility signals. (This prompts the question of how Hadza men learn about the connection between menstruation and pregnancy, especially as young men.) Although Hadza men were not interviewed, Howell (2010) suggests that Ju/'hoansi men are tracking menstruation. Of the interviewed pregnant women (n = 6), two-thirds told their husbands after one missed menstruation, suggesting that at least some men are aware of the timing of pregnancy because their wives told them.

One interesting question is whether men are also aware of the first return of menstruation for their breastfeeding wives. When menstruation returns to breastfeeding women, the first menstrual cycles are usually ovulatory [Tommaselli *et al*. (2000) found that over 80% of these cycles are ovulatory]. If a Hadza wife has not menstruated for more than a year (at least nine months plus any duration of lactational amenorrhea), then her husband may simply miss the signal for the return of ovulation. It may be that

Hadza women choose to inform their husbands and then the couple knows she may become pregnant again. At what point women choose to share menstrual information and how men themselves try to glean menstrual information are avenues for further investigation.

4.5.4 Absence of Menstruation

The two women who reported not experiencing menstruation before their first child (see Section 4.4.3) are not an anomaly among foragers. Hill and Hurtado (1996) briefly mention two other such women:

> "It is possible, however, for a woman to begin ovulatory cycling and conceive on her very first cycle, thus never menstruating prior to first birth. Precisely that seems to have happened at least twice in our Ache sample, once to a woman who first gave birth in the 1940s and again to a girl in 1993 who had not yet reached menarche in our August 1992 census, but gave birth to a child in the following April" (p. 306).

No further menstrual history data are given so it is unclear whether these same women faced future periods of amenorrhea. The two Hadza women are noteworthy in that they reported not *ever* seeing menstruation. Possibly, the women simply misreported. They may have wanted to avoid answering questions about menarche or menstruation. However, the disadvantages of this strategy would have become quickly apparent as I proceeded to ask additional questions for clarification. Furthermore, the women still participated in giving full answers to other questions in the interview.

It is biologically possible to conceive without menstruation. Conception can occur without menses if ovulation during post-partum amenorrhea precedes menses (Guz & Hobcraft, 1991). This would imply high fecundity, having the ability to conceive immediately following post-partum amenorrhea. These women represent a marked variation in Hadza fecundity. Such variation raises new questions for future studies, the foremost of which is, are there more Hadza women like them in the population?

The accounts of these women also have important implications for the diagnosis of primary amenorrhea. By clinical definitions, these women have experienced primary amenorrhea, the absence of menstruation. Cases of spontaneous pregnancies in the presence of primary amenorrhea have been noted (Das *et al*., 2010), but the two Hadza women already have three and seven living children, respectively. Based on these investigations, in a natural fertility population like the Hadza, primary amenorrhea should not be directly equated to primary sterility.

Primary amenorrhea is one of the menstrual dysfunctions related to athletic performance (Roupas & Georgopoulos, 2011). Studies have found higher rates of primary amenorrhea in athletes than in non-athletes (Dušek, 2001; Hoch *et al.*, 2009). Even in athletes though, the prevalence of primary amenorrhea is lower than that of secondary amenorrhea: 6% compared to 30% in Dušek (2001) and 8% compared to 30% in Hoch *et al*. (2009). Furthermore, there is a scarcity of follow-up studies on younger athletes diagnosed with primary amenorrhea who never menstruate yet conceive later in life. For example, Warren (1999) mentions ballerina dancers who have primary amenorrhea, yet their amenorrhea ceases in their later 20s. A useful comparative study to better understand the finding in the Hadza (and the Ache) would be an investigation of lifetime fertility in female athletes with primary amenorrhea. Unfortunately, no study has yet investigated this phenomenon.

4.5.5 Lactational Amenorrhea

Like dysmenorrhea, written accounts of the relationship between breastfeeding and amenorrhea date back to Aristotle (Anderson *et al.*, 1983; Cowie *et al.*, 2012). And like dysmenorrhea, there is a wide variation in reports across populations. For breastfeeding women, amenorrhea lasts from a few months upwards to two years (e.g. Lewis *et al.*, 1991). The finding that the majority of fully breastfeeding women are amenorrheic by six months post-partum even led to the development of the lactational amenorrhoea method (LAM) for birth control (Kennedy & Visness, 1992). Traditionally, nursing intensity and prolactin (a hormone involved in milk production as well as other functions) were used to explain long durations of amenorrhea, especially in light of studies on the Ju/'hoansi (Konner, 1978; Konner & Worthman, 1980). Today, it is recognised that neither nursing intensity nor prolactin alone predict the duration of lactational amenorrhea [see Valeggia and Ellison (2009) for a review of clinical and field evidence]. Instead, maternal energetics are also taken into consideration, like nutrition and activity patterns [e.g. Valeggia and Ellison's (2004) relative metabolic load model]. For example, Rosetta and Mascie-Taylor (2009) found a marked difference between the lactational amenorrhea of working and non-working women: a median of 636 days for rural tea workers compared to a median of 375 days for non-workers. Further discussion on energetics and lactation is available in Section 5.2.2.

Most breastfeeding women resume menstruation while they are still breastfeeding and before weaning (Ellison, 2001; Guz & Hobcraft, 1991). Patterns of resumption vary (Ellison, 1995), however, and the Hadza's view of time entails difficulty in measuring actual lactational amenorrhea. Again, direct observation would be required.

Nevertheless, Hadza women described menses returning in relation to children's ages. Indeed, references to children starting to walk parallel references from Ju/'hoansi:

> "The [Ju/'hoansi] women report that menstruation may resume any time after a surviving child has started to walk, which places the event in the last part of the first year of the child's life, at the earliest, while menstruation will resume much sooner, within a few months, following a child who dies at birth" (Howell, 1979, p. 121)[29].

In the Hadza, the median duration of breastfeeding and of closed, non-replacement interbirth intervals are both 2.5 years (Marlowe, 2010; Blurton Jones, 2016). [Blurton Jones (2016, p. 335) defines 'closed' intervals by the observation of both births and 'non-replacement' intervals by the survival of the first child.] Given the interbirth interval of 2.5 years, lactational amenorrhea has ended by at least 1.75 years of breastfeeding for some Hadza women. Additionally, since breastfeeding and interbirth intervals share the same median value, some women nurse directly leading up to the next child's birth, including during pregnancy.

By tracking their menstruation, Hadza women are aware of the end of lactational amenorrhea. Such awareness raises interesting questions for any behavioural shifts in women. Do Hadza women decide to tell their husbands of the return of menstruation? Do Hadza women change their coital frequency according to their menstrual status? Blurton Jones (2016, p. 354) found that peak reproductive success for Hadza women occurred at interbirth intervals between two and four years. An interesting follow-up could be to investigate to what extent women control these intervals through differences in attitudes or behaviours upon the return of menstruation.

4.5.6 Material Culture & the Lived Experience

A largely underreported aspect of the foraging lifestyle is the material culture and lived experience of menstruation. For a foraging population without literacy, teaching through oral tradition and by example is critical for survival. The Hadza boys and girls quickly become autonomous, productive foragers (Blurton Jones *et al.*, 1989; Hawkes *et al.*, 1995; Crittenden *et al.*, 2013). First menstruation is not an intuitive experience, however, and the connection between menstruation and fertility must be learned (either from others or through time).

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[29] Though Howell notes that one older woman referencing when her baby can walk had a child that appeared four years old.

This study establishes that Hadza mothers are a critical source of information for a range of menstrual topics, from menstruation's association with womanhood to the menstrual cleaning process. The study also establishes a material culture surrounding menstruation: menstrual cloths, soap from baobab and medicine from the bush for menstrual pain. Endicott and Endicott (2008) briefly describe Batek women using old loincloths for menses and some women observing restrictions from washing in rivers or streams.

How menstruation affects women's activities and female-specific material culture are interesting to consider from an evolutionary perspective. At what point did foragers begin to conceal, wipe or wash their blood? Even if ovulation itself is concealed, the concealment of blood disguises that a woman is cycling at all. In concealing the outward manifestation of cycling, a woman disguises that firstly, she has the capacity to become pregnant and that secondly, she is not yet pregnant.

From a cultural perspective, the lived experience of menstruation evokes different attitudes and meanings. While mixed emotions were associated with menarche for the Hadza, happiness was unanimously associated with menopause. The meaning of menstruation was most often associated with 'child'. As discussed previously, the moon too plays an important role in how Hadza women view menstruation. This study has focused on how the women track menstruation via the moon. Other cultural discussions depict Hadza rituals and beliefs in relation to the moon, menstruation and hunting (see Knight *et al.*, 1995; Power & Watts, 1996; Power, 2015). The next chapter addresses more of the lived experience of menstruation, including foraging behaviour and reported taboos.

4.5.7 Summary Points

- The reproductive timeline for the Hadza is around 26 years, from the estimated age at menarche of 16.8 to the estimated age at menopause of 42.8. During these years, Hadza women regularly track the moon, counting the months without menstruation to know if they are pregnant. They associate the absence of menstruation with pregnancy, breastfeeding and old age.

- Knowledge sharing, cultural practices and cultural materials are related to women's menstruation. Around the age of menarche, girls learn about the meaning of menstruation from their mothers. They also learn about how to wash. Cleaning is emphasised by the Hadza as a necessary activity during menses. Women produce soap from baobab to wash themselves and their menstrual cloths.

- The Hadza data highlight two potential pathways by which menstruation may affect a woman's foraging behavior. Firstly, menstruation-related activities require time. Producing soap from baobab fruits, cleaning oneself and one's menstrual cloths, and gathering medicine from the bush are all activities that require time from a Hadza woman's total activity budget. Secondly, some women experience pain during menstruation. More than half of Hadza women reported pain during menstruation. Dysmenorrhea may impact the extent to which a forager woman participates in her normal activities, especially if the pain is significant and/or long-lasting.

- Menstrual data from the Hadza challenge the Western notion of what is 'normal' for successful reproductive output. The Hadza have the shortest menses of any population, yet they also have around six children on average. One-fifth of the women report a menses length of one day only, and two women report primary amenorrhea, despite both having children.

4.5.8 Future Directions

The greatest shortcoming of the study is its reliance on a general self-assessment of women rather than actual observations of menstrual cycles. In order to ascertain actual cycle duration and menses duration, menstrual diaries recorded by the researcher are necessary. Snowden *et al*. (1983), in a WHO report on menstruation, recommends at least a 90-day observation window. Ideally, daily menstrual interviews would be accompanied by hormonal profiles, establishing a baseline for circulating hormones as well as assessing ovulation. For a low-density population like the Hadza, however, such measurements and samples would be both extremely difficult and costly to acquire and transport.

Equally time-consuming and invasive would be an examination of the average volume of blood loss for Hadza women. Appendix F offers a brief overview of the traditional methods for blood loss measurements and their inapplicability to the Hadza lifestyle. Although a visual representation system could determine units transferable to blood volume (and thereby, further elucidate what is meant by 'a little' or 'a lot'), such visual representations would be very difficult to validate (given that validation traditionally relies on sanitary products). This limitation as well as others are considered in Appendix F for any future study of blood loss in the Hadza.

There are other opportunities for study which are less costly and less complicated. For instance, attention should be given to Hadza men's views of menstruation. Future interviews could ask questions including, how did men first learn about menstruation?;

what do men think menstruation means?; and do men talk to women or their wives about menstruation?

Another topic deserving of further attention is lochia. Though not directly asked about, the blood after childbirth was spontaneously mentioned by a few women. How much blood and for how long lochia lasts is unclear in the Hadza. An initial interview regarding lochia could ascertain how this time period may affect foraging behaviour. Do the women stay in camp because of the bleeding? For how long? Do they rely on other helpers if they do not forage at this time?

The following chapter delves into those very questions from the viewpoint of menstruation. The chapter also explores how the different reproductive statuses documented in this chapter affect the Hadza women's foraging behaviours.

5 Foraging Behaviour & Reproductive Status

5.1 Introduction

A woman's reproductive status may present different demands on her time and energy. If the woman is also the primary caretaker for her children, she has even more demands on her time and energy allocation. How women allocate their time and energy may be viewed through the lens of life history theory. This theory interprets human life histories as moulded by fitness strategies which maximise reproductive success. Different histories represent different energetic investments in maintenance, growth and reproduction.

Life history frameworks have been used to investigate energy trade-offs, like investment in current offspring versus future offspring or investment in mating efforts versus parenting efforts (see Stearns, 1989 and Del Guidice *et al.*, 2015). Life history trade-offs in growth and reproduction have been used to explain the evolution of human pygmy body size (e.g. Migliano, 2005; Migliano *et al.*, 2007). Other frameworks investigate the timing, duration and evolution of a particular life stage, like childhood (e.g. Bogin, 1997). Some frameworks aim to explain a full suite of human life history characteristics (e.g. Hawkes *et al.*, 1998; Kaplan *et al.*, 2000).

A foundational principle of life history theory is the conservation of energy (e.g. Charnov *et al.*, 2001). Energy allocated to one process cannot be allocated to another. In the foraging environment, the energy acquired from wild foods must supply demands from maintenance, growth and reproduction. That energy must also supply demands from daily activities, like walking, digging, hunting, carrying and food processing. If a forager is to survive, she must at the very least meet basic maintenance requirements (e.g. the amount expended by her basal metabolic rate, or BMR). And if she is to reproduce, she must also meet the additional costs of menstruation, pregnancy and lactation (discussed below).

Reproduction is biologically much costlier for women than for men (Jasienka, 2009). For foraging women, these costs must be met simultaneous to the demands of their subsistence activities. No foraging woman simply stops all foraging efforts for the duration of pregnancy and the length of nursing. Instead, foraging women continue to fulfil their dual capacities as producers and reproducers. Lee (1980) summarises this dual role in Ju/'hoansi women:

> "Women are thus at the intersection of two critical systems within the foraging economy: the productive system and the reproductive system, each with its conflicting demands" (p. 323).

In the Ju/'hoansi, women are both the primary producers of food and the primary caretakers of children (Lee, 1979, 1980). The women bear not only the direct costs of childbirth and lactation, but also the associated costs of child-rearing. Forager women's energetic costs have been used to explain the low fertility levels in the Ju/'hoansi (Bentley, 1985) and Australian Aborigines (Cowlishaw, 1981), as well as differences in reproductive hormone levels generally (Bentley, 1999).

To what extent can a foraging woman fulfil her energetic demands by herself? Kramer and Ellison (2010) explain that rarely would a single person meet all energetic needs for growth and reproduction by herself. Likewise, Peacock (1991) explains that although it is not impossible for an Efe woman to meet subsistence and childcare demands alone, it is "very, very difficult" (p. 353). The division of labour, by sex and age, enables women to provision and be provisioned. For example, Kramer and Ellison's (2010) pooled energy model describes how costs are met by transfers of resources and labour from others.

The results from Chapter 3 suggest that Hadza women are capable of foraging for their TEE in addition to accruing a surplus of kilocalories. Yet, as reviewed in Section 1.3 and Section 1.5, hypotheses for the sexual division of labour share an underlying assumption that women's foraging is constrained by reproduction. This thesis seeks to test that assumption by analysing whether women's current foraging behaviours are differentially affected by reproductive status (e.g. menstruation, pregnancy and lactation) or lack thereof (e.g. post-menopausal status).

Past forager studies have identified differences in food returns and activity budgets by reproductive status. As examples, married, nursing Hadza women return with lower food returns than non-nursing women (Marlowe, 2003) and post-menopausal Hadza allocate more time to foraging than pre-menopausal women (Hawkes *et al.*, 1989).

Post-menopausal women's food production, in particular, has been used to explain the duration of the long post-reproductive timespan. The timing of menopause and the du-

ration of post-reproductive life are an evolutionary conundrum. Mayer (1982) summarises the nature of the paradox: how does natural selection simultaneously favour reproductive success while restricting reproduction? The grandmother hypothesis answers this question through inclusive fitness, explaining that grandmothers increase their reproductive success by providing for their grandchildren (Hawkes *et al.*, 1998; Hawkes, 2003; Hawkes and Blurton Jones, 2005).

The hypothesis builds on Williams' (1957) initial postulation that reproductive senescence is a fitness trade-off between maternal investment in extant offspring and future offspring. Initial support for the hypothesis, and indeed a "key stimulus" for the hypothesis itself (Hawkes & Smith, 2010, p. 43), was the evidence from Hawkes *et al.*'s 1997 paper. They concluded that post-menopausal Hadza grandmothers greatly control the nutrition of weaned offspring. These results and others are discussed in greater detail below.

The remainder of the chapter supplies important missing pieces for understanding the relationship between women's reproductive status and women's foraging. The chapter is divided into two parts. In Part 1, the study investigates Hadza women's self-assessments of how reproductive status affects their foraging activities. Interview data from the 2015 interviews of Chapter 4 are utilised. In Part 2, women's actual foraging is compared across reproductive statuses, e.g. are nursing women foraging less than non-nursing women? Food sharing is also compared, with references to gifts given and received, in order to analyse differential supplementation by reproductive status. The food eating and sharing data from Chapter 3 are analysed.

5.2 Background

5.2.1 Pregnancy

5.2.1.1 Energetic Demands

Reproduction is more costly for women, with pregnancy estimated to amount to an additional 375 kJ (90 kcals) per day in the first trimester, 1,200 kJ (287 kcals) per day in the second, and 1,950 kJ (466 kcals) per day in the third (Butte & King, 2005). Those estimates are derived from well-nourished, non-foraging women based on an average gestational weight gain of 12 kilograms. As Butte and King (2005) readily point out, however, pregnant women are not a singular group; energy intakes should be determined by population, depending on body sizes and lifestyles. Though the actual calorific costs of pregnancy in the Hadza are unknown, we can expect that they at least follow the relative

increases seen in other women. That is, the third trimester is most expensive, followed by the second trimester and followed by the first trimester.

The energy costs of pregnancy are driven by the addition of tissue mass. Pregnant women increase their overall tissue mass by adding fat stores, increasing maternal tissues (e.g. uterus and breasts), and growing the fetus and its associated tissues (Dufour & Sauther, 2002; Butte & King, 2005). The increased body mass then drives increased BMR and additional costs to physical activity (Dufour & Sauther, 2002).

Alongside the higher energetic costs of pregnancy, there are additional nutritional requirements. Picciano (2003) summarises the recommended increases in various nutrient intakes (while noting the difficulty in accurately measuring nutrient levels amidst pregnancy-related changes to the body). Of the macronutrients, protein is needed in additional quantities of 21 grams per day for development of maternal, fetal and placental tissues (Institute of Medicine, 2002; Picciano, 2003).

Too much protein, however, may be toxic. Speth *et al*. (1991) explains that there may be a protein threshold, below approximately 25% of total calorie intake, for pregnant women. Spielmann (1989) reviews a variety of taboos related to pregnancy and restricted protein intake. More recently, Hockett (2012) has revisited protein toxicity in relation to the extinction of Neanderthals[30]. He suggests that the levels of protein modelled for the Neanderthal diet (55-60% protein) would have been toxic to pregnant women. He further explores toxic levels of micronutrients like iron, vitamin A, and zinc, as well as under-consumption of vitamin C and carbohydrates.

5.2.1.2 Energetic Restrictions

How women meet their energetic demands is also influenced by food taboos. Taboos may restrict the energy sources for women, depending on their reproductive status. Menstruation, pregnancy and lactation have been associated with a variety of food taboos in hunter-gatherers [see review in Spielmann (1989)]. The food taboos usually involve protein and/or fat reduction (Spielmann, 1989). For instance, the most common food taboo for pregnant women is meat (Fessler, 2002). Cowlishaw (1981) reviews how such taboos can create nutritional handicaps for foragers, as in the Australian Aboriginal

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[30] Froehle and Churchill (2009) also relate the costs of pregnancy to comparisons between Neanderthals and anatomically modern humans. Assuming comparable caloric returns between Neanderthals and humans, they explain that differences in energy expenditure would have amounted to differences in energy allocation to pregnancy and lactation. They thereby link energetic competition between Neanderthals and humans to reproductive competition.

women. Such food taboos have been interpreted in many ways, e.g. as adaptive (Speth, 1991) or as a self-serving convention for men's monopolisation of power (Fessler, 2002).

5.2.1.3 Workload

In addition to her energetic and nutrient needs, the pregnant woman must also face a changing body which physically constrains her movements. How pregnancy affects work efforts and type of work is not well understood quantitatively in foraging populations. There have been studies of expectations and general ethnographic observations, however. In a cross-cultural sample of 202 'traditional' societies (including foraging groups), Jimenez and Newton (1979) found that continuation of full work duties was the most common pattern of activity for pregnant women, though many societies encouraged lightened workloads. Various ethnographies have also described pregnant foragers as continuing normal activities, e.g. in the Ju/'hoansi (Shostak, 1981, p. 178), the Ache (Hill & Hurtado, 1996, p. 250) and the Batek (Endicott & Endicott, 2008, p. 111**;** though they noted "as long into her pregnancy as she felt able").

Few studies have quantitatively compared the work efforts of pregnant, foraging women to non-pregnant, foraging women. Hurtado and Hill (1990) found that pregnant and nursing Hiwi women worked less and gathered less food, though they aggregated 'pregnant and nursing' into one category. Compared to all other women and men, pregnant and nursing Hiwi also had less seasonal variation in their work efforts. Peacock (1985, 1991) found that Efe women decrease their work intensity during late pregnancy and when caring for infants. She argued that the women's curtailment of strenuous activities during these periods is indicative of at least some energetic constraints, rather than merely logistical.

In the Hadza, Pontzer *et al.* (2012) found that the TEE of pregnant women was not significantly different from that of non-pregnant women. However, their sample size was only one pregnant woman, and she was being compared to others, not her pre-pregnant self. In the industrialised context, pregnant women have demonstrated a significantly lower TEE than their pre-pregnant TEE [e.g. in Spain (Amezcua-Prieto *et al.*, 2015) and in Singapore (Padmapriya *et al.*, 2015)]. Systematic reviews of multiple studies demonstrate that pregnant women decrease both the intensity and frequency of physical activity (Poudevigne & O'Connor, 2006; Gaston & Cramp, 2011; Abbasi & van den Akker, 2015). In pregnant women who maintain the same activity levels, TEE has been found to increase due to increases in BMR (Löf et al., 2005).

Ultimately, the higher energetic costs of pregnancy can be met by either increasing energy intake, decreasing energy expenditure, or a combination of both. How pregnant women meet the higher energetic costs may differ: through helpers, through changes in

time allocation (e.g. more resting), through lower foraging rates and through higher food intake. Alternatively, some women may simply not meet the energetic costs, affecting their gestation length and their infant's birth weight (Ellison, 2003).

5.2.2 Lactation

5.2.2.1 Energetic Demands

Lactation costs even more than pregnancy, with estimates of 2,620 kJ (626 kcals) per day for exclusive breastfeeding and 1,930 kJ (461 kcals) per day for partial breastfeeding (Butte & King, 2005).[31] On top of the additional caloric burden, Emery Thompson (2013) reviews other costs associated with lactation: the infant is larger, the period of lactation is longer, and the infant needs transport and protection.

Milk production is modulated by nursing patterns (McDade & Worthman, 1998). Such patterns include the frequency and duration of bouts as well as the total duration of nursing before weaning. Compared to agriculturalists and pastoralists, forager women tend to nurse for longer periods of time (Sellen & Smay, 2001; Fouts *et al.*, 2012). Nursing patterns in the Hadza have not been formally examined, but Hadza infants appear to nurse on demand until weaning around two to three years old (Marlowe, 2005b). Weaning may be delayed beyond three years if the Hadza woman has not become pregnant again (Woodburn, 1959).

Since Butte and King (2005) describe 'exclusive breastfeeding' as up to and including 5 months postpartum and 'partial breastfeeding' as 6 to 24 months, it is unclear to what extent and when caloric demands shift in foraging women like the Hadza. Does a longer period of 'exclusive breastfeeding' maintain a higher caloric expense? Again, as with pregnancy, despite the unknown caloric burden on the Hadza woman, nursing can at least be assumed as *relatively* more expensive. Another unknown consideration is to what extent Hadza women may rely on dietary supplementation versus weight loss as an energy supply. Whereas well-nourished women can supply some energy to lactation via weight loss (in the first six months), undernourished women or those who did not gain sufficient gestational mass are recommended supplementation for the full energy cost of lactation (Butte & King, 2005).

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[31] To calculate these estimates, Butte and King (2005) used a mean milk production of 749g per day in exclusive breastfeeding and a mean of 550g per day in partial breastfeeding. Although Butt and King (2005) represents a relatively older study, their results continue to be used in the most recent recommendations for energetic calculations of pregnancy and lactation (e.g. Lowensohn *et al.*, 2016).

Because Hadza women carry their infants while foraging and travelling, there are additional energetic costs in addition to lactation itself. As mentioned previously, the average Hadza one year old adds 8 kg of weight and the average two year old, 9.4 to 9.7 kg of weight to a mother's load (Blurton Jones, 2016, p. 319). When the infants are held by others, then the nursing mother reduces her load-bearing costs (though she still faces the carrying costs of foods, water and firewood). Hadza children are held by allomothers for more than 30% of total holding time, and the greater the relatedness, the more time spent holding the child (Crittenden & Marlowe, 2008). Meehan *et al.* (2013) found that some Aka caregivers reduce maternal energy expenditure by approximately 216 kilocalories in a nine hour observation period. In groups where caregivers participate in allomother nursing, such reductions in energy expenditures may be even greater. Hewlett and Winn (2014) provide a useful study comparing allomother nursing across 14 foraging groups. This form of allocare is absent in the Hadza but most famously characteristic of groups in the Congo Basin [see Hewlett (2014)].

5.2.2.2 Energetic Restrictions

As with pregnant women, food taboos restrict certain items for lactating women. Unlike with pregnancy, it is less clear how these restrictions may be adaptive, especially given the higher caloric demands for breastfeeding. For instance, increased dietary fat in lactating women does not appear to have adverse effects (Koletzko *et al.*, 2007), yet fat is restricted for many lactating women (see Spielmann, 1989).

5.2.2.3 Workload

In the aforementioned cross-cultural sample of 202 traditional societies (including foragers), Jimenez and Newton (1979) found that most societies expect workload restrictions for postpartum women. These restrictions loosen over time, however, with almost half of the societies expecting a full return to workload duties by two weeks postpartum. A more recent cross-cultural analysis from Eberhard-Gran *et al.* (2010) suggests a postnatal period of 40 days, during which the majority of cultures evoke special proscriptions about diets, rest, isolation or assistance from others.

Summarising the results from rural populations specifically, Ellison (2001) suggests that there is a remarkably similar activity pattern for lactating and non-lactating women. For instance, nursing Tamang women in Nepal rest for the first week post-partum but otherwise demonstrate no significant difference in work patterns compared to non-nursing women in the spring and monsoon seasons (Panter-Brick, 1989). However, the pregnant and nursing women worked less in the early and late winter, when workloads were lowest.

For foraging populations, differences in workloads for nursing women have been identified. Hurtado *et al*. (1992) found that nursing Ache and Hiwi women acquired fewer kilocalories and worked shorter hours than non-nursing women during all seasons. An earlier study also found that Ache nursing women were less efficient foragers than non-nursing women (Hurtado *et al*., 1985). But upon closer examination of both studies, there is an issue of statistical significance. Hurtado *et al*. (1985, pp. 20-21) report 'borderline' significance for comparisons in foraging time between nursing and non-nursing women ($p = 0.060$) and in production of kilocalories (in palm fiber acquisition) between nursing and non-nursing women ($p = 0.059$). Such findings suggests that more data are needed to understand the relationship, especially since their comparison included only nine nursing events. An examination of Hurtado *et al*.'s (1992) reported values also finds that statistical significance was not achieved for differences of acquisition rates nor foraging time between nursing and non-nursing women.

Although Hawkes *et al*. (1989) also suggest[32] a difference for nursing women in total foraging time in the Hadza, they too did not find a significant difference between the mean return rates of Hadza women and non-nursing ('middle adult') women. Mean return rates were based on total amount acquired (in kilograms) and total foraging time. The lack of significant difference may have been due to a small sample size; their sample included only three nursing women.

Other Hadza data from a larger sample size demonstrate significant differences between nursing and non-nursing women. Marlowe (2003) found that married, nursing women returned with significantly fewer kilocalories per day than non-nursing, married women ($n = 37$). The effect was further exacerbated by nursing frequency and the age of the mother's other children. The more frequent the nursing, the fewer kilocalories returned and the younger the woman's other child, the lower her return rate per hour.

Nevertheless, Marlowe's calculations for kilocalories per day and return rate per hour are still missing calorific data for women's out of camp eating and gifts. Based on the geometric mean values for eating and gifts found in Chapter 3, such a difference amounts to over 800 undocumented kilocalories per woman per day. Including these

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[32] In a later 2001 article, Hawkes *et al*. write "*As we also found among the Hadza*, foraging Ache mothers with nursing infants spent less time gathering food for themselves and their weaned children than women who were not lactating (Hurtado *et al*. 1985)" (p. 694; emphasis added). Statements like this run the risk of misleading the reader into accepting that a) the same results were found in the Hadza and that b) the results demonstrated significant differences. Although it is merely a generalised statement, it illustrates a larger problem of how we can mislead readers by not explicitly coupling findings with their non-significant outcomes.

kilocalories, in addition to kilocalories of foods brought back to camp, could either support Marlowe's findings or present a different story. Like pregnant women, nursing women may compensate for high energetic costs by increasing energy intake, decreasing energy expenditure or both. Nursing Hadza women may eat more outside of camp or receive more gifts to compensate for their energetic demands.

5.2.3 Menstruation

5.2.3.1 Energetic Demands

Like pregnancy and lactation, the menstrual cycle, too, can be viewed in terms of energy demands and energy savings (Strassmann, 1996b). Though menstruation is not nearly as costly as pregnancy or lactation (Jasienska, 2009), the menstrual cycle has been found to significantly affect intra-individual variation in BMR (Solomon *et al.*, 1982; Curtis *et al.*, 1996), resting metabolic rate (RMR) (Henry *et al.*, 2003) and sleeping metabolic rate (SMR) (Bisdee *et al.*, 1989; Meijer *et al.*, 1992). These results question the stability of metabolic rates over time for women, especially given the wider coefficient of variations (CV) found for some women [8-12% CV (Solomon *et al.*, 1982) and 3-12% CV (Curtis *et al.*, 1996)] than those reported for men [2-4% CV (Henry *et al.*, 1989)].

The menstrual cycle appears to affect food intake also. Double blind studies have found menstrual cycles significantly affecting the amount of kilocalories consumed (Dalvit, 1981; Manocha *et al.*, 1986), with higher consumption during the luteal phase. Whereas Gong *et al.* (1989) estimate the calorific differences to be around 200 to 300 kilocalories per day, Dalvit (1981) estimates the differences to be around 500 kilocalories per day.

5.2.3.2 Energetic Restrictions

How menstruation may affect food intake in foraging women has not been studied from the point of calorific intake. This subject has been studied, however, from the broader scope of food taboos. Spielmann (1989) includes the category of menstruation in her overview of taboos, documenting examples of taboos on fresh meat. In their ethnography of the Batek, Endicott and Endicott (2008) write that Batek women cannot consume meat during menstruation. (Apparently, though, women are given larger portions of meat at other times to compensate for the loss at menstruation.) Woodburn (1964) too records a menstrual-related food taboo in the Hadza: a wife cannot collect a certain berry species.

5.2.3.3 Workload

In non-foraging societies, menstruation has been linked to work absenteeism, school absenteeism and even physical confinement [e.g. menstrual huts of the Dogon (Strassmann, 1997)]. As mentioned previously, dysmenorrhea, especially, affects work absenteeism (see Section 4.5.1). Menstrual pain is also connected to absenteeism in school (Teperi & Rimpelä, 1989; Singh *et al.*, 2008), with increases in severity linked to greater absences (Busch *et al.*, 1988).

How menstruation affects the workload of foraging women, however, has not been well-studied. Do foraging women experience an equivalent 'absenteeism', or do they carry out their daily routines? As with accounts of the menstrual experience, accounts of menstruation and work in foraging women are also lacking and very limited to generalisations or anecdotes. For example, Endicott and Endicott (2008, p. 29) describe menstruating Batek as continuing normal activities and participating in group rituals, however they do not present any behavioural data. As another example, Goodman *et al.* (1985b) observe that Agta women hunt while menstruating. In the case of the Hadza, on the other hand, the taboo against picking a particular berry species suggests a menses-related restriction on at least some foraging activities. For forager groups generally, no formal study has explicitly evaluated changes in women's work during menstruation.

5.2.4 Post-Menopausal Status

5.2.4.1 Energetic Demands

Post-menopausal women no longer face the energetic costs associated with pregnancy, lactation and menstruation. In other words, they cease being constrained by the physiological demands of reproduction. Furthermore, older ages are significantly associated with lower BMR, independent of physical activity or body size and composition (Klausen *et al.*, 1997). As a result, post-menopausal women expend no energy on pregnancy, lactation and menstruation and have lower metabolic rates than younger women.

5.2.4.2 Energetic Restrictions

Food taboos are also lifted for post-menopausal women in many groups. In Cameroon, Doowaayo women cannot eat warthog, except after menopause and Mbo women cannot eat duiker, except after menopause (Fomine, 2009). Post-menopausal Aka foragers in the Congo Basin are allowed to eat all animal species, unlike pre-menopausal women and adolescent girls (Takeuchi, 2013). In west Malaysian groups like the Orang Asli and Batek, food taboos usually concern animal protein but are minimal or non-existent for post-menopausal women (Angsongna *et al.*, 2016).

5.2.4.3 Workload

Examining the workload of a post-menopausal woman requires a much wider timeframe than that of a pregnant, lactating or menstruating woman. Spanning up to a few decades, post-menopausal status is a category that includes young grandmothers and old grandmothers, stronger women and more frail women. Hill and Hurtado (1996) detail a useful illustration of the broad category of post-menopausal status and its time-associated changes. They ascribe two phases to the assistance given by Ache grandmothers. In the first phase, younger, stronger grandmothers collect food and do housework to ease the burden of their daughter's or daughter-in-law's workload. In the second phase, when they are older and those activities are too physically taxing, they babysit their grandchildren. Once the grandmothers become very old or can no longer relocate with the band, then they are left behind or killed (Hill & Hurtado, 1996).

Post-menopausal women[33] continue to be productive members in many forager groups. During the root season, post-reproductive Hiwi women acquire more kilocalories than reproductive women (Hurtado *et al.*, 1992). Post-menopausal Hadza women forage longer than pre-menopausal women (Hawkes *et al.*, 1989). Other Hadza women consistently nominate post-menopausal women as hardworkers (Blurton Jones, 2016) and as best at 'finding bushfoods' (Cashdan *et al.*, 2012). Cashdan *et al.* found that most nominees were over 60 years, and Blurton Jones found a peak of nominees around that same age (before a decline in nominations after 70 years).

The original post-menopausal data from Hawkes *et al.* (1997), however, have some limitations. Firstly, only nine post-menopausal women are observed (p. 556), two of whom are maternal grandmothers, one of whom is a 'more distant' relation and another whose relationship is not mentioned (p. 554). Secondly, the age of menopause is not established; post-menopausal status is assigned by behaviour alone. Indeed, the study assigns 'senior' women the status of 'grandmother' according to their behaviours toward children. Thirdly, the study relies on a series of proxy measures. For instance, no data were collected for the distribution of the grandmothers' foraged food.

In Hawkes *et al.*'s study, the use of foraging time as a proxy for foraging returns is particularly problematic. Hurtado *et al.* (1992) found an opposite relationship between the two variables. They observed that post-reproductive Hiwi women worked fewer hours but acquired more kilocalories than reproductive women (Hurtado *et al.*, 1992). Additionally, Chapter 3 demonstrates that the longer a woman forages, the more she

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[33] It should be noted that studies investigating how post-menopausal status influences foraging patterns do not normally include very old grandmothers. The studies are self-selective in this way; since those older grandmothers may not leave camp, they are not in the observation dataset.

eats. So even if the post-menopausal Hadza are foraging for longer, they may be bringing back less because they eat more.

More recent data from the Hadza support the view that grandmothers promote the growth and survival of their grandchildren, particularly grandchildren under five years old (Blurton Jones, 2016). However, the key indicator used by Blurton Jones is presence or absence of grandmothers. As a result, the actual pathways by which Hadza grandmothers affect their grandchildren are still debatable. Hill and Hurtado (2009) conclude that provisioning is not a route by which grandmothers increase grandoffspring survival. Documenting the flow of resources from post-reproductive women, they find that post-reproductive Ache and Hiwi women are not important provisioners of younger kin. According to their study, post-menopausal Ache and Hiwi contribute negligible amounts of food to the calorie deficit of reproductive couples (Hill & Hurtado, 2009).

5.3   Part 1: Self-assessment of Workload & Provisioning

5.4   Part 1: Interview Data

During the interviews conducted in the late wet season of 2015, women were asked three sets of additional interview questions. The first set focused on workloads at different reproductive stages, the second on workloads during menses, and the third on provisioning.

The first set of questions compared the difficulty of workloads at three different reproductive stages (i.e. pregnancy, breastfeeding, and post-menopause). Because the Hadza do not have words for 'menopause' or 'post-menopause', the terminology for 'old woman' was used to communicate old age and post-menopause. (This same terminology was used by Hadza women when talking about post-menopausal women during the menopausal questions.) The women were asked when it is hardest to dig tubers and when it is hardest to pick berries. This question set was asked of 33 women from 7 camps. The 33 women were aged 17 to 85 years (median = 36 years). All women had experienced menstruation and at least one of the reproductive statuses. Five women were pregnant, three women were breastfeeding, and ten women were post-menopausal at the time of interview.

The second set of questions asked whether women did their usual work during menstruation. Follow-up questions were asked of various tasks (e.g. digging tubers, picking berries and fetching water) during menstruation as well as questions regarding why

some women choose not to work during menstruation. This second set of questions was asked of 43 women from 9 camps. The sample ranged in age from 16 to 76 (median = 36 years). All women in the sample had experienced menstruation, and eight were post-menopausal.

The third set of questions centred on provisioning. The women were asked if you stay home, then who brings you food? If Person A was the answer, I then asked what if Person A is not here? I continued this way of questioning until the respondent named either herself or no one further. This question set was asked of 29 women at 7 camps, with ages ranged from 17 to 63 (median = 35 years).

The different sample sizes for the three sets of questions reflect time restraints as well as later developments of questions. The first and third set of questions regarding difficulty of workload at different stages and provisioning were developed after visiting the first two camps. Top priority was given to questions focused on menstruation, and more questions were asked to women if time permitted.

5.5 Part 1: Data Analysis

Entry and analysis for the interview data followed the same procedures as defined in Chapter 4. As with Chapter 4, quotations of longer than five words are designated by codes and have Swahili translations available in Appendix H. The one-sample proportions test with continuity correction was again applied for determining the significance of a majority answer given. The Barnard's exact test for comparing categorical data in 2x2 contingency tables was applied as well.

For the first set of interview questions, it is possible that a woman's current reproductive status biased how she assessed a workload comparison across statuses. Therefore, pregnant women's answers were compared to non-pregnant women's answers. Similar comparisons were made for breastfeeding women and for post-menopausal women.

The second set of interview questions revealed the unexpected finding that the majority of women claim not to work during menstruation (see Section 5.6.1.3). Given this unexpectedness, exploratory analyses were conducted to assess multiple explanatory variables. The binary variable of work during menstruation was analysed with respect to age, marital status, parity, camp, and menstrual factors (menses length, blood loss, and menstrual pain). For testing camp, a Fisher's exact test was applied (for a 2x9 contingency table). Potential bias from post-menopausal recall was also tested, and post-menopausal women were excluded from irrelevant analyses (e.g. current parity and current marital status as affecting current menstruation decisions).

In the provisioning set of questions, analysis focused on the potential association of pregnancy, breastfeeding, post-menopausal status and work during menses with the number and type of providers listed. For example, a woman might have named four providers: her husband, her daughter, her sister and a neighbour. Based on the various providers named, seven provider types were identified (see Section 5.6.1.4). A paired comparison pattern model was used to determine which provider types were the top ranked (e.g. did women most often rank their husbands as providers?). These top ranked providers were then examined with respect to a woman's reproductive status. The number of providers each woman listed was also analysed with respect to reproductive status (e.g. did pregnant women list more providers than non-pregnant women?). Since the number of providers is not normally distributed (see Section 5.6.1.4), non-parametric tests were applied.

5.6 **Part 1: Results**

5.6.1.1 **Digging Tubers**

The women were asked when it is hardest to dig tubers: when you are pregnant, when you are breastfeeding or when you are 'old'. Most women selected one of the three categories as their answer. A minority of women chose two categories as their answer (24%) and one woman chose all three. Of the one category answers, no woman answered breastfeeding.

Table 5.1 summarises the breakdown of the women's answers. Pregnancy was the most common answer. Although the singular answer of 'pregnancy' did not retain a statistically significant majority ($n = 33$, one-sample proportions test with continuity correction, $p = $ ns), a significant majority of women (72.7%) did include pregnancy in their overall answers to when it is difficult to dig tubers ($n = 53$, one-sample proportions test with continuity correction, $p < .025$, 95% CI [0.54, 0.86]).

Table 5.1 Hadza Women Assess Difficulty of Digging Tubers by Reproductive Status

Response	*Percentage of Women (n = 33)*
Pregnancy	45.5%
None	18.2%
Pregnancy & Breastfeeding	12.1%
Pregnancy & Old Age	12.1%
Old Age	9.1%
All	3.0%

5.6.1.1.1 During Pregnancy

Of the women who included pregnancy in their answers, they explained that it is difficult to dig when pregnant or that they cannot dig when pregnant, e.g. "it's hard to dig tubers if you are pregnant" (T1) and "if I am pregnant, I cannot dig tubers" (T2). One woman qualified that you cannot dig as many tubers: "during pregnancy, you cannot dig a lot of tubers" (T3). Other women referenced specific difficulties like bowing, fatigue and dizziness. Women described the physical restraints of bowing: "if I am pregnant it is difficult to dig because I cannot bow (down); the pregnancy is grown" (T4); "if you are pregnant, to bow (down) is not easy" (T5); "if the stomach is big, once you kneel when digging, the child will get hurt" (T6). As for fatigue and dizziness, women explained, "if you are pregnant, you will rest and sit because you are tired" (T7), "if you are pregnant, you are very tired; you cannot dig" (T8) and "you feel a bad dizziness".

The majority of pregnancy answers included qualifications as to the size of the pregnancy. Some women used the adjective of 'very' to qualify size: "it is more difficult if I am very pregnant" (T9) and "if you are very pregnant". Others used reference to the growth of the pregnancy: "when the pregnancy is grown, doing work is a problem" (T10); "it is easy to dig tubers when breastfeeding but when the pregnancy is very grown, it is hard" (T11); and "if (pregnancy) is small, you are going to dig tubers; if it is growing it is very difficult, you stay at home" (T12). One woman specifically qualified the size of the pregnancy by number of months: "if you are seven months' pregnant you cannot dig, but if five months' (pregnant) you can just dig" (T13).

5.6.1.1.2   During Breastfeeding

No woman answered only breastfeeding; breastfeeding was either included with pregnancy or with pregnancy and old age. For those who included breastfeeding as difficult, the reason for difficulty was the child: "the child disturbs" and "because the child will be holding your digging stick; it is a problem" (T14). Many more women, however, mentioned breastfeeding in order to discount it as difficult. As examples, "not hard if breastfeeding" and "if you are breastfeeding, you dig; it is not hard when breastfeeding" (T15). Another woman explained "if you are breastfeeding, you lay down the child, you dig, you remove, you roast, you carry (and) you bring the child back home" (T16).

5.6.1.1.3   During Old Age

The answer of 'old age' alone was the second least frequent answer. However, if, like pregnancy, the total occurrence of old age is considered, then the frequency of old age is higher: 24% of women included old age in at least part of their overall answer. Women who included old age in their answers explained, "if you are old, you cannot dig" (T17), "it is hard, but you have to try harder to dig" (T18), and "it is hard, you dig a little (and) nothing" (T19).

5.6.1.1.4   No Difficulties

After pregnancy, the second most frequent answer was that none of the options was difficult. Some women generalized "it is not hard, you just dig" (T20); "you dig anytime, you can rest, like for one hour" (T21); and "for us Hadza, there is no trouble, it is not hard" (T22). Other women specifically discounted certain options: "it is not hard, even if I am breastfeeding a child, I must dig the tubers" (T23) and "no, it is not hard, even if you are pregnant, you just dig, you remove (the tubers)" (T24).

5.6.1.1.5   Comments on Provisioning

At the point of assessing difficulty of digging in different reproductive stages, the question range of provisioning (see Section 5.6.1.4) had not yet been asked. Yet spontaneous mentions of provisioning still emerged in some women's answers. These answers were provoked only by the original question of which option was most difficult.

For those women answering pregnancy as difficult, they mentioned receiving help from husbands, neighbours and girls: "if you are pregnant, you stay at home; the husband brings you food" (T25); "if (the pregnancy) is very grown, I cannot dig, the neighbours share with me" (T26); and "if you are big, if you are grown (referring to pregnancy), you cannot do work, you cannot dig, you just stay. A girl goes to dig [or] if there are three

girls, they go to dig; they bring //*ekwa* (to) this mother here. You eat and rest well, there is no distress" (T27).[34]

Girls, specifically daughters, were also mentioned by one woman who chose old age as most difficult: "if you are growing older, if you are old, you do not dig; you are staying at home, children will bring. Your daughters, they are digging (and) bringing the food to come to call 'mama', you eat (and) sit; you are growing old" (T28). Even one woman who did not assess any of the categories as difficult still described what her husband contributes: "it is not hard, but easy; I dig (and) my husband will find meat" (T29).

5.6.1.1.6   Current Reproductive Status & Women's Answers
Currently pregnant women did not select pregnancy in their answers more frequently than non-pregnant women (n = 33, Barnard's exact test, Wald statistic = 1.69, p = ns). Breastfeeding women, however, did select breastfeeding in their answers significantly more frequently (n = 33, Barnard's exact test, Wald statistic = 2.02, $p < .05$). Similarly, post-menopausal women selected old age significantly more frequently (n = 33, Barnard's exact test, Wald statistic = 2.28, $p < .025$).

5.6.1.2   Picking Berries

The women were asked to compare when it is hardest to pick berries/fruits: when you are pregnant, when you are breastfeeding or when you are old. As with digging tubers, most women selected one of the three categories as their answer. For this question, a smaller minority selected two categories as their answer (9%), one woman chose all three categories (not the same woman who selected 'all' for digging), and one woman said "I don't know".

Table 5.2 presents the women's answers. Though 'none' was the most frequent answer given, it was not statistically significant (n = 33, one-sample proportions test with continuity correction, p = ns). Pregnancy was the second most frequent answer given. However, if all instances of pregnancy are tallied from women's overall answers, then pregnancy was the most frequently reported answer (42%). Still, the answer was not reported significantly more frequently than the other answers (n = 33, one-sample proportions test with continuity correction, p = ns).

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[34] If English-speaking women described help from 'girls' there might be clarification required as to whether younger than peer-aged 'girls' or peer-aged 'women' colloquially referred to as 'girls' is intended. In the case of Swahili, there is a distinction between young girls as '*wasichana*' and women as '*wanawake*'. Thus, the use of '*wasichana*' in the context of provisioning quotes (in this section and elsewhere) signifies help given by young girls.

Table 5.2 Hadza Women Assess Difficulty of Picking Berries by Reproductive Status

Response	*Percentage of Women (n=33)*
None	39.4%
Pregnancy	30.3%
Old Age	15.2%
Old Age & Pregnancy	6.1%
I Don't Know	3.0%
All	3.0%
Pregnancy & Breastfeeding	3.0%

5.6.1.2.1   During Pregnancy

As with digging tubers, the themes of tiredness and size of pregnancy emerged for pregnancy answers. For instance, "if I am pregnant, it is difficult; I am tired (and) relax" (T30), "when you are very pregnant, you cannot (literally: fail to) pick fruits" (T31), and "even when you are pregnant (you work) but when the pregnancy is very grown, it is impossible" (T32). A specific difficulty was identified in relation to trees: "if the pregnancy is very big, you cannot climb up trees" (T33). Another woman described the quantity of fruits as affected: "during pregnancy, you cannot pick very many berries because you are pregnant" (T34).

5.6.1.2.2   During Breastfeeding

Similarly to the answers for digging tubers, no woman selected breastfeeding alone as her answer. Only two women included breastfeeding in their answers, one alongside pregnancy and the other along with pregnancy and old age. Neither of these women described why they chose breastfeeding. For other women who chose pregnancy as most difficult, they used breastfeeding as an example for comparison. Some explained "I pick a little bit more when breastfeeding" (T35) and "it is easier when you are breastfeeding" (T36). One woman detailed: "if I have a baby in my stomach I cannot pick berries, it is not hard for old age. When I am breastfeeding is when I am starting to pick berries" (T37).

5.6.1.2.3   During Old Age

For those who answered 'old age', no explicit reasons were given for why picking berries during old age is difficult. One of the translated answers for an older woman was that "it is very difficult; she cannot pick something from the tree" (T38). Others described "when you are old, it is hard" (T39) or "when you are old, you cannot (literally: fail to) pick" (T40).

5.6.1.2.4   No Difficulties

The amount of women answering 'none' more than doubled between digging tubers and picking berries. The women explained "it is not hard", "there's no problem; I go", "you will just pick", and "even if you are pregnant you pick" (T41). One woman detailed: "it is not hard, you pick, you fill the pot and put it on (your) head, and carry the child on (your) back or if you are pregnant, you carry the fruits on (your) back" (T42). Another woman posed the question: "I do, if I don't do the work, who will do (it)?" (T43).

5.6.1.2.5   Comments on Provisioning

Just as with difficulty of digging, the theme of provisioning spontaneously arose in answers about picking berries. Once again, no questions about provisioning had yet been asked. Women choosing pregnancy as difficult described help from husbands, friends and girls: "the husband will pick for you if you are pregnant" (T44); "it is hard, until you sit down and they cut for you by machete" (T45); and "if you are fully pregnant, […] you cannot (literally: fail to) walk, the girls are going to pick (berries) and bring (them) home; you are tired, you stay" (T46). Another woman, who answered old age as difficult, described help from girls and a husband: "if you are growing older, if you are old, you cannot pick (or) go to pick, the girls and their father go to pick and bring (food), you are staying at home and continuing to eat" (T47).

5.6.1.2.6   Current Reproductive Status & Women's Answers

Currently pregnant women did not answer pregnancy significantly more often than non-pregnant women ($n = 33$, Barnard's exact test, Wald statistic = 0.62, p = ns), and neither did breastfeeding women answer breastfeeding significantly more often ($n = 33$, Barnard's exact test, Wald statistic = 2.08, p = ns). In contrast, post-menopausal women chose old age significantly more often than other women ($n = 33$, Barnard's exact test, Wald statistic = 2.28, $p < .025$). (Of course though, the younger women had yet to experience picking berries or digging tubers at old age.)

5.6.1.3   Workload & Menstruation

5.6.1.3.1   Usual Work

Women were asked whether they do their usual work during menstruation. Although the question was open-ended, all of the women's answers were directly transferrable to the answers of 'yes' or 'no'. Of the 43 women asked, the majority of women (60%) said they do not do their normal work during menstruation. This percentage was not a significant majority according to the one-sample proportions test ($n = 43$, with continuity correction, $p =$ ns). Nevertheless, the percentage is still much higher than expected. When testing the results against the expected value of all women working, the finding of 60% not working during menses is significant ($n = 43$, Barnard's exact test, Wald statistic = 6.10, $p < .001$).

Many of the non-working respondents were emphatic about not working during menses. They repeated 'no' and drew out the sounds of *"ah ah ah ah"* for no. For instance, women said "no, no, I stay home" and "no, no, until when it is over, then you are doing work" (T48). Women mentioned resting (e.g. "I rest") and waiting until menstruation ended [e.g. "I stay at home until I cease menstruation, then I am doing work" (T49)]. In contrast to the non-working respondents, the working respondents said, "I do my job", "you do your work well; there is no problem" (T50). One woman asked "Which job? I am able to work during menstruation" (T51) whereas others started talking about specific jobs: "you are just working, you are going to dig" (T52) and "you go to dig tubers or if there are baobab fruits you pound them a little" (T53).

5.6.1.3.2   Digging, Picking and Fetching

Following from the open-ended question of whether women do their usual work during menstruation, I asked three subsequent questions regarding specific activities. Women were asked if they dig tubers during menstruation, pick berries during menstruation and fetch water during menstruation.

Three of the non-working women answered that they dig during menstruation (a seeming contradiction to their original answer). All other non-working respondents said they did not dig during menses. One explained, "until I get better, then I go to dig tubers" (T54) while another said "you are not allowed to dig" (T55). The latter respondent added further, "because you are not allowed to touch anything you just sit inside until it is finished" (T56). Some women commented about doing other activities instead: "I go to bathe" and "to wash".

All of the working respondents said that they dig while menstruating. Some explained "I go digging my tubers; there is no problem" (T57) and "I go to dig the tubers (and) bring (them)" (T58). I also asked if they had the same amount of tubers as usual, and all

agreed. For instance, one woman explained "as usual, you dig and get many (roots) as normally, you come back (and) feed your children like normally; there is no problem during menstruation" (T59).

All of the non-working respondents but one answered they do not pick fruits during menstruation. Three of the working respondents also said they do not pick fruits at menses. Despite having answered that they do their regular work and dig tubers, these women explained, "you cannot pick up the fruits" (T60), "but I do not pick fruits" (T61), and "I pick fruits, but we do not pick fruits if we are menstruating" (T62)[35].

All women, both non-working and working respondents, said that they will fetch water. Women talked about men seeing them while fetching: "if there are not many men, I go" (T63) and "you walk with the women, or if there are men there, they will see the blood!" (T64). They also talked about fetching water in order to clean: "they go to clean their clothes with water" (T65*)* and "I fetch, even going during […] menstruation, if given my heavy clothes" (T66).

5.6.1.3.3   Reasons to Stay at Home

All of the non-working respondents said they stayed at home. One explained "none are walking; a little blood, we stay here" (T67*)*. Another had a spontaneous mention of provisioning: "yes, mom goes to pick and bring (fruits) home (and) you eat" (T68).

Both non-working and working women were asked if they knew other women who stayed at home during menses. All responded that they knew other women doing this (e.g. "yes, others stay"). One working woman said: "there are some who will see it is menstruation, they will stay at home; they cannot be walking around" (T69).

Non-working women were asked why they stay at home. Almost all of the answers related to walking. One woman answered with a question: "why should I walk during menstruation?" (T70). Other women related the walking to blood falling or coming out: "I stay; if I walk, blood is coming out" (T71) and "I cannot walk when I am bleeding; if I walk, blood is falling" (T72).

Two themes emerged as to why the combination of walking and menstruation was seen as problematic. The first was the notion that bleeding increased or worsened if you walk. Women explained: "because of the way of menstruation, if I walk around, (the blood) is increasing, if I stay at home during menstruation, (it) is not increasing; it finishes early" (T73) and "now if I stay home, the conditions (also: symptoms) will not be worse" (T74).

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[35] In this quote as well as the previous quote, the word '*mdabi*' was specifically used rather than the general word for fruits. This references the *Cordia* genus of Hadza berries.

The second theme was the idea that people see the blood falling. Another woman said, "if you walk, the blood may come out (and) people might see" (T75).

I asked the women follow-up questions if they stay at home because of pain or because of the blood. No one answered because of pain, and women agreed because of blood: "no pains, the blood will fall" (T76). One woman explained: "if I decide to stay, I can stay, if I decide to walk, I walk; menstruation does not prevent me in anything" (T77).

Working women were asked to speculate as to why they thought other women stay at home. One woman explained "because of our taboos […] until you have finished" (T78). Others said they did not know or "just staying to sleep". The latter was consistent with non-working answers like "I rest for three days".

5.6.1.3.4 Comments on Taboos

Taboos, like provisioning comments, were spontaneously mentioned by the women during interviews. No questions were directly asked regarding taboos or restrictions. Instead, mentions of taboos arose within women's answers to other prompted questions.

Two women specifically used the Swahili word for taboos (*miiko*). One woman used the word in explaining why women stay at home at menses (see T78). Another woman mentioned taboos for men during menses: "in our taboos husbands are not allowed to touch arrows, it is bad, but (for the) decision to take the digging stick, I am going to dig with the digging stick, I am not staying, I am walking" (T79).

Other mentions of taboos are inferred from the use of words like "not allowed to", "cannot" and "shameful". For example, Hadza women talked about not being allowed to dig or even allowed to touch anything (see T55 and T56). Explaining why she stays home during her menstruation, another woman said, "I stay at home because that is shameful for our people, to go out and walk around (and) men seeing is shameful" (T80). Answers like this involved extrapolation to the larger we, as in "our people" or "for us".

The most common taboo spontaneously mentioned by women was the taboo against picking fruits at menses. Women repeatedly used phrasings like "you cannot" and "we do not" (e.g. T60, T61 and T62). As noted previously, the general word for fruits (*matunda*) was not applied in these instances. Women used the word *mdabi* instead, referring to the *Cordia* genus of berries (see Appendix B and Appendix C). This distinction was made by women despite the question itself referring to fruits generally.

5.6.1.3.5 Factors Affecting Decision to Work

Because there was a surprising number of women who reported not working, analyses were conducted to identify any potential explanatory variables. A woman's age was not significantly associated with whether a woman reported working during menses ($n = 43$,

probit regression, p = ns) nor was her post-menopausal status (n = 43, Barnard's exact test, Wald statistic = 0.93, p = ns). Current number of children alive (post-menopausal women excluded) was not significantly associated with whether a woman said she worked during menses (n = 43, controlled for age, probit regression, p = ns). Neither reported blood loss (n = 24, Barnard's exact test, Wald statistic = 0.12, p = ns) nor reported menstrual pain (n = 32, Barnard's exact test, Wald statistic = 0.46, p = ns) was significantly associated with whether a woman worked.

Factors such as having a husband, reported menses duration, and which camp the responders were living in were all found to be significantly associated with a woman's report of working during menses. Women with husbands reported not working during menses significantly more frequently than women without husbands (n = 35, post-menopausal women excluded, Barnard's exact test, Wald statistic = 1.81, $p < .05$). Reported menses length also had a significant association with whether a woman worked (n = 30, post-menopausal women excluded, 2x3 contingency table, Fisher's exact test, $p < .05$). Interestingly, the working women were uniformly distributed across menses lengths of one, two and three days. The non-working women, on the other hand, were mostly (64%) concentrated at the menses length of three days.

Camp too was found to be significantly associated with women's answers (n = 43, 2x9 contingency table, Fisher's exact test, $p < .025$). Yet it was visually evident that two camps may be biasing[36] the results: at one camp, all women reported not working (n = 8) and at another camp, all women reported working (n = 5). Since the results were potentially biased by one or both camps, another Fisher's test was run firstly to the exclusion of the camp with the larger sample size. This test revealed that camp was no longer significantly associated with a woman's decision to work (n = 35, 2x8 contingency table, Fisher's exact test, p = ns). In other words, the spread of answers was not significantly different across the other camps. For the majority of camps (n = 6), women more often reported not working.

The two statistically significant factors, husband and menses length, were added to a binomial model to predict whether or not a woman worked at menses. When added together, the husband effect lost significance (n = 30, p = ns). Thereby, menses length was the most important predictor of whether or not a woman worked at menses in this sample (n = 30, probit regression, $p < .05$, R^2 = 0.21). A one day increase in menses length increased the likelihood of not working by 23% (OR = 1.23, 95% CI: [0.63, 1.84]). Women

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[36] Even with removal of these two camps, however, the same percentage of women (60%) reported not working at menses across the remaining camps.

who said they do work at menses had a median menses length of 2 days while women who said they do not work had a median length of 3 days.

5.6.1.4 Provisioning

5.6.1.4.1 Provider Type
The 29 Hadza women named a total of 57 types of people in provider roles. Nine of the providers were specifically named individuals. All types of providers were divided into seven categories based on the following (listed in order of decreasing frequency):

1) *Husband*: This category included only husbands. Although *mume* is the traditional Swahili word for husband, the Hadza women more frequently use *mzee wangu* (literally: my old man) to describe their husbands.

2) *Mother*: This category included only mothers. *Mama* was the Swahili word used by the women, as in "mother will bring for me".

3) *Neighbour/Friend*: This category included references to friends, neighbours, and colleagues. As examples, Swahili phrases for 'my colleague', 'my friend', and 'my neighbour' were used. In one instance, when a woman answered with 'my neighbour', I then asked who and she answered with "a friend, if she/he has cooked food, she/he will give me food" (T83), thereby highlighting the interchangeability of neighbour and friend.

4) *Children*: This category included children, male and female. Children were referenced with the Swahili words for "girl", "boy", and "children". In particular, women used the adjective big to distinguish older children as bringing them food. They also described multiple children as helping, like "a girl or two girls and a boy are helping to bring (food)" (T81).

5) *Relatives*: This category included relatives, two instances of 'paternal aunts', two instances of 'sister', one instance of 'relative', and one instance of 'father'. The category also included three adult nieces (specifically named individuals), who were treated as one answer level of relatives.

6) *Grandmother/Bibi*: This category has retained the Swahili word *Bibi* because the word appeared in all answers of this category. It signifies both grandmother and older woman. For this reason, *Bibi* was not included in relatives as women may have referenced a *Bibi* in camp who was not necessarily their grandmother.

7) *Myself*: This category is limited only to those that answered themselves. These women did not say any other provider. For instance, one woman explained, "no one, I go myself to find and bring food from the bush" (T82).

When prompted if you stay at home, who will bring you food, two of the women listed only themselves. The remaining women proceeded to name at least one provider or more, before listing themselves or no one else. Once they finally listed themselves, it was

in the context of "I walk" or "I go to dig tubers (and) bring" (T84). In one case, a final answer was "I will sleep without eating".

Some women specifically referenced the types of food to be provided, like "if my husband goes to pick fruits, he will bring (them) to me, or honey, he will bring (it) to me" (T85) and "the bigger children, if there are my little children, then they are gathering not as many baobab fruits" (T86).

The category of neighbour/friend also revealed some interesting commentary. For instance, one woman asked "where will they (neighbours) go?" Another one said "my neighbours are in Sangeli [a different camp from that of the interviewee at time of interview], there are no neighbours here today" (T87). Neighbours, as an answer for one woman, also included field researchers. After answering her husband as a provider and being asked if he was not here then who, one woman said, "neighbours, like you and Emily [fictionalised name]; Emily comes and brings food" (T88). When asked if they are not here, then who, she listed another researcher's name! These answers were treated as one answer level of 'neighbour/friend'.

Due to three nieces treated as one instance of 'relatives' and three field researchers as one instance of 'neighbour/friend', the total of 57 named providers is treated as 53 providers. Table 5.3 breaks down provider type by total providers listed:

Table 5.3 Provider Type Breakdown by Total Providers Listed ($n = 53$)

Provider	*Percentage of Total (n = 53)*
Husband	35.8%
Mother	18.9%
Neighbour/Friends	15.1%
Children	11.3%
Relatives	9.4%
Grandmother/Bibi	5.7%
Myself	3.8%

Although Table 5.3 suggests that 'husband' and 'mother' are the most important providers, it was necessary to test whether they were significantly chosen by the women. To do this, a test was needed which would take into account the rank order of the providers not only between women but within woman. The paired comparison pattern model was used in R, with responses coded as consecutive integers, and all seven categories included. 'Husband' and 'mother' were significantly chosen answers: $p < .001$ and $p = .005$, respectively.

Table 5.4 presents provider position (whether the provider was named first, second or third) with respect to provider type (e.g. of all the providers named first, how many were 'husband'?). Table 5.5 presents provider type with respect to provider position (e.g. of all the ''husband' mentions, how many were in Position 1?). The cut-off of three levels of provider positions was chosen because only two women named four or more providers and an optional category of 3 and above or 4 and above would have been biased by those two women. The women who named more providers are included, but only their top three answers are represented.

Table 5.4 Breakdown of Provider Position Relative to Provider ($n = 53$)

	Position 1	Position 2	Position 3	Total Instances per Provider
Husband	63.2%	26.3%	10.5%	$n = 19$
Mother	100.0%			$n = 10$
Neighbours/Friends	50.0%	37.5%	12.5%	$n = 8$
Myself	100.0%			$n = 2$
Children	16.7%	83.3%		$n = 6$
Relatives		40.0%	60.0%	$n = 5$
Grandmother/Bibi			100.0%	$n = 3$

Table 5.5 Breakdown of Provider Relative to Position Number (*n* = 53)

	Position 1	*Position 2*	*Position 3*
Husband	41.4%	33.3%	22.2%
Mother	34.5%		
Neighbours/Friends	13.8%	20.0%	11.1%
Myself	6.9%		
Children	3.4%	33.3%	
Relatives		13.3%	33.3%
Grandmother/Bibi			33.3%
Total Providers per Position	*n* = 29	*n* = 15	*n* = 9

Despite husbands and mothers both being significantly chosen providers, Table 5.4 and Table 5.5 visually demonstrate how these answers differ from one another. Whereas women who named their husbands did so across all three positions, women who named their mothers only did so in the first position. Additionally, even though mother is exclusively named in the first position, husband still appears more frequently than mother in that very position.

Provider type was examined with respect to a woman's reproductive status. Given the small sample sizes of pregnant, breastfeeding and post-menopausal women, it is difficult to determine any trends toward provider type. For breastfeeding women, the sample size is too restrictive (*n* = 3) to note any possible trends. Of the six pregnant women, half had mother as their first choice and one-quarter had husband as their first choice. However, mother was not listed in any other position, whereas husband appeared again as second choice and third choice (following the comparison mentioned above). All but one of the pregnant women named 'husband'. Notably, the one exception did not have a husband at the time of interview. For the six post-menopausal women, half had husband as first choice and one-quarter had mother as first choice, a switched scenario to pregnancy answers. Husband appeared again as a third choice, bringing husband to appear in two-thirds of the post-menopausal answers. The apparent distributions for the small sample sizes of pregnancy and post-menopausal then conformed to the overall dominance of mother and husband as choices.

Provider type was also examined with respect to whether women work during menstruation. The working and non-working groups had larger (though still small) sample sizes from which to study any trends toward provider types. The analysis was restricted to only the provider type listed in Position 1. A Fisher's exact test was applied to a 2x5 contingency table. Whether a woman worked during menstruation was not found to be significantly associated with the type of provider she listed (n = 26, Fisher's exact test, p = ns).

5.6.1.4.2   Provider Count

The women listed on average 1.93 providers (median = 2, SD = 1.39). However, it was evident from the scatterplot that an answer of seven respondents was a potential outlier. This list of seven by one woman included six of the nine specifically named individuals in the total providers. It seems this woman had answered the question in a highly specific way, making herself an outlier in that respect already. With that outlier removed, the mean reported number of providers is 1.75 (median = 1.5, SD = 1.02). The distribution of the number of providers is not normal (Shapiro-Wilk normality test, p < .005; kurtosis = -1.02; skewness = 0.40). Log transformations and square root transformations did not yield normal distributions.

Due to the non-normal distribution of provider count, non-parametric tests were applied to assess how reproductive status may have affected the number of providers listed. Currently pregnant women did not name significantly more providers than non-pregnant women (Mann-Whitney U test, U = 51, n_1 = 6, n_2 = 22, p = ns). Similarly, post-menopausal status was not significantly associated with the number of providers listed (Mann-Whitney U test, U = 60, n_1 = 6, n_2 = 22, p = ns). Breastfeeding status could not be investigated because of an insufficient sample size: only two women were breastfeeding (the third was excluded as the outlier).

Women's report of working during menstruation, however, was found to be significantly associated with provider count. Women who do not work during menses reported significantly more providers than women who do work during menses (Mann-Whitney U test, U = 39.5, n_1 = 13, n_2 = 12, p < .05). Applying the effect size guidelines of Cohen (1988), there was a moderate effect size (z = 2.07, r = .41). The median reported number of providers decreased between non-working women (median = 2) and working women (median = 1).

5.7 Part 2: Observational Assessment of Workload & Reproductive Status

5.8 Part 2: Data Analysis

As in Chapter 3, linear mixed models (LMMs) and generalized linear mixed models (GLMMs) were applied in this chapter. Again, camp and woman were treated as crossed random effects (see Chapter 3). For this chapter, new factors were investigated related to reproductive status. Pregnancy status, breastfeeding status and post-menopausal status (above age 43 based on results from Chapter 4) were used. Pregnant women were observed on 26 follow days, nursing women on 76 follow days, and post-menopausal women on 84 follow days.

Although data analysis for previous sections has mostly centred on exploratory analysis, this section focuses on specific predictions related to reproductive status, workload and provisioning. Given that pregnant women and nursing women require more kilocalories, I predict that they use one or more of the following strategies outside of camp:

a) Eat more absolutely
b) Eat more relatively to amount foraged
c) Rest more
d) Give fewer gifts
e) Receive more gifts
f) Forage less absolutely

Furthermore, given that post-menopausal women require less kilocalories (since physical reproductive costs have ceased), I predict that they use one or more of the following strategies while outside of camp:

a) Eat less absolutely
b) Eat less relatively to amount foraged
c) Rest less
d) Give more gifts
e) Receive less gifts
f) Forage more absolutely

To evaluate the above predictions, kilocalories eaten, foraged, given and received were determined as in Chapter 3. The additional variable of 'rest' was used as total time recorded resting during the trip outside of camp. Other additional outcome measures were whether or not a woman ate, whether or not she gave/received gifts, the total number of gifts given and the total number of gifts received.

The significant results from Part 1 allow for other predictions to be drawn based on women's self-evaluations of foraging difficulty by reproductive status. Given the previous results, I also predict that pregnant women will forage less during tuber trips than non-pregnant women. To test this prediction, a subset of follow data was created for only those follows where tubers were acquired ($n = 99$).

5.9 Part 2: Results

The results of the hypothesis testing are summarised in the following section. Table 5.6 displays all significant results across the three reproductive statuses.

Table 5.6 Summary of Significant Associations for Pregnancy, Breastfeeding and Post-menopausal Statuses

	Absolute eating	Relative eating	Resting	Gift Giving	Gift Receiving	Absolute foraging
Pregnancy	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Breastfeeding	*ns*	*ns*	*ns*	Increased likelihood of giving $p < .001$, $R^2 = 0.20$ OR = 2.16 Increased number of gifts given $p < .010$, $R^2 = 0.17$ $d = 0..37$	*ns*	*ns*
Post-menopausal	*ns*	Decreased relative consumption $p < .05$, $R^2 = 0.44$ $d = 0.21$	Decreased rest $p < .025$, $R^2 = 0.46$ $d = 0.36$	*ns*	Decreased likelihood of receiving $p = .010$, $R^2 = 0.42$ OR = 2.24	Increased foraged amount $p < .025$, $R^2 = 0.44$ $d = 0.25$

5.9.1 Absolute Eating

The distribution of kilocalories eaten was again log-normalised for comparing whether pregnancy status, breastfeeding status or post-menopausal status was significantly associated with total eaten. None of the statuses was found to be significantly associated with the amount a woman consumed during her follow, controlled for follow duration (n = 263, linear mixed models, p = ns for pregnancy, p = ns for breastfeeding and p = ns for post-menopausal). As in Chapter 3, whether or not a woman ate on a follow was also considered. Again, none of the three reproductive stages was significantly associated with whether a woman ate or not during the foray (n = 263, generalized linear mixed models, p = ns for pregnancy, p = ns for breastfeeding and p = ns for post-menopausal).

5.9.2 Eating to Foraging Ratio

Pregnancy and breastfeeding status were not significantly associated with the ratio of kilocalories eaten to total kilocalories foraged. Post-menopausal women ate less relative to their total foraged compared to pre-menopausal women (n = 198, linear mixed model, $p < .05$, R^2 = 0.44). The size of the effect was small (d = 0.21). Post-menopausal women ate a median of 14.9% of total foraged while pre-menopausal ate a median of 21.0%.

5.9.3 Resting

Not all follows recorded resting behaviour so the sample size for testing rest in relation to reproductive status was limited to 115 person/days. On average, the women rested for 35 minutes (SD = 31.5, median = 25, range from 5 to 135 minutes). Resting was positively skewed (skewness = 1.25) and as such, the outcome variable was log-normalised before applying mixed models. Neither pregnancy nor breastfeeding affected total resting time (n = 115, linear mixed models, p = ns and p = ns, respectively). Both age ($p < .005$) and post-menopausal status ($p < .025$) were significantly associated with resting time, with older, post-menopausal women resting less. Comparing a model of age to a model of post-menopausal status, post-menopausal status was the stronger predictor, with a lower AIC and higher R-squared (R^2 = 0.40). Trip duration was also significantly associated with resting time ($p < .001$), with longer trips associated with more rest. When compared to a model of post-menopausal status only, a model with follow length and post-menopausal status revealed a lower AIC and higher R-squared (R^2 = 0.46). Thereby, a woman's menopausal status and time spent outside of camp were significantly associated with her resting time. The size of the effect of menopausal status was moderate (d =

0.36). A post-menopausal woman rested for a median of 5.6% of total time outside of camp while a pre-menopausal woman rested for a median of 8.9%.

5.9.4 Gift Giving

Neither pregnancy nor post-menopausal status was significantly associated with whether a woman gave gifts or not ($n = 263$, generalized linear mixed models, $p = $ ns and $p = $ ns, respectively). Breastfeeding status, however, was significantly associated with whether a woman gave a gift or not. Breastfeeding women were significantly more likely to give gifts than non-breastfeeding women ($n = 263$, generalized linear mixed model, $p < .001$, $R^2 = 0.20$). Breastfeeding status increased the odds of giving a gift by a factor of two (OR = 2.16, 95% CI: [1.61, 2.91]).

As in Chapter 3, total kilocalories of gifts given were log-normalised. None of the reproductive stages was significantly associated with the total kilocalories of gifts given per follow. In the follows for which gifts were given ($n = 119$), the number of gifts given per woman ranged from one gift to 31 gifts (mean = 4, $SD = 4.6$, median = 2). The distribution was positively skewed (skewness = 3.01) and normalised through a log-transformation. Controlling for follow length duration, neither pregnancy ($p = $ ns) nor post-menopausal status ($p = $ ns) were significantly associated with the number of gifts.

However, breastfeeding status, controlled for follow length, was significantly associated with more gifts given ($n = 119$, linear mixed model, $p < .010$, $R^2 = 0.17$). Indeed, all but three of the follows with seven or more gifts ($n = 19$) were follows of breastfeeding women. The effect was moderate ($d = 0.37$), with breastfeeding women giving a median of 3.5 gifts and non-breastfeeding women giving a median of 2 gifts. Additional analyses demonstrate that breastfeeding women gave a large proportion of their gifts to their nursing children (see Section 5.10.7).

5.9.5 Gift Receiving

Post-menopausal women were significantly less likely to receive gifts than pre-menopausal women ($n = 263$, generalized linear mixed model, $p = .010$, $R^2 = 0.42$). Post-menopausal status decreased the likelihood of receiving gifts by twofold (OR = 2.24, 95% CI: [1.64, 3.08]). No significant differences were found for pregnant or breastfeeding women ($n = 263$, generalized linear mixed models, $p = $ ns and $p = $ ns, respectively).

For total kilocalories received, the data were again log-normalised. As with gifts given, none of the reproductive stages was significantly associated with the total kilocalories for gifts received per person/day. During the follows in which gifts were received ($n = $

114), the number of gifts per woman ranged from 1 gift to 26 gifts (mean = 3.77, *SD* = 4.55, median = 2). Like the distribution of gifts given, the distribution was positively skewed (skewness = 2.89) and thereby log-transformed. Controlled for follow length, pregnancy (*p* = ns), breastfeeding (*p* = ns) and post-menopausal status (*p* = ns) were not significantly associated with total number of gifts received.

5.9.6 Absolute Foraging

Overall, breastfeeding women and pregnant women did not foraging significantly differently, with control for follow length (*n* = 198, linear mixed models, *p* = ns, *p* = ns). Post-menopausal women, on the other hand, were found to forage significantly more (controlled for follow length) than pre-menopausal women (*n* = 198, linear mixed model, *p* < .025, R^2 = 0.44). The size of the effect was small (*d* = 0.25). Post-menopausal foraged a median of 3,761 kilocalories per follow day while pre-menopausal women foraged a median of 3,111 kilocalories.

5.9.7 Pregnancy & Tuber Digging

On trips where women acquired tubers (*n* = 99), there were no significant associations between pregnancy and total kilocalories foraged per hour (linear mixed model, *p* = ns) nor pregnancy and total kilocalories eaten per hour (linear mixed model, *p* = ns). Nevertheless, the data were limited by few pregnant women in the tuber subsample: only 8 person/days included pregnant women. Additionally, the representation of pregnant women in the total tuber acquisition trips (8.1%) is not significantly different than their representation in trips without tuber acquisition (11.1%).

5.10 Discussion

5.10.1 Self-reported Difficulties in Workload

This is the first study to test foraging women's perceptions of differing workloads by reproductive status. The Hadza women most frequently reported pregnancy as difficult for picking berries and digging tubers, with the latter retaining a significant majority answer. Pregnant women were not biased toward choosing pregnancy status as most difficult, further underscoring its majority answer position. The reasons for choosing pregnancy included its physical constraints and symptoms like fatigue and dizziness.

The women also consistently qualified the difficulties of late (very grown or very big) pregnancy.

The answer of 'none' was also an important indicator of the Hadza women's workload assessment, since the women were given three options and purposefully chose to discount all three. Assessments might have been limited, however, by the use of 'old age' as a proxy for post-menopausal status. Although the same language was applied as the Hadza use to describe grandmothers and other post-menopausal women, there is the possibility that some women interpreted this category differently. For example, some women might have only answered with respect to much older women.

Overall, few women included breastfeeding status in their answers: only five for digging and two for picking. No woman answered breastfeeding as a singular answer when assessing either digging or picking. Furthermore, many women specifically discounted difficulties while nursing. These findings highlight the importance of retrieving actual perspectives from foraging women. There exist widespread assumptions about the inherent difficulties of foraging while nursing [e.g. balancing trade-offs for the Ache is "very difficult" (Hurtado *et al.*, 1992, p. 211)]. A missing yet integral part of this discussion is how foraging women themselves view work difficulties while nursing. Even when women in this study were asked follow-up questions like whether you dig fewer tubers if breastfeeding, they themselves did not perceive any differences.

Perspectives from forager women are crucial to understanding how their decision-making operates. Although researchers can measure the extra carrying costs of nursing children and track the distances that women walk, the women's attitudes and perceptions of the lived costs are an important part of the total picture. These perspectives also highlight the expectations of the Hadza women. They seem to expect that digging tubers is most difficult for pregnant women, especially late in pregnancy. On the other hand, they seem to expect that digging and picking are not as difficult for breastfeeding women.

These expectations of the difficulties in workload are important considerations in a group that shares widely. Since the women do not expect as much difficulty for breastfeeding and older women, then they may not expect to give them more food or to receive less food from them. With pregnant women, however, Hadza women generally agree that there is greater difficulty in foraging when pregnant and thereby, they may expect special treatment for these women, i.e. giving them extra food or receiving less food. This seems to be the case from descriptions by Woodburn (1982): "sharing rights for pregnant women are particularly emphasised by the Hadza: they have the right to ask anyone for food at any time and are believed to be at risk if they are refused" (p. 442). The present findings, however, suggest that pregnant women did not receive more gifts of food than non-pregnant women outside of camp. Such sharing rights for pregnant

women may then be a phenomenon occurring inside of camp, when men have also returned with their acquired food stuffs.

5.10.2 Self-reported Workload at Menstruation

The finding that 60% of the Hadza women say they do not do normal work during menses is surprising. No study before has investigated foraging women's self-reported workloads during menses. Other mentions of forager groups reference menstruating women as continuing normal activities (see Section 5.2.3). Even generalizations about the Hadza depict women as having "unrestricted" access to staple food stuffs (Blurton Jones, 2016, p. 399).

Apparently, however, many Hadza women claim to restrict their workloads at menses. In general, the women who reported not working during menses reported neither digging tubers nor picking berries. Likewise, most of the women who reported working at menses reported digging tubers and picking berries. Fetching water was the only activity that remained unrestricted, with all women reporting fetching water at menses, particularly for bathing.

In a few exceptional cases, some of the working and non-working women's answers appear inconsistent. Of the women who reported not working during menses, three clarified that yes, they do dig tubers. Similarly, three of the women who said they do their normal work during menstruation, also said they do not pick berries. Although these answers seem to be contradictory, all six answers are consistent with picking certain berries as taboo (discussed in Section 5.11.3). In other words, all six women consistently reported not picking during menses, even though they inconsistently considered 'normal work' to be wholly inclusive of digging and picking. (None of the non-working women appeared to consider normal work to be inclusive of fetching water, given that all answered that they still fetched water at menses.)

If women are reporting their actual behaviours, then these results demonstrate that for around two days every month many Hadza women do not forage and rely on others for food. This creates a dependency whereby the menstruating woman does not contribute food and instead relies on contributions from others. Again, this may highlight the importance of women's expectations, that the Hadza may expect some women not to forage because they are menstruating.

None of the women reported menstrual pain as a reason for staying home and not working. Almost all answers related instead to walking, from the point of view of blood falling or the point of view of others seeing blood. Some Hadza women seem to think that blood loss increases if they forage during menses. Some are also cautious about others

seeing the blood as it falls. The reasoning for staying at home appears to be based on visualisations of the blood itself. That is, the visualisation of more blood falling because of movement and the risk of visualisation from others, like men, who may see the blood. The latter point is interesting because if a young adult woman stays behind at camp because of menstruation, men may actually take this as a signal that the woman is menstruating.

Surely, if women are not foraging for any food at menses, then they must be signalling to at least someone (provisioners presumably) that they require food. Based on women's descriptions of provisioners (see Section 5.6.1.4), it can be expected that mothers and husbands are important sources at times when women do not forage for food. The presence of a husband could be a potential indicator for women who are capable of not working at menses, given the significant association between women with husbands and those reportedly not working. How women signal to their husbands and to what extent husbands forage any differently if their wives remain at home at menses are interesting questions for future exploration.

Menses length was the most important factor associated with non-working women. This association is striking precisely because the women who are most often not working at menses are also those with the longest menses. Three consecutive days of not working is a significantly greater burden than one day of not working. Still, menses length explained a limited amount of total variance. Further exploration is needed for understanding those women who do not work at menses. Indeed, the considerable autonomy of the Hadza is always a necessary factor for consideration. Even in the presence of taboos (discussed in Section 5.11.3), Hadza may act highly individualistically, as they do in other arenas of decision-making (e.g. camp movements).

Additionally, women may only be able to cease work at menses in the right set of circumstances. There may firstly need to be an availability of provisioners. Secondly, the provisioner(s) must be receptive to a monthly contribution. In other words, the provisioner must be accepting of the expectation that menses constrains work, rather than rejecting that these women are scroungers or non-contributors. Alternatively, provisioning at menses may reflect a sharing relationship based on reciprocal altruism. Interview data from men are critical to better understand the context in which women do not work at menses. From the perspective of women, it is evident that even those women who do work at menses are familiar with other women who also cease working at menses.

How widespread the phenomenon of not working at menses is for the Hadza is not yet clear. The majority of women reported not working and all women reported knowing other women who do not work. Yet these results are still lacking observational data on women menstruating and not working. Without observational data, conclusions can

only be drawn with regards to what women say they do, rather than what they actually do. Nevertheless, the interview results raise this critical issue for the first time, placing a new demand for actual observations of women's work at menses and of provisioning at menses. This type of future work is discussed in Section 5.11.9.

5.10.3 Taboos

No menstrual-related taboo was as consistently mentioned as the taboo against *Cordia* berries at menstruation. Woodburn (1964, p. 275) first documented this same taboo in his dissertation. He described the menstruating wife as prohibited from picking these berries; otherwise, the berries would fall from the trees. More recently, Power (2015) documented this same taboo in her discussion of gendered Hadza rituals.

The colouration of the berries is particularly relevant, as *Cordia* berries are bright red or reddish orange in colour. Restrictions on eating red-coloured foods at menstruation appear in other groups around the world. Red fruits are prohibited for menstruating women in Papua New Guinea (Meyer-Rochow, 2009) and for Luvale women in Angola and Zambia (White *et al*., 1958) and red foods for menstruating Toba women in Argentina (Vazquez & Rodriguez, 2009). For the Akan of Ghana, Agyekum (2002) describes euphemistic expressions of menstruation which liken female genitalia and menstrual blood to red fruit and red-coloured palm oil, respectively.

Red berries have an intuitive visual symbolism for menstrual blood. When and how the taboo arose is a fascinating question, but the taboo has at least persisted since Woodburn's (1964) documentation. Interestingly, red is one of only three colours (including white and black) named consistently across all Hadza (Lindsey *et al*., 2015). Based on these findings, Lindsey *et al*. (2015) suggest that Hadzane is representative of an early stage in colour term evolution.

Woodburn (1964) argues that the observance of menstrual taboos by both women *and* men is important to defining marriage[37]. He reports that husbands are restricted from touching poisoned arrows and putting their arms into bee nests. Similarly to the predicted fate of the berries dropping from trees, the arrows will fail and the bees' honey will be eaten if the taboos are not observed. Although the restriction on honey is not well-documented, the taboo on poisoned arrows has been consistently reported by Hadza adults (e.g. Power, 2015 and this study).

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[37] He further notes that couples observe behavioural restrictions not only at menstruation but also during pregnancy and when the wife has a child. Woodburn (1964, p. 274) argues that these restrictions are a source of confirmation for the couple's marital status.

If these taboos are fully observed, then women are restricted from food sources at menstruation, both by not picking berries and by their husbands not hunting with poison. This is particularly problematic for women who do not work at all during menstruation. These women must depend entirely on someone else to bring them food, and the husband's taboo limits his capacity as a provisioner.

Menstrual restrictions on women's and men's food sources are in conflict with provisioning of children. If a woman does not pick berries or even work at all at menstruation, then she has neither food for herself nor for her dependents. As noted previously, Hadza children do forage a large amount of foods successfully on their own (Blurton Jones, *et al.*, 1994; Crittenden *et al.*, 2013). Still, they do not meet all of their energetic requirements, and younger children require more provisioning. The menstrual taboos, if observed, necessitate extra provisioning for mothers and their dependent children.

Consensus about taboos is a key indicator for women's attitudes and expectations about actual observance of taboos. The taboo around digging at menstruation is lacking cultural consensus. Some women reported not being allowed to dig while others reported digging. The berries taboo is much stronger, especially since it prompted some working women to refine their working status; although some said they did work, they clarified they did not pick berries. Furthermore, the women described not picking a specific type of berry, despite the question addressing fruits generally.

Although the majority of women reported not working at menses, the consensus about this taboo may be differentially affected by camp. With all camps included, there was a statistically significant difference in reports of working at menses across camps. Two camps, however, were obvious potential outliers: one in which all interviewees said they did not work and another where all interviewees said they did. Removal of the larger camp from the sample then revealed that camp was not significantly associated with women's answers. Nevertheless, the fact that these two camps were strictly divided keeps the question open as to how camp composition may influence reports of working taboos or working expectations among women. Indeed, as discussed in Section 5.11.9, there still remains the broader question of what women actually do at menses compared to what they say they do.

5.10.4 Women's Providers

Prior to the provisioning set of questions being asked, women spontaneously mentioned provisioning in their other answers. Provisioning by husbands, children and neighbours was spontaneously referenced in assessments of work difficulties for digging and picking. In particular, the assessment of pregnancy as most difficult included provisioning

comments. The women used conditional language, emphasising the type of provisioning needed or expected, e.g. "if you are pregnant", "if the pregnancy is very grown" or "if you are growing older". Provisioning was also spontaneously mentioned in the menstruation set of questions, e.g. one Hadza woman explaining that her mother will pick and bring fruits.

Such spontaneous mentions help elucidate at least part of the Hadza women's thought processes. For instance, a woman is asked which reproductive state is most difficult to dig, and she answers by including reference to neighbours sharing food. This line of thinking is firstly, the assessment of which state is most difficult (e.g. pregnancy) and secondly, how this difficulty is countered with help from other Hadza. The response is immediately contextualised in relation to food provisioning by others. These descriptions once again underline the importance of sharing for the Hadza.

According to the women, when they stay at home, their husbands and mothers are the most important provisioners of food. Interestingly, the pattern of ranking these two providers differed. Women who named mothers only did so in the first position or not at all. Husbands have a more flexible position, being named in all three. This trend suggests that while mothers and husbands are both primary provisioners of food, husbands have an additional advantage as back-up or alternative sources.

The type of provider named was not significantly associated with the women's reproductive status or whether or not she claimed to work during menstruation. For the small sample sizes of pregnant and post-menopausal women, the distributions of husband and mother as choices were in line with the overall distribution for all women. The lack of differences further suggests the universality of mothers and husbands as preferential choices for provisioners.

Only two women named themselves without naming any other provider. All other women named at least one provider type. There is a recognition that others, even those unrelated, can feed you, if you cannot feed yourself. At the same time, however, the number of providers listed was not very high and women were quick to resort to themselves. This may demonstrate the importance of autonomy and independence. Some of the comments were particularly indicative of the autonomous approach to decision-making (e.g. "I will sleep without eating").

The low number of provisioners listed is partially explained both by how the women answered and by how the answers were categorised. The open-ended question was posed as 'who' brings you food. Besides the nine individually named providers, the remaining providers were listed as general familial designations or other categories. For instance, with the answer of 'neighbours', the women referred to a general, larger group

of people. If they had individually listed out which neighbours, then the number of provisioners could have grown substantially. Similarly, with an answer like 'children', the women with a higher parity might have listed several more provisioners, if naming each child helper.

Given the women's generalised answers, the provider count is not as reflective of the total providers listed as much as the total *provider types*. In fact, the distribution of the seven general categories encompasses a wide range (maybe even the full range, for some women) of the types of people available as helpers. Still, this spread of answers was found across women, rather than within woman. The average woman only named around two provider types. The low count per woman further highlights the significance of mothers and husbands as consistently chosen answers. In other words, despite the array of provider types listed, women had a clear preference for around two provider types, the majority of which were husbands and mothers.

The number of providers listed did increase significantly, however, for women who said they do not work at menstruation. If women are not working during menses (as they claim), then they do need a mechanism for receiving food during menses. Otherwise, not working during menses would be unsustainable. That these women list more providers suggests the potential availability of helpers they have at their disposal. There may also be an element of self-selection; those women who can afford to stay at home during menses are already those women who are able to use provisioners.

5.10.5 Grandmothers as Providers

One interesting consideration is the extent to which women named grandmothers as providers. If the category of *Bibi* is strictly considered, then only three were listed. (However, as noted previously, this category is not directly equivalent to grandmothers, since women may have had older, unrelated women in mind.) An additional measure for grandmothers is the number of mothers named who are actually grandmothers. Mothers of all women who named their mother as a provider were crosschecked in the Hadza census file. All but one of the mothers are grandmothers[38]. Although the singular exception was not yet a grandmother, she had a pregnant daughter at the time of interview.

An additional consideration is how many of the so-called mothers are post-menopausal grandmothers. Of the mothers listed as providers ($n = 10$), 60% are post-menopausal (all

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[38] That most adult women had a living mother is consistent with Blurton Jones' (2016, p. 363) finding that about 70% of Hadza women in their first 10 years of childbearing have a living mother.

six women above the age of 60, with one confirming from interview data as post-menopausal). The other 40% of mothers are pre-menopausal grandmothers (two confirmed from interview data and the remainder below age 41). These data raise two key issues for grandmother hypothesis debates: the role of pre-menopausal grandmothers and the direct provisioning of adult offspring.

Some studies have used grandmotherly behaviour as a proxy for post-menopausal status (e.g. Hawkes *et al.*, 1997). However, not all grandmothers are post-menopausal. Indeed, on average, a Hadza woman will become a grandmother by around the age of 38 [given age at first birth at approximately 18.95 (Blurton Jones, 2016)], whereas menopause will occur around five years later (see Chapter 4). Anecdotally there are differences between younger and older grandmothers (e.g. Hill & Hurtado, 1996), but no systematic study directly compares the provisioning from pre-menopausal foraging grandmothers and post-menopausal grandmothers. Grandmothers may provision differentially or equally before and after the menopausal transition. If a grandmother provisions equally as a pre-menopausal and a post-menopausal woman (i.e. she continues her same behaviours regardless of menopausal status), then the question of why menopause occurs so early relative to total lifespan remains[39].

This line of questioning may be extended to the increasing ages of post-menopausal women. How do grandmotherly behaviours shift over time, even in post-menopausal women? The grandmother hypothesis seeks to explain the duration of the post-menopausal lifespan, yet it is unclear to what extent current evidence supports the *entire* span. There is no study that systematically checks for differential effects of grandmothers across age groups. Furthermore, there appears to be a bias toward looking at younger post-menopausal grandmothers, a type of data collection bias noted previously.

Besides the need to consider grandmothers' differential behaviours by menopausal status and by age, there is also the need to consider her differential behaviours by offspring and grandoffspring. The primary focus of grandmother provisioning studies tends to be grandchildren (e.g. Sear *et al.*, 2000). Although most studies have focused on grandmother effects in grandchildren, there are some studies which examine the grandmother's effect on the mothers of the grandchildren. For example, maternal grandmothers in rural Ethiopia were found to assist their daughters with heavy domestic workloads

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[39] It is important to note that the current formulation of the grandmother hypothesis focuses on explaining the lifespan after menopause, rather than the specific timing of menopause. Many explanations have been proposed for explaining the emergence of menopausal timing itself (see reviews, for examples, in Peccei, 2001, Mace, 2013 and Croft *et al.*, 2017).

(Gibson & Mace, 2005). In the Aka, grandmothers were associated with significant reductions in maternal energy expenditure (Meehan *et al.*, 2013). Neither study, however, directly examined grandmother provisioning.

The current finding that adult women named their mothers as provisioners raises the importance of direct provisioning of adult offspring, including those without children. Two of the Hadza women who listed their mothers as provisioners do not yet have children. Yet both of their mothers are post-menopausal grandmothers with grandoffspring from other adult children. Direct provisioning to one's children induces a stronger fitness benefit than provisioning less closely related grandchildren (a coefficient of relatedness of 0.5 compared to 0.25).

These findings highlight the broader question of how grandmothers provision across the spread of offspring and grandoffspring. There have been interesting studies on the treatment of male versus female grandoffspring as well as paternal versus maternal grandmothers (e.g. Fox *et al.*, 2009; Sheppard & Sear, 2016). Anecdotally, Hill and Hurtado (1996) suggest that more care is given to younger daughters:

> "After a woman's youngest child is independent, the mother spends most of her time visiting her grown offspring and helping them in whatever way possible. It is our impression based on a very small sample that the women spend considerably more time living with their youngest children than they do with older ones" (p. 235).

Blurton Jones *et al.* (2005) document that grandmothers are more likely to live with their daughters than sons, more likely with their nursing daughters that non-nursing daughters and less with their daughters with teenage children. Blurton Jones (2016, p. 373) also found that grandmothers have a significant influence on younger daughters, below 25 years old. The presumption for these data is that the more time grandmothers spend in a daughter's camp, the more opportunity for care and provisioning.

There remains a lack of studies which differentiate actual provisioning of offspring and grandoffspring across the ages of foraging grandmothers. One noteworthy exception is the study of Hooper *et al.* (2015). Analysing data from the Tsimane forager-horticulturalists, they distinguished between net transfers from mothers to children and from grandparents to grandchildren. Individual-level data allowed the researchers to distinguish effects across age and sex. They found that grandparents give significant net transfers to their grandchildren and that parents give significant net transfers to their daughters, up into their mid-20s. This study is discussed in further context in Section 5.11.9.

5.10.6 Observed Workload for Pregnancy

The lack of differences in workload measures for pregnant women is surprising, given that pregnancy is energetically costly and that women reported the greatest difficulties in workload at pregnancy. These results suggest that energy compensation for pregnant women is not explained through the out of camp behaviours identified. Two other possible behavioural routes for energetic compensation are differences inside of camp and/or frequency of foraging outside of camp. For behaviours inside of camp, women may be compensating in other ways like more eating or resting.

An alternative route is that women do not change their behaviours during forays but they do change the frequency of their forays. For the Efe women of the Ituri Forest, for instance, Peacock (1991) observed that pregnant women carried their heavy loads less frequently. She describes the observed behaviours in pregnant Efe:

> "It is interesting that pregnant women did not seem less *capable* of carrying heavy loads: when they did carry loads, the weights were not significantly different than that carried by cycling women. They did, however, reduce the number of occasions on which loads were carried" (p. 351; original emphasis).

Reduction in the frequency of foraging may help compensate for extra energetic costs. In this way, pregnant women may rest more and forage less overall, despite no shift in actual foraging behaviours when they do decide to leave camp.

From testing the representation of pregnant women digging tubers, there does not appear to be a significantly reduced frequency in pregnant women on tuber trips. This is in contrast to a possible reduction in frequency as well as women's reports of digging tubers as most difficult at pregnancy. However, the sample is extremely limited, with only 8 follow days of pregnant women.

The problem of small sample sizes is further compounded by the limitation of women in *late* pregnancy. Indeed, the women from the interview dataset were quick to clarify that difficulties occurred when pregnancy was 'late' or 'very big' or 'grown'. Additional comments from women were also suggestive of reductions in frequency of workload, particularly at later pregnancy. For instance, one woman said "if I become pregnant and it grows to this [referring to very pregnant], then I stay at home" (T89). A pregnant women in her third trimester said, "I am not working very much, a little" (T90).

However, the sample size of women in their third trimester (estimated with reference to the child's date of birth) is only six person/days for two women. This is an extremely limited sample size which restricts an investigation into how late pregnancy may alter eating, foraging, resting or gifts. It is still possible that pregnancy does alter these behaviours but only late pregnancy demonstrates such differences.

Another shortcoming is that the point of comparison is between women, not within woman. Other studies of reproductive status in foraging women compare non-pregnant or non-nursing to other pregnant and nursing women (e.g. Hurtado & Hill, 1990). Yet, an alternative point of comparison is within woman, i.e. is the pregnant woman eating less or foraging less than she eats or forages in a non-pregnant state? Of the repeat follow women in the study sample, five women had follow days from when they were pregnant and from when they were not pregnant. The results of a preliminary analysis for kilocalories foraged per hour outside of camp within woman suggest no significant differences by pregnancy status ($n = 5$, paired t-test, $p = $ ns). These results demonstrate that either there is no difference by pregnancy, or that once again the small sample size continues to be too limiting to reveal significant differences. The issue of sample sizes is further discussed in Section 5.11.9.

5.10.7 Observed Workload for Breastfeeding

The only significant differences found for breastfeeding women were related to gift giving. Breastfeeding women were more likely to give gifts and gave more gifts (relative to duration of the foray). These findings were the opposite of the predictions set out in Section 5.9. Given that breastfeeding women have the highest energetic costs of any reproductive status, they were expected to compensate energetically by receiving more, not giving more.

As with pregnant women, breastfeeding women do not appear to compensate for energetic costs by different behaviours in eating, foraging or resting outside of camp, compared to non-breastfeeding women. Unlike with pregnant women, however, the sample size was much larger, and as such, these findings are further supportive of the lack of significant differences by breastfeeding status. The results are directly in line with women's self-reported difficulties in workload (see Section 5.11.1), in which the least amount of women reported digging and picking as difficult at breastfeeding.

Despite nursing women having the highest energetic costs, they were more likely to provision others with energy than non-breastfeeding women. This recorded behaviour, along with the finding that breastfeeding women gave more gifts generally, is very surprising. The women with the highest costs are also those most likely to give to others.

Gifts given to nursing children help explain the large number of gifts from nursing women. Of the total gifts given by nursing women, about one-third were given to the mother's infant (29.4% of 255 total gifts). Women gave gifts to their infants significantly frequently on those follow days where gifts were given ($n = 46$, 82.6% of follow days,

one-sample proportions test with continuity correction, p < .0001, 95% CI [0.68, 0.92]). Figure 5.1 illustrates a woman giving a small gift of a tuber to her child.

Figure 5.1 Nursing Hadza Mother Transferring a Tuber to her Child. Photograph: Fitzpatrick, 2015.

Adult foods, like the tuber displayed above, may be given to infants at an early age. Endicott and Endicott (2008, p. 115) report this same phenomenon in the Batek. They describe gifts given to infants, like a piece of meat given to a baby that is not yet able to chew it. Woodburn (1959) describes how in the Hadza, the mother will soften the meat by chewing it before the child eats it. Documenting the supplementation of the Hadza infant's diet, Woodburn (1959) discusses how fat is introduced within a few days of the child's birth. Baobab (either as the pulp mixed with water or as pounded seeds with water) is also used to supplement the mother's milk from a very early stage. By age 18 months (or earlier), the baby will be consuming tubers, berries and meat (Woodburn, 1959).

The supplementation of nurslings outside of camp is an undocumented form of food production by nursing women. Interestingly, Hames (1992) argues that estimates of food production from a breastfeeding woman should actually include the milk she produces daily. He argues that by adding the value of breast milk, it is possible that differences

between nursing and non-nursing women in terms of food production may be erased. Of course, this depends on how 'food production' is qualified. Many studies are concerned with amount 'foraged' and breast milk, in these instances, would not be considered a foraged food stuff. However, for studies concerned with overall caloric contribution, breast milk is indeed a caloric contribution from the mother.

Hames' approach necessitates a longer term approach to foraging energetics not easily captured by a daily approach based on actual food stuffs. However, his recognition of an overlooked form of food production by nursing women is directly applicable to the current findings. Inclusion of the food production in the form of gifts from nursing mothers, particularly to their nurslings, may be another route by which differences in nursing and non-nursing women are discounted.

That breastfeeding women gave more gifts may help explain why Marlowe (2003) found a significant difference in foraging for breastfeeding women and this study did not. Marlowe's (2003) study defined foraging as the amount of food brought back to camp. As such, his calculation of total foraged did not include the amount of kilocalories the woman consumed and the amount of kilocalories the woman gave away as gifts. The results of this study suggest that nursing women do not demonstrate a statistically significant difference in total amount foraged compared to non-nursing women.

Sample sizes may also help explain the different result from Marlowe's (2003) study. In his t-test comparison, Marlowe reports a total sample size of 37 which includes both the nursing and non-nursing women. It is unclear exactly how many nursing women were tested; he reports 17 women with children under 3 years old and 6 women with children under 1 year old. If all women were nursing, then Marlowe's sample would have been 23 women, or 23 person/days of food returns. In this study, data were analysed from 29 nursing women across 76 person/days.

As with pregnancy, a within-woman comparison is an important consideration for investigating the effect of nursing status. For nursing women, there is firstly the comparison of how a woman forages while nursing and while not nursing. Preliminary analyses suggest that women do not forage significantly differently per hour when they are nursing ($n = 5$, paired t-test, p = ns). Once again, however, the sample size is limited to only a handful of women. Furthermore, only two of these women are compared to their non-nursing selves, the remainder are compared to their pregnant selves.

Another within-woman comparison is how nursing women forage differently when an infant accompanies them on the foray. In the foray sample, nursing women brought their nursling with them on a significant majority of follow days ($n = 76$ follow days, 68.4%, one-sample proportions test with continuity correction, $p < .005$, 95% CI [0.57, 0.78]). The

sample size was too restrictive to test within-woman differences, as only three women had repeat follows in which they did and did not bring their infants. A follow-up analysis of between women, however, revealed a significant difference. Nursing women foraged significantly less per hour when they brought their infants with them ($n = 41$, linear mixed model, $p < .025$, $R^2 = 0.19$). The presence of an infant had a moderate effect on foraging ($d = 0.55$); the median foraged per hour for nursing women without their infants was 1,012 kilocalories compared to 695 kilocalories for nursing women with their infants. This finding suggests that although nursing women do not forage differently as a group, they do forage significantly differently relative to whether or not an infant is present.

5.10.8 Observed Workload for Post-Menopause

Four of the hypotheses for post-menopausal women were supported by the data: that post-menopausal women eat less relatively to amount foraged, rest less, receive fewer gifts and forage more. The first three mechanisms support the overall finding that post-menopausal women foraged significantly more than pre-menopausal women.

Relative to their total foraged, post-menopausal women ate less than pre-menopausal women. These results are congruent with Hawkes *et al*.'s (1989) finding that post-reproductive women spent significantly less time eating than reproductive women. Whereas Hawkes *et al*. (1989) relied on observation hours, these results are based on kilocalories consumed relative to kilocalories foraged.

Increased resting time by age and post-menopausal status is also consistent with previous findings in the Hadza (Hawkes *et al*., 1989, 1997). Hawkes *et al*. (1989) documented post-reproductive women spending more time foraging. (Though the difference was not significant for the wet season.) Increased foraging time was observed for increasing ages as well (Hawkes *et al*., 1997). Hawkes *et al*. (1997) included resting in their calculation of total food acquisition. More foraging time, in combination with less rest, is further support that post-menopausal women forage more.

Eating less and resting less are both mechanisms which help explain how post-menopausal women forage more. That post-menopausal women are also less likely to receive gifts suggests that they rely more on their own efforts than supplementation from others. Since gifts received were subtracted from the total foraged calculation (see Equation 1), these results demonstrate that post-menopausal women physically forage more kilocalories than reproductive women.

The phenomenon of receiving less gifts by menopausal status may be directly linked to men as gift givers. In Chapter 3, men were found to be the gift givers for 28% of all gifts received by women (the majority of which were honey). If this form of gift giving is a

type of strategy for costly signalling, for example, then men would be expected to target women of reproductive age. Preliminary analyses demonstrate that of the gifts men gave, only 5% ($n = 6$) were given to women above age 43 (including two from husbands, one from a brother-in-law and three from married men). Men's gift giving out of camp appears to be almost entirely biased toward reproductive-aged women.

Compared to analyses of pregnant and breastfeeding women, an analysis of within-woman differences for post-menopausal samples is more difficult. To examine how a woman changes her foraging behaviours from pre- to post-menopausal requires a larger time frame (especially for clearly demarcating that menstruation has ceased). To assess whether a woman has ceased requires information from the woman herself. This study used the age of 43 as a marker for post-menopausal women generally, but it is still possible that individual women had menopause above or below this age. For this reason, it is not possible to conduct a preliminary analysis of comparing within-woman, as that would include a level of specificity that is not available from the data.

Nevertheless, the between-women analyses have important ramifications for understanding how post-menopausal forage differently outside of camp. These out of camp data from post-menopausal women contribute to debates on the grandmother hypothesis and the sexual division of labour. The following section discusses the significant findings with respect to the grandmother hypothesis.

5.10.9 The Grandmother Hypothesis

Data on the differences between pre- and post-menopausal women's foraging are vital to discussions on the grandmother hypothesis (see Section 5.1 and Section 5.10.5). To date, evidence from Hadza grandmothers has been supportive of the grandmother hypothesis. This evidence is largely circumstantial: based on the foraging time of grandmothers (Hawkes *et al.*, 1989, 1997) and on the presence or absence of grandmothers (Blurton Jones, 2016). In Blurton Jones' (2016) most recent tests, he finds that the presence of grandmothers is significantly associated with grandchildren's weight and survival, with the greatest effects for children at two and three years old (p. 373). Grandmother status is assigned by presence of grandchildren, so there is not a distinction between pre-menopausal and post-menopausal grandmothers.

There is still ongoing investigation into the mechanisms by which grandmothers induce fitness benefits. The present findings further contribute to the circumstantial evidence base that post-menopausal women are both capable of significant provisioning and forage significantly more than pre-menopausal women. The findings demonstrate that post-menopausal women not only forage more overall, but also eat less relative to their

total foraged. The mechanisms by which they forage more include resting less and eating relatively less while out of camp.

The mechanisms by which these foraging behaviours translate to fitness benefits remain to be investigated. Blurton Jones (2016) found that the two most responsive targets for Hadza population growth are children under five years old and young women's fertility. He did not find a significant effect of grandmother presence on women's fertility. However, when he restricted the analysis to women's successful interbirth intervals, Blurton Jones (2016) found that women with a living mother had significantly shorter median and mean interval lengths.

The present findings raise an additional potential mechanism for grandmotherly care: continued food transfers to direct offspring. These food transfers may directly support the grandmother's offspring and indirectly support her grandoffspring (either by the maintenance of the mother's health or by subsequent food transfers from mother to grandoffspring). Again, however, adult women name mothers as providers; direct observation would be required to confirm if they actually are providers.

Direct observation of food transfers is critical, considering the results of Hill and Hurtado (2009). Hurtado *et al*. (1992) originally found that postreproductive Hiwi women foraged more kilocalories per day during the root season and hypothesized that grandmothers buffer against the effects of carbohydrate stress. When Hill and Hurtado (2009) examined provisioning of families in the Ache and Hiwi, however, they concluded that postreproductive Hiwi and Ache "contributed very little to meeting the food deficits of high-dependency families" (p. 3868).

Still, there are limitations with the study of Hill and Hurtado (2009). They did not observe the food transfers; instead, they estimated food deficits via estimated consumption and estimated production. They also did not observe food consumption. The researchers used body size (height and weight measures) to calculate consumption. Additionally, the Ache data combined pre-contact family compositions with post-contact food production.

Hill and Hurtado (2009) concluded that postreproductive women contributed little because of their low proportion in the population and because younger men produced more[40]. Despite the study's limitations, these are important findings in that they seek to elucidate the *magnitude* of the grandmother effect. That is, even if postreproductive women were observed to forage more than other women (as in the Hiwi), their total

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[40] Hill and Hurtado (2009) also cited additional reasons for Hiwi postreproductive women contributing less: being married to less productive husbands and being very old (though the full age range is not noted).

numbers and their productivity compared to men help determine the magnitude of their contributions.

The aforementioned study of Hooper *et al.* (2015) also studied the magnitude of the grandmother effects, by directly examining the direction and volume of food transfers. Unlike Hill and Hurtado (2009) who focused on need through food deficits, Hooper *et al.* considered the interactive effect of need plus relatedness. They found that grandmothers contributed significant net transfers to their grandchildren during their 40s and 50s. During those same ages, grandmothers are also giving positive net transfers to their direct offspring. On average, the grandmothers provided an additional mean of 117 kilocalories per day to grandchildren.

However, the Hooper *et al.* study also had limitations in the way that food consumption and sharing were measured. The researchers did not observe actual consumption nor sharing; they collected interview data around two times per week from Tsimane households. These interview data were collected from representative 'adult heads' of households or other older family members. Their data, therefore, are liable to bias since second-hand reports were used for detailing what was eaten and what was shared.

Comparisons to Hadza data may be less straightforward due to observed differences in the Ache, Hiwi and Tsimane. For example, the Ache women forage for fewer hours and the male contribution to the diet is higher and the Tsimane participate in horticultural food production. Nevertheless, these two studies highlight the necessity of investigating actual food transfers from postreproductive Hadza. Even if grandmothers forage more, the magnitude of the effect depends on how this extra foraging translates to actual food transfers to offspring and grandoffspring. The magnitude also depends on how much of their own foods that grandmothers consume inside camp, since they ate relatively less outside of camp.

5.10.10 Division of Labour & Reproductive Constraints

The observed workload for post-menopausal women is the only workload to conform to the hypotheses set out in Section 5.9. Besides the circumstantial support for the grandmother hypothesis mentioned previously, this observed workload may also represent circumstantial evidence of reproductive constraints around foraging efficiency. Age alone cannot account for increased foraging efficiency, since increasing experience does not increase digging efficiency (Blurton Jones & Marlowe, 2002) and strength of Hadza women peaks around age 25 (Marlowe, 2010). Nor can individual work ethic account for the difference, since the group of post-menopausal women is treated as a whole.

One possible explanation for the difference is the lack of energetic costs from pregnancy, lactation and menstruation that reproductive-aged women face. Though post-menopausal women may still be encumbered by young and adult offspring, they are unencumbered by the direct physiological costs of child-bearing. An important follow-up to Pontzer *et al*.'s (2012) study of TEE in the Hadza would be to consider the TEE of post-menopausal women as they forage.

The findings for post-menopausal women are particularly important in light of the lack of findings for almost all other variables. Of all potential variables associated with foraging in this study, only time and post-reproductive status were significantly associated with foraging. Thereby, of all the potential interindividual differences between women identified, only the post-reproductive status accounted for a significant difference.

The higher productivity of post-reproductive Hadza women appears to be a consistent trait, given the results of this sample size over three years and the results of Hawkes *et al*. (1989) from years prior. The consistency of this trait suggests that between-women differences are an important feature of the Hadza's sexual division of labour. Although differences were not found for pregnant women, there were differences found between nursing women who brought their infants foraging and those who did not.

The higher productivity of nursing women foraging without their infants and the higher productivity of post-menopausal women support that reproductive constraints contribute to between-women differences. Since no between-women differences were found for pregnant women, then this may support that either constraints are not operating or that constraints are compensated for by other measures (e.g. eating more in camp or foraging less frequently). These data suggest that, at least for those follow days where pregnant were observed to forage, they did not forage significantly differently from other women.

5.10.11   Summary Points

- Compared to other reproductive stages, late pregnancy is perceived as the most difficult time for digging tubers and picking berries. Hadza women stress the challenges associated with physical constraints, dizziness and fatigue. The stages of breastfeeding and post-menopause are not generally perceived as difficult periods for digging and picking.

- The majority of Hadza women report not working during menstruation. Reasons for not working include the blood loss associated with walking and Hadza taboos. Cultural taboos restrict the foods that women and men are permitted to forage when a wife is menstruating. A woman's menstrual pain does not appear to affect her decision to work. The availability of provisioners, on the other hand, may affect this

decision; women who do not work at menses report a higher number of provisioners than women who do work.

- Hadza women describe a range of provisioners who bring food to them when they stay at home. Of all the provider types, husbands and mothers are the most highly ranked provisioners. When talking about the difficulties of late pregnancy, Hadza women also describe the help and food provided by others.

- Despite the women's emphasis on the difficulties of late pregnancy as well as the extra energetic costs, pregnancy was not associated with any significant changes in women's foraging behaviours. These data do not support that pregnancy status is associated with changes in a woman's eating, sharing, resting or foraging while she is outside of camp. However, the pregnancy data are also the most limited in terms of sample size (especially with regards to women in late pregnancy).

- Unlike the pregnancy data, the breastfeeding data support an association between reproductive status and changes in women's foraging outside of camp. Nursing status is associated with changes in sharing behaviour. Food supplementation to nurslings helps explain nursing women's greater likelihood of giving and higher number of gifts given. Nursing women also forage more kilocalories per hour when they do not bring their nurslings on a foray.

- The post-menopausal data offer the strongest support for an association between reproductive status and changes in foraging behavior. Post-menopausal women eat less relative to what they forage, rest less and forage more kilocalories overall compared to pre-menopausal women. The association between post-menopause and total kilocalories foraged is particularly significant. No other variable, except for time, is significantly associated with women's total foraged kilocalories outside of camp. This association underscores the importance of considering reproductive status in the context of women's foraging behaviours.

5.10.12   Future Directions

A limitation of the menstruation and provisioning questions is the lack of observational data. How often do menstruating women actually stay at home? If women stay at home, then who is actually observed to bring them food? As documented by other researchers, there is the potential discrepancy between described and observed behaviours, especially with reported taboos (e.g. Aunger, 1992). Nevertheless, obtaining such observational data would require time and vigilance: the fieldworker would need to observe a

woman who stayed at home, either due to menses or other reasons. Such observations would not be random, but dependent on those women who decided to stay home. Furthermore, the fieldworker may encounter cultural sensitivities, as the woman who stays at home may not want to draw attention to herself (particularly from males).

It is unclear how widespread the phenomenon of not working at menses is for the Hadza. The majority of women reported not working, and all women, even the working respondents, said they knew other women who stay at home at menses. Still, documenting the actual span of the phenomenon requires recorded observations for work of menstruating women. An alternative measure is approximating women's adherence to menstrual taboos by using monthly scan data from inside of camp. The frequency of appearance of women in camp who report working at menses compared to those who report not working may be compared. One limitation for this proxy measure is the difficulty in accounting for other reasons of staying in camp, like babysitting, illness or injury.

A broader question is how widespread this phenomenon may be across foraging populations. Given the dearth of menstrual data on foraging women generally (see Chapter 4), it is unsurprising that there are no systematic studies of women's foraging behaviours at menses. These results suggest the importance of gathering such data about menstruation. To understand how or why foraging women make certain decisions, it is important to consider the ways in which menstruation may impact their choices.

In addition to testing the frequency of forays for menstruating women, future studies should investigate the frequency of forays for pregnant women. Hadza women described their workloads as most difficult in late pregnancy. Testing this description has proved problematic due to small sample sizes. Previous Hadza studies also demonstrate limited sample sizes for pregnant women (e.g. Pontzer *et al.*, 2012). Studies of other foraging populations also face this limitation. For example, Hurtado *et al.* (1992, p. 193) describe the exclusion of pregnant women in their comparison of food acquisition rates because the sample sizes were too small in the Hiwi and Ache data.

Ideally, future studies should examine the foraging patterns of pregnant women in *late* pregnancy. To examine late pregnancy, however, is even more restrictive in sample size. This study estimated a pregnant woman's trimester by backwards calculation from the birth date of the newborn. Data from women in their third trimester comprised only six person/days for two women, a very restrictive sample. It is interesting to consider how such a restrictive sample size may actually be a manifestation of these women foraging less frequently and thereby, being observed less frequently.

Another important follow-up to this study is how Hadza men view the needs of their wives at menstruation, at pregnancy and at breastfeeding. A woman's decision to stay

at home during menses or during late pregnancy is linked to how she thinks she can or will be provisioned. Staying at home translates to a loss of kilocalories not only to herself, but also to her dependents. Do Hadza men report changes in behaviours or attitudes toward their wives if they are menstruating, nursing or pregnant? Marlowe (2003) suggested that Hadza husbands help their nursing wives by provisioning, though he did not demonstrate how much of the husbands' foods were actually given to the nursing wives. Wood and Marlowe (2013) estimate that wives consume around 18% of their husbands' food on average, but to what extent this number differs for breastfeeding wives is undocumented.

Anecdotally, forager husbands in other groups have been described with a mix of behaviours toward wives in different states. Ache men have been described as neither altering their behaviours nor their provisioning toward pregnant wives. Hill and Hurtado (1996) record the following impressions of Ache husbands:

> "They do not (as far as we could tell) change their behaviour toward their pregnant wives in any way in order to alleviate their work load, pamper them, or provide them with a special diet. In fact, a good number of men admitted abandoning a female partner during pregnancy, only to return several months after birth had taken place (or sometimes not returning at all)" (p. 275).

In contrast, Batek men are described as assisting their wives. Although not directly mentioning the reproductive states of pregnancy or breastfeeding, Endicott and Endicott (2008) do describe help more generally: "when wives were sick or wanted to rest, their husbands might dig tubers for their families" (p. 87). This behaviour may be partially explained by the larger overlap in digging activities of men and women, an overlap that is not applicable to the Hadza. Though both examples are restricted as general anecdotes, they raise the question of whether Hadza men are more like the neutral Ache husbands or the helping Batek husbands.

Ultimately, nursing women and pregnant women do not appear to reduce their energy output in behaviours outside of camp. Since they are in an energetically costly state, they must either not be reducing their output, reducing it through other physiological mechanisms (e.g. metabolism) or reducing it through in-camp behaviours. A necessary follow-up study is the examination of food consumption and resting by women inside of camp. Preferably, such an examination could include differences by reproductive status as well as any supplementation from husbands or others. Indeed, although researchers have documented the amount that men consume of their foods brought back (e.g. Wood & Marlowe, 2013), these analyses are still lacking for Hadza women. Such analyses are particularly critical for the outcome of post-menopausal women's foraged foods. This

study demonstrates that post-menopausal women have more kilocalories available to be shared, but how these kilocalories are actually shared inside of camp is unanswered.

6 Conclusion

The Hadza are an ideal population from which to consider the long-standing anthropological debates on the sexual division of labour. They are a representative population because they lie at or near the median value of warm-climate foragers for numerous traits, including their degree of sexual division (Marlowe, 2007, 2010). The Hadza are also the population which continue to spark ongoing debates on the provisioning and costly signalling models (e.g. Hawkes *et al.*, 2014; Wood & Marlowe, 2014).

This study contributes evidence to debates on the sexual division of labour by introducing new biocultural data on the Hadza women's reproductive timeline and new calorific data on the women's eating and sharing outside of camp. The thesis investigates two overlooked aspects of forager women's lives: how much they eat and share outside of camp and their lived experience of menstruation. By investigating the women's experiences from menarche to menopause, the study incorporates perspectives from the forager women themselves.

The following chapter discusses this study's implications with respect to the sexual division of labour. Answers to the central research question are presented. The chapter concludes with a discussion on broader implications for studies on reproduction and on forager diets.

6.1 Provisioning & the Sexual Division of Labour

Costly signalling and provisioning models have traditionally relied on food returns to model men's and women's relative contributions to the sexual division of labour. Foods brought back to camp are the initial starting point from which sharing is modelled. In-camp food exchanges are used to determine how men and women provision themselves and others.

Yet the results of this study demonstrate that food returns are only one part of a total continuum of sharing. Significant sharing between the sexes and within the sexes occurs outside of the central place. Hadza women regularly share and receive foods that are consumed outside of camp. They also receive a large proportion of gifts (28% of all gifts received) from Hadza men.

Women's eating and sharing outside of camp amount to over 800 kilocalories. This out of camp provisioning also involves a different makeup of food types than women consume inside of camp. For example, whereas honey is the least frequently consumed (of the five food types) by women inside of camp (Berbesque *et al.*, 2011), it is the third most consumed outside of camp. In terms of kilocalories, honey comprises the largest portion of women's out of camp eating; yet Marlowe (2010) found that honey constitutes less than 1% of total kilocalories brought back to camp by women. These markedly different results reveal that food data may tell very different stories, if out of camp foods are not taken into account.

Food transfers carry more information than kilocalories, however. They carry information about women's and men's motivations. Sharing may be explained by kin selection or reciprocal altruism. Alternatively, sharing outside of camp may be a manifestation of costly signalling. This study argues that honey transfers by men outside of camp meet the conditions of a costly signal and should be tested as such.

How much provisioning occurs outside of the central place is a vital component to the sexual division of labour. The extent to which a woman fulfils her energetic demands outside of camp has a knock-on effect for her in-camp eating and in-camp sharing. If a woman provisions others outside of camp, then a similar knock-on effect occurs for their in-camp eating and in-camp sharing.

This study demonstrates that women regularly provision themselves outside of camp. When women self-provision outside of camp, they lower their caloric needs in camp. They also have more kilocalories with which to provision their children. In fact, the children may require less kilocalories due to their own self-provisioning (e.g. Crittenden *et al.*, 2013).

Although Hadza women satisfy their entire TEE on many days outside of camp (20% of total follow days), this study supports that women are generally still in demand of kilocalories upon returning to camp. The average woman consumes 326 kilocalories outside of camp per day, roughly 18% of her total TEE. In this way, men's contributions may help fill her remaining calorific demands. Nutritionally, women are also able to satisfy their macronutrient requirements from their own foods outside of camp. Nevertheless, these requirements are more difficult to fulfil if baobab and certain berry species are not collected. When women collect only tubers, they face a substantial deficit of lipids and proteins.

Because of women's high variability in eating and sharing outside of camp, there are fluctuations in caloric and nutritional demands. As such, men's contributions to women will be more calorifically and nutritionally important on some days than on other days.

Debates on the sexual division of labour have deliberated as to how and why men provision. But these results from Hadza women suggest there is another important question: when do men provision? Men's calorific provisioning should be modelled with respect to women's calorific demands. Such modelling will test whether men provision more on days when women have higher demands for kilocalories.

The question of when men provision also applies to women's reproductive lives. If a woman's reproductive status changes her foraging behaviours, then she may be more in need of provisioning according to her status. The next section explores answers to the central research question: *how, if it all, does a woman's reproductive status change her foraging behaviour outside of camp?*

6.2 Reproductive Status & Women's Foraging Behaviours

Evidence from the observational data and the interview data support that a woman's reproductive status is linked to changes in her foraging outside of camp. This study found that there are both perceived and observed differences for women's foraging in relation to reproductive status. Hadza women perceive that foraging is most difficult during late pregnancy. They also report not working at menses. Observations of breastfeeding and post-menopausal women demonstrate significant differences in foraging behaviours. The following section summarizes these findings for Hadza women's menstruation, pregnancy, breastfeeding and post-menopause.

6.2.1 Menstruation

The majority (60%) of Hadza women report that they do not work at menstruation. They describe menstrual-related taboos for their foraging behaviours and for their husbands' foraging behaviours. Menstruation is also associated with time spent on other activities, like cleaning oneself and one's menstrual cloths as well as producing soap from baobab and medicine from the bush for menstrual pain.

These data from the Hadza indicate that menstruation may influence women's behaviours in other hunter-gatherer groups. To date, the physical and cultural experience of menstruation has been vastly overlooked in forager groups. The Hadza data reveal many routes by which menstruation may affect foraging. For example, menstrual-related activities may take time from a woman's total activity budget. Although Hadza women did not complain of menstrual pain in relation to workload, dysmenorrhea may affect other forager women's activities.

If Hadza women do not work during menses, then they are in demand of provisioning from others. Interestingly, the women who reported not working at menses named significantly more provisioners than those who said they work. Because Hadza women reported regularly menstruating, then the demand for provisioning may be a regular occurrence for those who do not work at menstruation.

6.2.2 Pregnancy

The majority of Hadza women report that digging tubers and picking berries are difficult during pregnancy. They emphasise the distinction of late pregnancy, in particular. The Hadza women also link this time period to receiving help from others, describing the provisioning of food from others like their husbands.

The observed behaviours of pregnant women, however, do not support that pregnancy status is associated with changes in foraging behaviours. No significant associations were detected for their eating, sharing, resting or foraging outside of camp. Nevertheless, the sample size of women in late pregnancy is extremely small. It is possible that a larger sample size of women in their third trimester may reveal differences in foraging patterns. Another possibility is that pregnant women may change their frequency of foraging outside of camp. The small number of sample days from pregnant women overall (n = 26), compared to the number of days for breastfeeding women (n = 76) and postmenopausal women (n = 84), lends support to this possibility.

6.2.3 Nursing

Despite the lack of findings for pregnant women, nursing status is associated with changes in foraging and gift giving. Nursing women forage less kilocalories per hour when they bring their nurslings with them outside of camp than nursing women who do not bring their nurslings. They are also more likely to give gifts and give a higher number of gifts than non-nursing women. Gifts to nurslings help explain these differences.

The nursing data are indicative of a demand for provisioning from others. The median kilocalories foraged per hour for nursing women with their nurslings was around 300 kilocalories lower than the median for nursing women without their nurslings. Depending on the length of the foray, mothers with their nurslings may have a stronger demand for provisioning when they return to camp. To be noted, however, mothers without their nurslings may be also be reliant on another form of provisioning. In order to forage without their nurslings outside of camp, they had to rely on others to care for their child.

6.2.4 Post-menopause

Post-menopausal status is associated with changes in all four of the behaviours tested: eating, resting, sharing and foraging. Post-menopausal women eat less relative to what they forage, they rest less on the forays, they are less likely to receive gifts from others and they forage more overall. Each of these observed changes is consistent with the finding that post-menopausal women forage more.

The significance of these findings is made more prominent by comparison to other variables tested. This thesis tested a wide range of reproductive and non-reproductive factors to understand the variation in women's eating, sharing and foraging outside of camp. Of all the interindividual differences between women that were tested, only a woman's post-reproductive status was related to a difference in her total foraging. The breadth of the associations found for post-menopausal women, in addition to the sweeping lack of associations for other variables, strongly suggests that post-menopausal status influences women's foraging behaviours.

Post-menopausal women appear to be the least in need of provisioning once they return to camp. Indeed, they are even positioned to be an important source of provisioning, since they have foraged more than other Hadza women. Although the findings provide circumstantial evidence in support of the grandmother hypothesis, further study is required to document how post-menopausal share their kilocalories inside of camp.

The results from post-menopausal women support Bliege Bird and Codding's (2015) argument that considerations of the sexual division of labour should include other relationships within the sexes and between the age groups. Too often models apply aggregate numbers for men's and women's relative contributions. These post-menopausal data reveal important between-women differences that would be obscured by aggregated data.

6.3 Broader Implications

6.3.1 Menstruation & Fecundity

Menstrual data from the Hadza have interesting implications for our understanding of fecundity. Menstrual patterns are used as indicators of reproductive health, endocrine and uterine function (Dasharathy *et al.*, 2012), and deviations from 'normal' ranges are suggestive of problems with fecundability, fecundity, and fertility (e.g. Jensen *et al.*, 1999). For instance, shorter menses is associated with higher risk for spontaneous abortion, lower fecundity and anovulation (Vitzthum *et al.*, 2001; Small *et al.*, 2006;

Dasharathy *et al*., 2012) and lighter bleeding is associated with anovulation (Dasharathy *et al*., 2012). Given the Hadza's menstrual characteristics then, problems with their reproductive output might be expected. Yet the Hadza still achieve successful pregnancies, maintaining a TFR of approximately 6.2 (Blurton Jones *et al*., 1992; Blurton Jones, 2016). Do their shorter (potentially lighter) menses actually result in lower fecundity?

Possibly, Hadza menstruation does conform to the relationship between fecundity and menstrual characteristics identified in 'Western' samples. The Hadza data may conform both within population and between populations. Within their population, Hadza women with shorter, lighter menses may be less fecund than other Hadza women. Additionally, between populations, Hadza might demonstrate lower fecundity than other women with longer menses and heavier bleeding. For testing either of these scenarios, however, fecundity data would be needed from the Hadza as well as comparable menstrual and fecundity data from other natural fertility populations.

An alternative possibility is that Hadza menstruation does not conform to the identified relationship in Western women. The Hadza's shorter, lighter menstruation may be achieved through a different pathway than in Western women. Shorter, lighter menstruation in Western women may be abnormal and reflect other abnormalities (e.g. hormonal-related problems) which also affect fecundity. This same pattern of menstruation in the Hadza, however, may reflect environmental constraints and adaptations. In other words, the pattern may be 'normal' to the Hadza and still achieve 'normal' fecundity because the source of variation is different environmental circumstances, rather than abnormal functioning. This is directly in line with medical anthropologists' treatment of 'normal' human reproduction as culturally or environmentally determined (McElroy & Townsend, 2014) and with the overreliance on WEIRD societies for defining normality (Henrich *et al*., 2010). For the Hadza, one possibility is that shorter, lighter menstruation has even adapted as an energy-saving mechanism. To what extent fecundity is compromised by this menstrual pattern remains to be known.

In fact, there is yet another possibility that fecundity is not affected by menstrual characteristics after all. Wise *et al*. (2011) found no significant association between fecundability and menses length or blood loss. There could be confounding variables that are controlling both menstrual outcomes and fecundity outcomes. Regardless, the pairing of 'abnormal' menstrual functioning with successful reproductive outcomes in the Hadza deserves further investigation. Indeed, the finding that two of the Hadza women never experienced menstruation, yet still had children, extends this notion to the extreme; zero days and zero blood loss yet successful reproductive output.

6.3.2 Measuring Forager Diets

Ultimately, this study has important implications for broader research on forager diets and foraging efficiency. There is a general lack of consistency across calorific calculations in foraging groups. This lack of consistency hampers comparisons not only within populations, but also between populations. The first outstanding issue is the widespread use of proxy measures. Many studies apply shortcuts for eating or acquisition data. For example, some studies total all food brought back to camp and divide by the number of people in camp (e.g. Marlowe & Berbesque, 2009). Other studies use body size as a measure of consumption [e.g. in the Ache (Hill & Hurtado, 1996) and in the Ju/'hoansi (Howell, 2010)].

Some of these proxies are problematic because they lack systematic correlations to that which they seek to measure. For example, BMI was neither significantly associated with eating nor foraging in this study. As another example, foraging time has been used as a proxy for total foraged (e.g. Hawkes *et al.*, 1997). Yet increased time is also associated with increased eating (from this study), and Hurtado *et al.* (1992) found an inverse relationship between total foraging time and total foraged. For these reasons, the use of foraging time as a proxy may directly mask the more efficient producers.

Comparable data from outside of camp would also shed light on the variability within populations. This study found that Hadza women's eating and foraging had considerable daily variability. An aggregated average for amount foraged, the number most often reported in studies, does not adequately capture such high variance. This variance underscores the total division of labour. As Hill *et al.* (1987) write, "regardless of the *motivation* of food sharing in hunting and gathering bands, one of the *effects*, in almost all cases, is that the risk of getting food on a single day is reduced" (p. 24; original emphasis). This notion of risk reduction has long-dominated discussions of the sexual division of labour (e.g. Winterhalder, 1986). Risk continues to be one of the most important facets for consideration, particularly with respect to male-targeted and female-targeted foods (e.g. Codding *et al.*, 2011) and observed sex differences in risk-seeking (Apicella *et al.*, 2017).

Another outstanding issue is the exclusion of edible mass from total kilocalorie calculations. As Crittenden and Schnorr (2017) highlight, the accessible portion, not the food's total composition, is that which determines biological value. Various foraging studies have relied on simple conversions from kilograms to kilocalories without clearly denoting calculations of edible percentages. As a result, kilocalorie estimates may be inflated. Such inflation produces a knock-on effect for subsequent comparisons. For instance, Gurven and Hill (2009) recall how laboratory errors in measuring the edibility of palm fibers in the Ache discounted earlier conclusions based on palm fiber acquisition rates.

The current study has calculated edible mass where possible in the food charts of the Appendices. Nevertheless, these calculations are still limited because actual digestibility is an unresolved factor.

Edible mass for tubers is a key calculation which calls for reconsideration of past studies' estimates in the Hadza and other foragers. Schnorr *et al.* (2015) calculated the edible mass for tubers (see Appendix B), and the low percentages of edibility for some species were particularly surprising: only 26% of *//ekwa* and only 49% of *makalita*. This means that any past calculations of these species are substantially overestimating their actual caloric value [e.g. Hawkes *et al.* (1995)]. Even if studies apply similar conversions between kilograms and kilocalories, they will report considerably different caloric estimates if edible mass is not considered. Schnorr *et al.*'s results drastically alter tuber calculations and have ramifications for other forager calculations with similar tuber species.

There is a clear need for standardisation across calorific methodologies in behavioural ecology studies of foragers. This study is the first to systematically document the amount of kilocalories eaten outside of camp for forager women. Such documentation still required proxy measures via visual estimations of food consumed on the spot. For comparisons across other forager groups, it is important to acquire comparable consumption data outside of camp – especially as forager groups continue to rely less and less on wild foods throughout the world.

7 References

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Appendix A: Food Weights
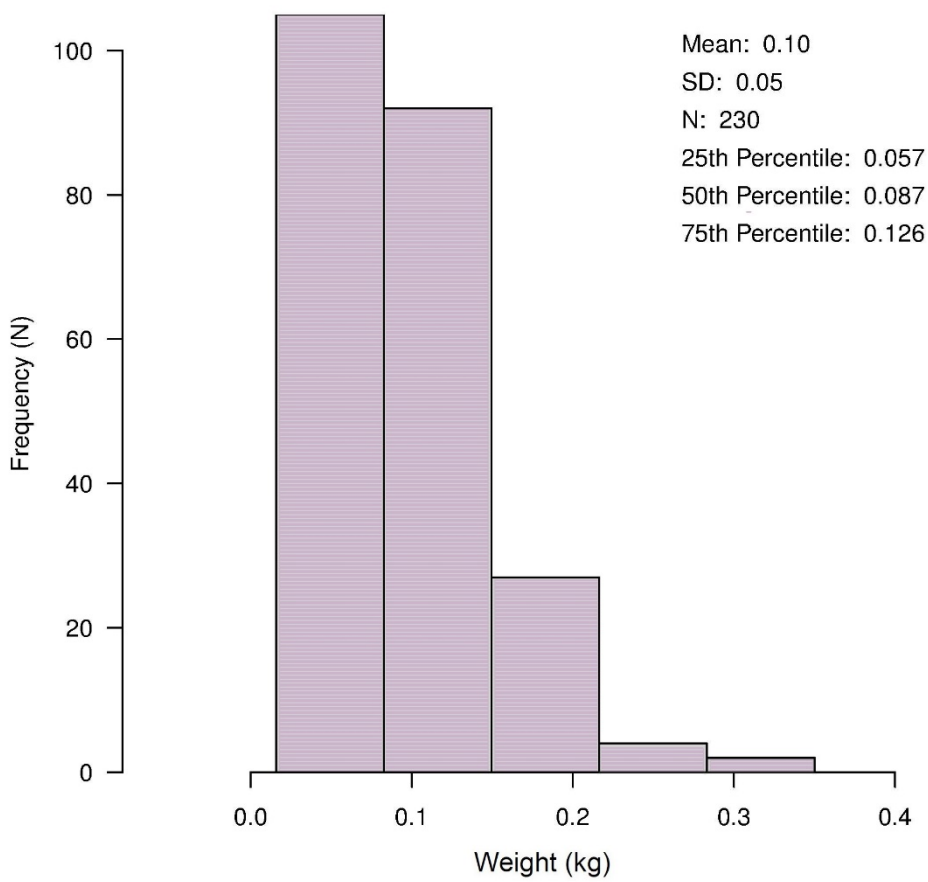
Figure A.1 Distribution of Baobab Pod Weights (*n* = 230).

Mean: 0.42
SD: 0.25
N: 436
25th Percentile: 0.253
50th Percentile: 0.377
75th Percentile: 0.552
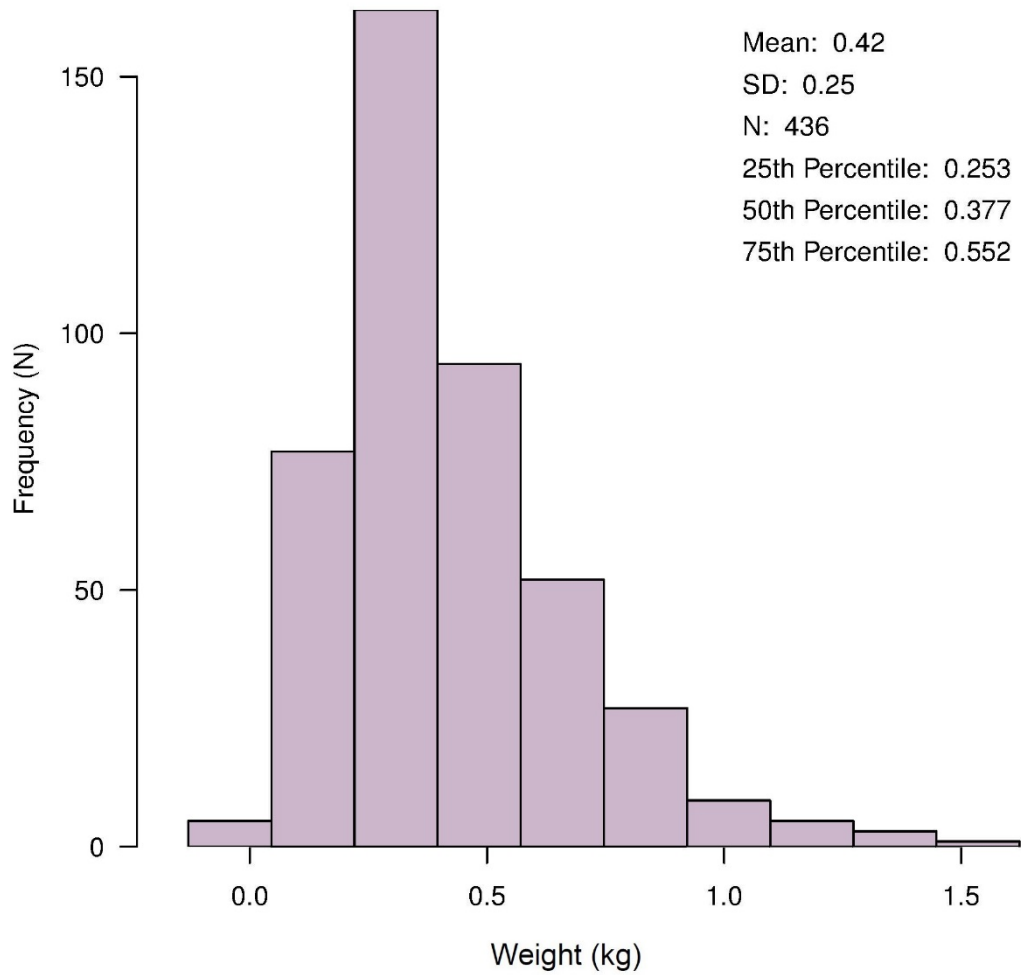
Figure A.2 Distribution of *//ekwa* Tuber Weights (*n* = 436).
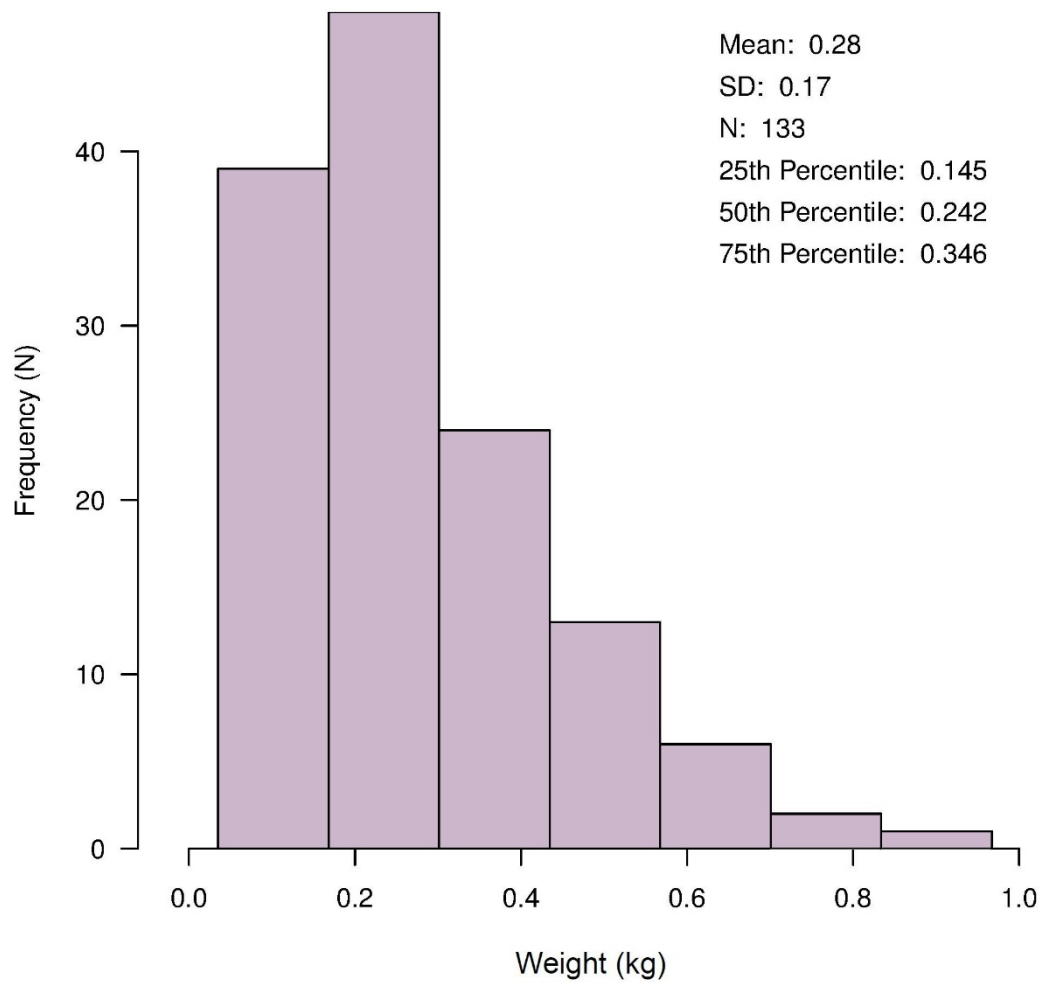
Figure A.3 Distribution of *Makalita* Tuber Weights (*n* = 133).
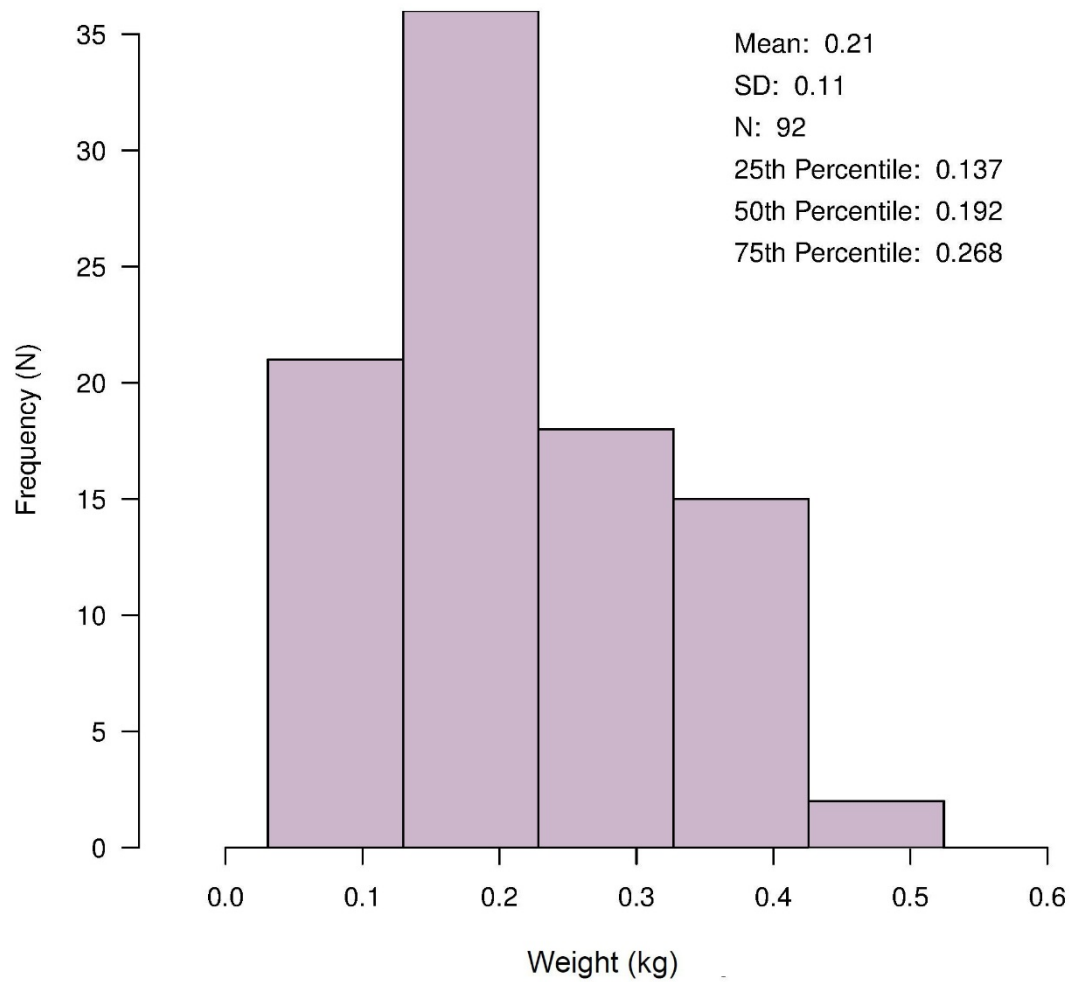
Figure A.4 Distribution of *Shakeako* Tuber Weights (*n* = 92).
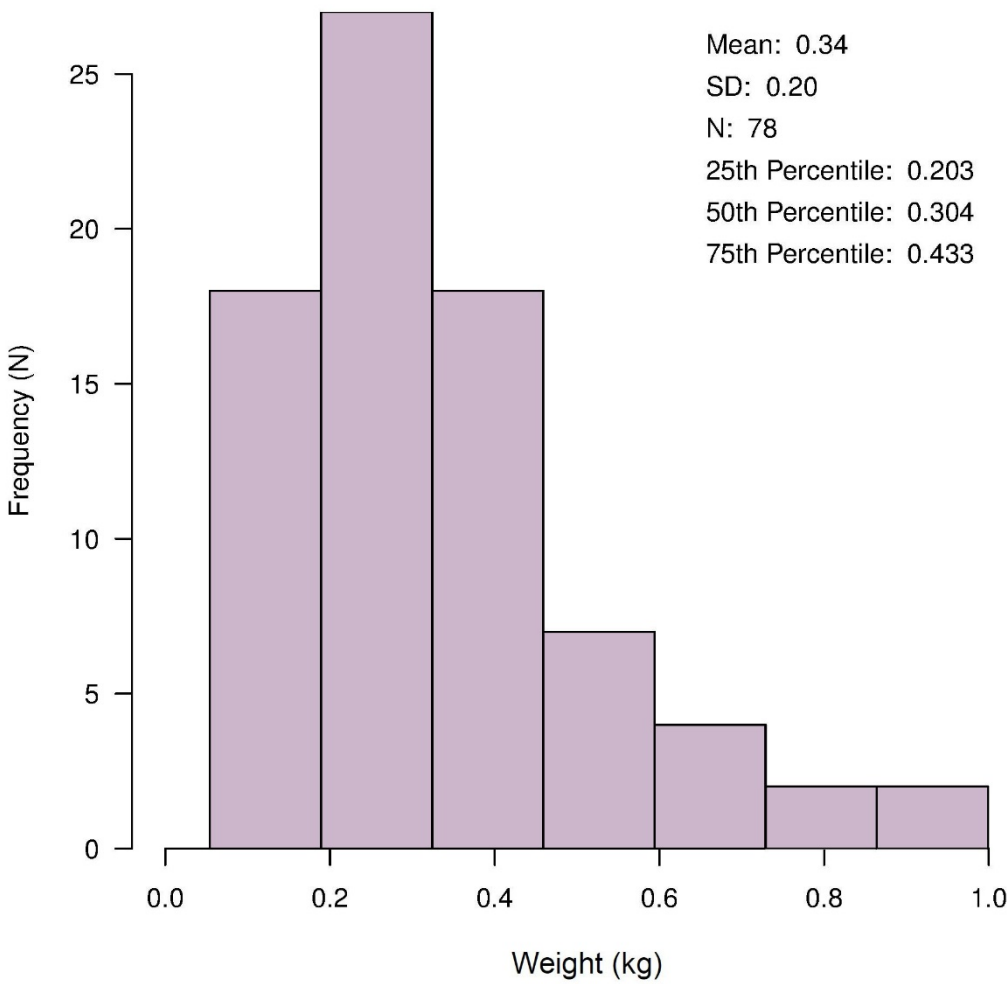
Figure A.5 Distribution of *Shumuwako* Tuber Weights (*n* = 78).

Mean: 0.17
SD: 0.03
N: 58
25th Percentile: 0.146
50th Percentile: 0.16
75th Percentile: 0.189
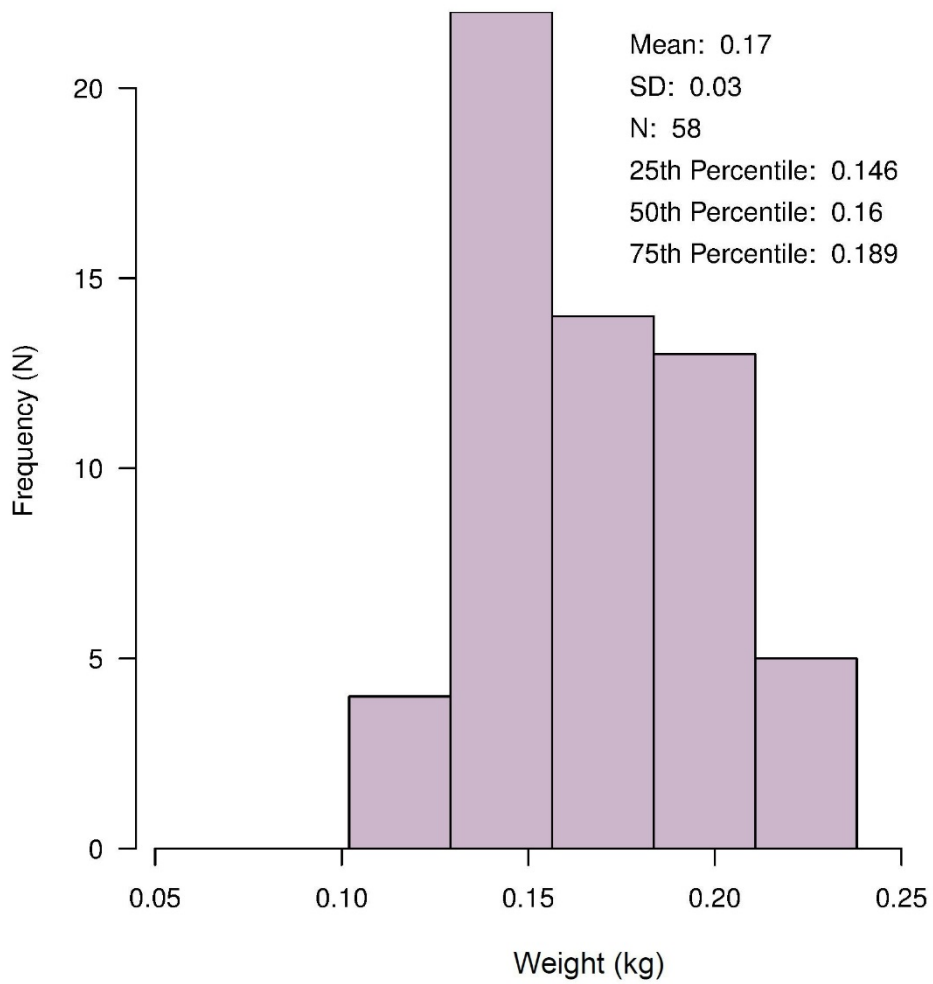
Figure A.6 Distribution of Von der Decken's Hornbill Weights (*n* = 58).
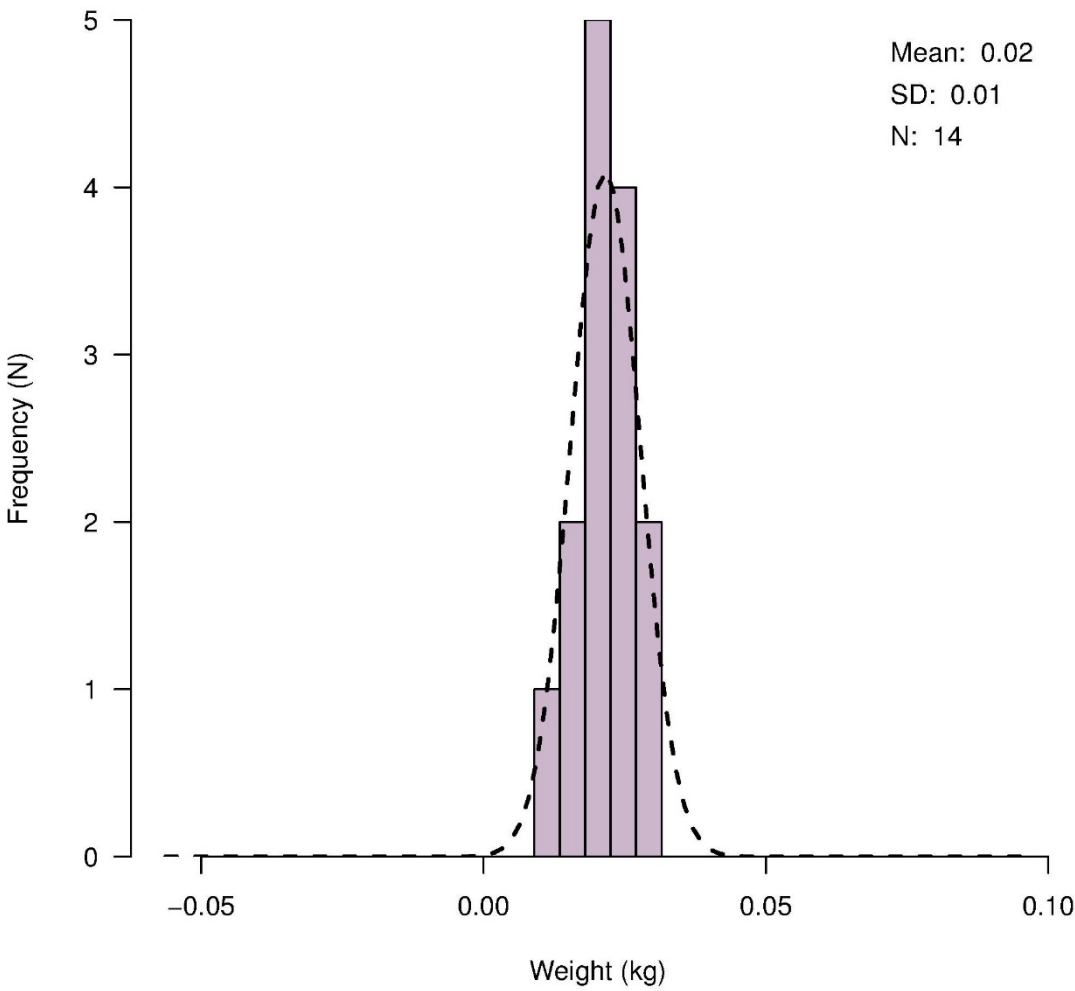
Figure A.7 Distribution of Red-billed Quelea Chick Weights (*n* = 14).
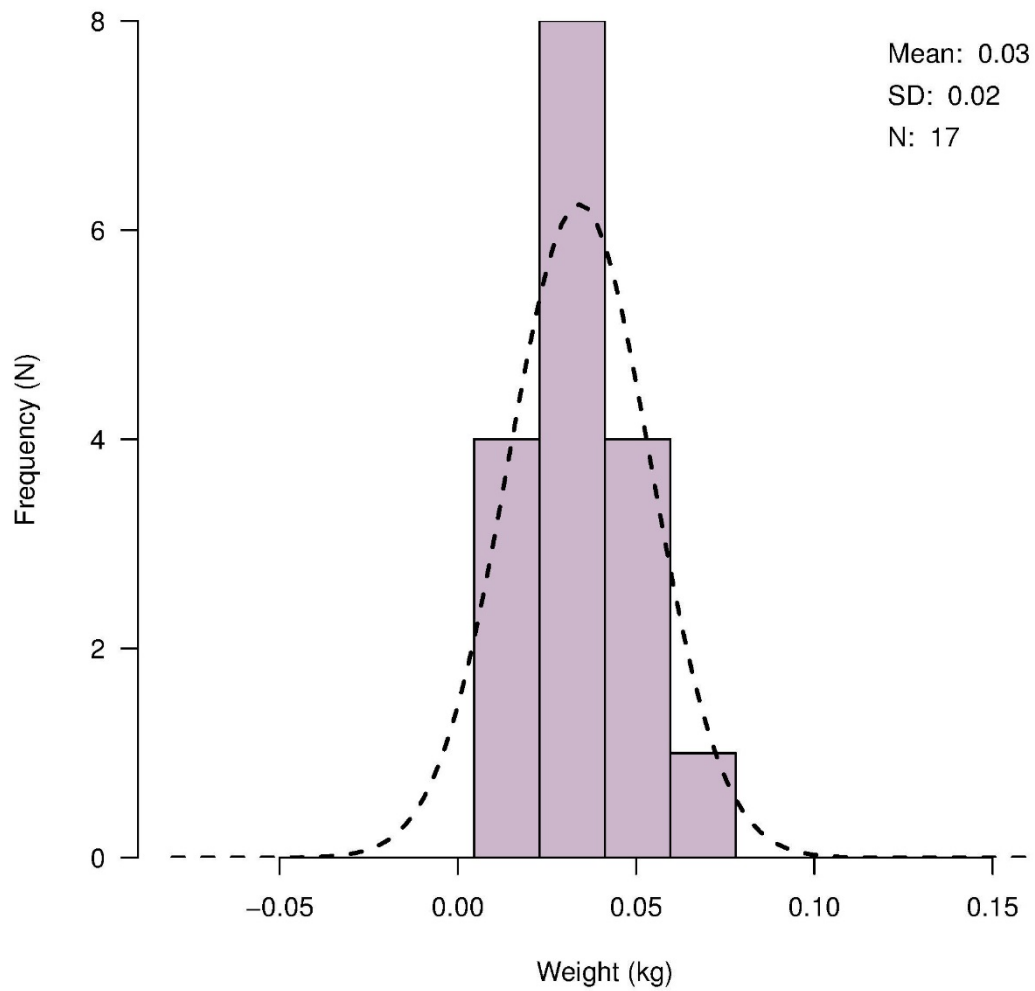
Figure A.8 Distribution of Red-billed Quelea Egg Weights (*n* = 17).
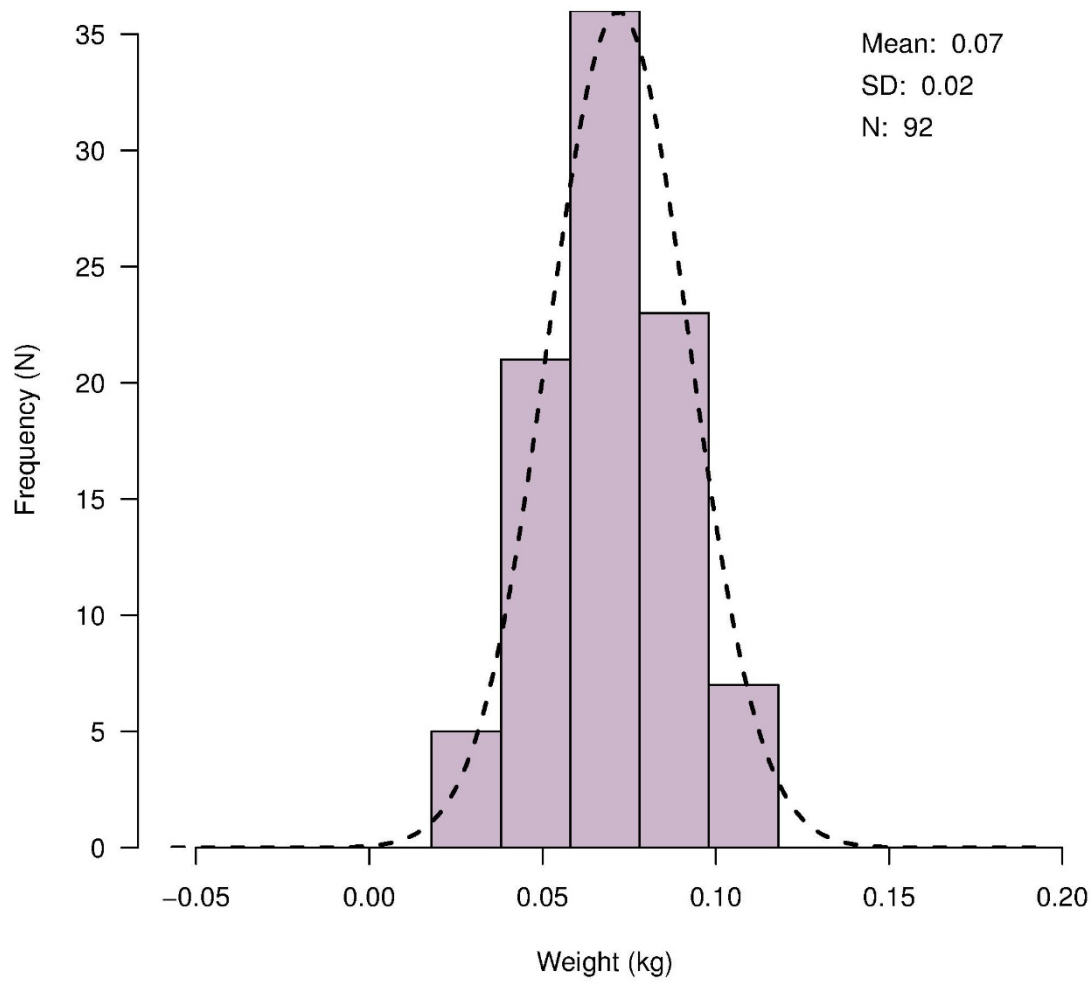
Figure A.9 Distribution of Elephant Shrew Weights (*n* = 92).

Appendix B: Physical Composition of Foods

Table B.1   **Physical Composition of Hadza Berries/Fruits**

Hadza Name *Genus species*	Diameter[†] (mm)	Total Mass (g)	Seed Count[†] (g)	Seed Mass[†] (g)	Edible Mass[‡] (g)
Chukwayabe[a] *Grewia villosa* Willd.	10	0.50	1-2	0.06	0.41
Congolobe[b] *Grewia bicolor* Juss.	6	0.32	1	0.09	0.23
Hlukwayabe[a] *Grewia villosa* Willd.	10	0.50	1-2	0.06	0.41
Kisinubi[c] *Cordia sinensis*	20	1.13	1-4	0.07	0.99
Mbilipe[d] *Grewia flavescens* Juss. *Grewia platyclada*	13.5	1.02	1-2[1]	0.07[2]	0.92
Ngwilabe[e] *Grewia similis* K. Schum.	6[3]	0.32	1	0.08	0.24
Tafabe[f] *Salvadora persica* L.	10	0.74	1	0.03[4]	0.71
Tl'atanako[g] *Grewia pachycalyx* K. Schum.	20	1.88	1[5]	0.07[2]	1.81
Undushipi[c] *Cordia sinensis*	20	1.13	1-4	0.07	0.99

†For estimates of diameter, seed count, and seed mass, the plant databases SEPASAL, PROTA4U, and JSTOR Global Plants were consulted, as well as the Tanzania-specific publications of Mbuya *et al*. (1994) and Ruffo *et al*. (2002).

‡Edible mass is used here as the mass of berry pulp digested by the Hadza. See Section 2.2.2 about the treatment of seeds.

[1] Seed count from Gebauer *et al*. (2013).

[2] Seed mass estimates not available. This estimate is derived as the mean from the other *Grewia* species in the table and *Grewia mollis*.

[3] The estimate represents the lower range of *G. similis*, based on relative comparisons to *mbilipe* and *congolobe* from photographic evidence (Berbesque & Marlowe 2009).

[4] Additional seed data used from Pritchard *et al*. (2004).

[5] With very limited data available for *G. pachycalyx*, no seed count could be determined. One seed is used as a conservative estimate.

[a] Estimate derived from volume, calculated dry density (g/mm^3) from Saleem *et al*. (2012) and Elhassan and Yagi (2010) and moisture content from Table C.1**.**

[b] Estimate derived from volume, the moisture content from Table C.1, and the calculated dry density (g/mm^3) for *Grewia mollis* (Saleem *et al*., 2012), a species matching the lower range diameter of 6 mm.

[c] Total mass estimate for *Cordia ovalis* (Wilson & Downs, 2012), a species of the same genus, also present in Tanzania, with a matching volume and similar moisture content (Ruffo *et al*., 2002). Seed count and mass estimates were derived for *Cordia sinensis*.

[d] Estimate derived from the wet density (g/mm^3) of *Grewia cyclea* and *Grewia occidentalis* (Viljoen, 1983; Spehn & Ganzhorn, 2000), both species within the midrange of *Grewia* fruit diameters.

[e] As moisture content is unavailable for *G. similis*, an average moisture content for the other *Grewia* species was used (19.4). This moisture content, along with volume and dry density for *Grewia mollis* (Saleem *et al*., 2012) were used to calculate the mass estimate.

[f] Estimate derived from dry mass weight for *S. persica* (Sharma & Ramawat, 2013) and moisture content from this study.

[g] Total mass estimate for *Grewia glandulosa*, a species matching the volume and 4-lobed structure of *G. pachycalyx* (Spehn & Ganzhorn, 2000).

Table B.2   **Physical Composition of Other Hadza Fruits**

Hadza Name *Genus species*	Diameter[†] (mm)	Total Mass (g)	Seed/Stone Count[†](g)	Seed/Stone Mass[†](g)	Edible Mass (g)
Mashalobe[a] *Vangueria acutiloba* Robyns or *Vangueria apiculata* K. Schum.	19.5	10.3	1[1]	1.82	8.48
Hogoyobe[b] *Ficus sycomorus* L.	30	15.9	___	0.00[2]	15.9
Pawe[c] *Sclerocarya birrea*	35	28.4	1	13.7	14.7

[†]For estimates of diameter, seed/stone count, and seed/stone mass, the plant databases SEPASAL, PROTA4U, and JSTOR Global Plants were consulted, as well as the Tanzania-specific publications of Mbuya *et al*. (1994) and Ruffo *et al*. (2002).

[1] The estimate of one seed was used based on Crittenden's (2009) descriptions of *mashalobe*. Seed mass for *V. acutiloba* was used.

[2] As Crittenden (2009) reported, Hadza typically consume *F. sycomorus* with its small seeds. Furthermore, estimated seed mass was found to be negligible (0.001 g).

[a] Estimates were derived for *V. apiculata* using volume for *V. apiculata*, the reported moisture content (see Table C.2), and the dry mass density (g/mm^3) from a related species, *V. infausta* (Chaiu *et al*., 2013). The estimated weight is consistent with descriptions of *V. apiculata* as smaller than *V. infausta* (Maundu *et al*., 1999).

[b] Estimate derived from dry weight of Makishima (2005) and moisture content from Table C.2.

[c] Estimates derived from Petje (2008) and Andrew (2014).

Table B.3   **Physical Composition of Baobab**

Hadza Name *Genus species*	Total Mass (g)	Seed Mass (g)	Shell Mass (g)	Pulp Mass (g)
N//obabe *Adansonia digitata*	87[1]	34.8[2]	39.2[3]	13

[1] Median from this study (see Figure A.1).

[2] Derived from estimates of seed mass as a mean 40% of total weight (Shukla *et al.*, 2001; De Caluwé *et al.*, 2009).

[3] Derived from estimates of shell mass as a mean 45% of total weight (Shukla *et al.*, 2001; De Caluwé *et al.*, 2009).

Table B.4   **Physical Composition of Hadza Tubers**

Hadza Name *Genus species*	Shape[†]	Total Mass[‡] (g)	Edible Mass* (g)
//ekwa *Vigna frutescens*	Cylindrical	377	98
Do'aiko *Vigna macrorhyncha*	Spherical	192	140
Makalita *Rhynchosia comosa* or *Eminia entennulifa*	Spherical	242	119
Matukwayako *Coccinea surantiaca* or *aurantiaca*	Spherical	758	553
Shakeako *Vigna macrorhyncha*	Spherical	192	140
Shumuwako *Vatoraea pseudolablab*	Spherical	304	158

[†] Shape assignment based on descriptions from Vincent (1985) and Schnorr *et al*. (2015).

[‡] Total mass based on median values of tubers reported in Appendix A. Mass for *C. surantiaca* or *aurantiaca* based on median value from sample of 18 tubers.

* Edible mass percentages were determined by Schnorr *et al*. (2015) as 26% for *V. frutescens*, 49% for *E. entennulifa*, 52% for *V. pseudolablab* and 73% for *I. transvaalensis*. The edible fractions take into account peel weight (the outer, inedible bark of tubers), quid weight (the chewed wad of fiber spit out after eating) and differences across cooked and raw tubers (the average includes both). The edible percentage of *I. transvaalensis* was used for *V. macrorhyncha* because of descriptions of its thin, papery peel (Vincent, 1985), whereas the thicker peels of the other tubers account for the majority of edible mass loss. The same percentage was also applied to *C. aurantiaca* because of Galvin *et al*.'s (nd) report of no quid and the peel as 6.6% of total mass for Galvin *et al*.'s one specimen (calculated by this study). Though only one sample, this low estimate lies outside the range of reported values from Schnorr *et al*. and suggests that the specimen is most likely belonging to the higher end of edible mass proportions.

Table B.5   **Body Composition of Three Bird Species (*Q. quelea*, *T. deckeni* and *S. decipiens*)**

Common Name Hadza Name *Genus species*	Total Mass (g)	Skeletal Mass (g)	Feather Mass (g) [†]	Gizzard Mass (g)	Edible Mass (g)
African Mourning Dove[a] !tsa po ako *Streptopelia decipiens*	156	6.17	9.36	8	132
Red-billed Quelea chicks[b] Tso ma *Quelea quelea*	22	0.73	1.32	1.05	19
Von der Decken's Hornbill[c] Ng'imwako *Tockus deckeni*	160[e]	10.75	9.6	8	132

[†] Estimates for feather mass based on feather mass averaging 6% of total body mass across bird species (Stettenheim, 2000).

[a] Body mass from Robertson (1988) [and closely matching estimated mean of 156.57g (*n*=7) that this study calculated from Hadza food returns]. Skeletal mass from Prange *et al*. (1979) with gizzard estimate derived from allometric relationship to body mass found in Isler and van Schaik (2006).

[b] Mean (and median) total mass from this study (see Figure A.7), with skeletal mass from Jones (1976) and the gizzard mass based on mean percentage of gizzard mass as 4.75 (±0.53) of fresh body mass for the juvenile house sparrow *(Passer domesticus)*, a passerine bird with similar body size to the *Quelea* chick (Chappell *et al*., 1999).

[c] Median from this study (see Figure A.6), skeletal mass from Prange *et al*. (1979) and gizzard estimate derived from allometric relationship to body mass found in Isler and van Schaik (2006).

Table B.6   **Body Composition of Elephant Shrew (*Elephantulus spp.*)**

Common Name Hadza Name *Genus species*	Total Mass (g)	Skeletal Mass (g)	Fur Mass (g)	Edible Mass (g)
Elephant shrew[a] Doloka *Elephantulus sp.*	70	3.36	1.82	64.8

[a] Mean mass from this study (see Figure A.9), with skeletal mass derived from the allometric equation of Prange *et al*. (1979) and fur mass from the relative fur to body mass found in voles (Kenagy & Pearson, 2000).

Table B.7   **Egg Composition of Red-billed Quelea (*Q. quelea*)**

Common Name Hadza Name *Genus species*	Total Mass **(g)**	Shell Mass **(g)**	Edible Mass **(g)**
Red-billed Quelea egg[a] Ule *Quelea quelea*	2	0.14	1.86

[a] Estimated total mass from Meijer and Drent (1999) and shell mass (with membrane removed) from Jones (1976).

Appendix C: Nutrient Composition of Foods

Table C.1   **Nutrient Composition of Hadza Berries/Fruits**

Hadza Name *Genus species*	Moisture (%)	Lipids (%)	Protein (%)	Simple Sugars (%)	TNC (%)	Fiber (%)	Ash (%)	Energy (kcal/100g)
Chukwayabe[a] *Grewia villosa* **Willd.**	24	1.44	5.40	55.3	___*	10.2	3.65	256
Congolobe[b] *Grewia bicolor* **Juss.**	26	1.48	8.88	48.9	___*	9.77	4.96	244
Hlukwayabe[a] *Grewia villosa* **Willd.**	24	1.44	5.40	55.3	___*	10.2	3.65	256
Kisinubi[b] *Cordia sinensis*	73	0.49	3.40	18.6	___*	3.13	1.40	92.3
Mbilipe[c] *Grewia flavescens* **Juss.** *Grewia platyclada*	15	0.98	6.53	7.5[1]	56.3	32.1	2.55	260
Ngwilabe[d] *Grewia similis* **K. Schum.**	__	0	8	__	23	__	__	124
Tafabe[e] *Salvadora persica* **L.**	44.0	6.64	9.80	21.9	35.4	4.92	8.85	252
Tl'atanako[f] *Grewia pachycalyx* **K. Schum.**	12.6	2.51	7.69	__	57.4	25.9[2]	2.5	305
Undushipi[g] *Cordia sinensis*	65.9	0.83	4.48	14.6	14.4[3]	9.64	4.24	92.6

— Estimated values not available.

—* Murray *et al*. (2001) did not measure starch in these berry species and assumed that the berries contained trace amounts.

[1] This estimate is for reducing sugars, and thereby does not include non-reducing sugars like sucrose.

[2] This estimate is for crude fiber only and should be considered an underestimate for total dietary fiber.

[3] The discrepancy between simple sugars and TNC is the result of reliance on multiple studies for one value compared to a singular study for the other. TNC values for *undushipi* were derived from Crittenden (2009) only.

[a] Estimates derived from Murray *et al*. (2001) only, as this study analysed the berries in the "raisin-like state" eaten by the Hadza (p. 6).

[b] Estimates derived from Murray *et al*. (2001). *Kisinubi* analysed separately from *undushipi* because of the name distinction by the Hadza, though they appear to be the same species.

[c] All estimates derived for *Grewia flavescens* from Elhassan and Yagi (2010).

[d] Kilocalories derived from and other estimates used directly from Schoeninger *et al*. (1999).

[e] Estimates derived from Cade and Greenwald (1966), Maundu *et al.* (1999), and Crittenden (2009).

[f] No known estimates available for *G. pachycalyx*. Estimates derived for *Grewia occidentalis,* a species similar to *G. pachycalyx* from Wehmeyer (1986), Lawes (1990) and Wilson and Downs (2012).

[g] Estimates derived from Murray *et al*. (2001) and Crittenden (2009).

Table C.2   **Nutrient Composition of Other Fruits**

Hadza Name` *Genus species*	Moisture (%)	Lipids (%)	Protein (%)	Simple Sugars (%)	TNC (%)	Fiber (%)	Ash (%)	Energy (kcal/100g)
Mashalobe[a] *Vangueria acutiloba* Robyns or *Vangueria apiculata* K. Schum.	24.8	0.05	3.55	13.9	21	20.9	4.6	98.7
Hogoyobe[b] *Ficus sycomorus* L.	35.4	3.42	2.06	26.1	17.2[1]	22.2	2.39	138
Pawe[c] *Sclerocarya birrea*	84.6	0.30	0.51	8.34	13.2	3.39	0.54	41.4

[1] The discrepancy between simple sugars and TNC is the result of reliance on multiple studies for one value compared to a singular study for the other. Simple sugar values for *hogoyobe* were derived from Crittenden (2009) only.

[a] All estimates derived from Crittenden (2009).

[b] Estimates derived from Gaynor (1994), Maundu *et al*. (1999), Lockett *et al*. (2000), Crittenden (2009)**,** Acipa *et al*. (2013), and Kassa *et al*. (2015). It should be noted that reported averages for moisture spanned a wide range [23.6 from Crittenden (2009), 82.7 from Maundu *et al*. (1999), and 87.5 from Lockett *et al*. (2000)].

[c] Estimates derived from Maundu *et al*. (1999), Murray *et al*. (2001), Saka *et al*. (2008), Magaia *et al*. (2013a), Magaia *et al*. (2013b), and Hiwilepo-van Hal *et al*. (2014).

Table C.3   **Nutrient Composition of Baobab**

Baobab Component	Moisture (%)	Lipids (%)	Protein (%)	Carbohydrates*(%)	Fiber (%)	Ash (%)	Energy (kcal/100g)
Pulp[a]	16.2[1]	1.16	3.53	53.2	38.6[2]	3.86	232
Seeds[b]	6.54	22.9	24.8	29.4	33[3]	5.75	384
Pulp and Seeds[c]	9.18	17	19	35.9	34.8	5.23	343

*Carbohydrates replaced simple sugars and TNC as categories since the majority of studies only reported carbohydrates.

[1] Moisture demonstrated considerable variation. Crittenden's (2009) mean of 56.5% from Hadzaland baobab is more than double the second highest reported estimate (25.9%) from Shukla *et al*. (2001) and is vastly different from the other estimate from Hadzaland, 4.7% (Murray *et al*. 2001).

[2] This estimate reflects total dietary fiber from only Murray *et al*. (2001), Crittenden *et al*. (2009), and Magaia *et al*. (2013b). The estimated fiber from all studies was 15.4%, but this value reflects a majority of crude fiber reports.

[3] This estimate reflects values for dietary fiber of Lockett *et al.* (2000), Murray *et al*. (2001), and Magaia *et al*. (2013b). The estimated fiber from all studies was 19.7%, but this value reflects a majority of crude fiber reports.

[a] Estimated values derived from the compiled dataset of De Caluwé *et al*. (2009) in addition to values from Maundu *et al*. (1999), Crittenden (2009), Magaia *et al*. (2013a) and Magaia *et al*. (2013b).

[b] Estimated values derived from the compiled dataset of De Caluwé *et al*. (2009) in addition to values from Maundu *et al*. (1999), Magaia *et al*. (2013a) and Magaia *et al*. (2013b).

[c] Estimates based on the ratio of seeds (72.7%) to pulp (27.3%) in fresh weight of 100g of baobab with shell removed (see Table B.3).

Table C.4   **Nutrient Composition of Hadza Tubers**

Hadza Name *Genus species*	Moisture[1] (%)	Lipids (%)	Protein (%)	Carbohydrate (%)	Fiber (%)	Ash (%)	Energy (kcal/100g)
//ekwa[a] *Vigna frutescens*	70.2	0.85	1.54	22.8	7.88	2.60	82.9
Do'aiko[b] *Vigna macrorhyncha*	85.7	0.76	2.32	16.0	2.98	3.60	67.9
Makalita[c] *Rhynchosia comosa* or *Eminia entennulifa*	74.4	0.77	0.74	19.9	6.34	3.56	54.6
Matukwayako[d] *Coccinea surantiaca* or *aurantiaca*	86.5	0	1.67	12.4	1.80	2.12	45.5
Shakeako[b] *Vigna macrorhyncha*	85.7	0.76	2.32	16.0	2.98	3.60	67.9
Shumuwako[e] *Vatoraea pseudolablab*	77.91	0.81	0.67	18.3[2]	3.62	2.66	77.3[2]

[1] Moisture content is only reflective of data from Galvin *et al*. (nd) and Crittenden (2009) (where applicable), as Vincent (1985) assumed moisture of 70% in her analysis.

[2] The carbohydrate value is reflective of a high estimate from Galvin *et al*. (nd): 41.7 compared to 12.9 and 15.7 from Crittenden (2009) and Vincent (1985), respectively. The resultant kilocalorie estimate was also much higher (additionally due to the lower moisture content). Because Galvin *et al*. reported similar values for four different *shumuwako* samples, these higher estimates were still included in the analysis.

[a] Estimates derived from Galvin *et al*. (nd), Vincent (1985) and Crittenden (2009).

[b] Estimates derived from Vincent (1985) and Crittenden (2009).

[c] Estimates derived from Galvin *et al*. (nd) and Crittenden (2009).

[d] Estimates derived from Crittenden (2009) only.

[e] Estimates derived from Galvin *et al*. (nd), Vincent (1985), Crittenden (2009) and Migata (2011) (crude fiber only).

Table C.5   **Nutrient Composition of Hadza Meat**

	Common Name Hadza Name *Genus species*	Moisture (%)	Lipids (%)	Protein (%)	Ash (%)	Energy (kcal/100g)
Birds	African mourning dove[a] !tsa po ako *Streptopelia decipiens*	72.5	4.39	21.63	1.35	126
	Red-billed quelea chicks[b] Tso ma *Quelea quelea*	67.7	6.04	15.25	3.29	133
	Von der Decken's hornbill[c] Ng'imwako *Tockus deckeni*	—	—	—	—	126
Mammals	Common baboon[d] Ne'e'ko *Papio anubis*	71.2	3.7	22.3	1.8	112
	Common warthog[e] Kwahi *Phacochoerus africanus*	74.0	2.00	23.57	1.25	132
	Dikdik[f] Gewedako *Madoqua kirkii*	74.5	0.9	23.4	1.2	102
	Elephant shrew[g] Doloka *Elephantulus sp.*	73.1	3.0	19.1	2.0	109
	Thomson's gazelle[h] Lalako *Eudorcas thomsonii*	74.7	2.0	23.7	—	113
Reptiles	Leopard tortoise[i] K'olowako *Geochelone pardalis*	—	7.00	17.00	—	135

[a] Estimates derived from data of wild turtle doves, *Streptopelia turtur*, sharing the same genus as the African mourning dove (Turienzo *et al*. 2010).

[b] Moisture derived from Pope and Ward (1972) and used to derive estimates from Jaeger *et al.* (1989).

[c] Caloric estimate used from other adult bird, *Streptopelia decipiens*, since no nutritional information available for *Tockus deckeni*.

[d] Estimates used for yellow baboons, *Papio cynocephalus*, a species also found in Tanzania and sharing the same genus as the common baboon (Malaisse, 2010; Cawthorn & Hoffman, 2015).

[e] Mean water content from Hoffman and Sales (2007) and calorific data from Bender (1992). All other values derived from Hoffman and Sales (2007) and Bender (1992).

[f] Estimates from and kilocalories derived from royal antelope, *Neotragus pygmaeus*, a species belonging to the same tribe (Neotragini) as dikdik and other small antelope (Ntiamoa-Baidu, 1997).

[g] Moisture estimate for *Elephantulus edwardi* from Leon *et al*. (1983). Other estimates from data of *Aethomys kaiseri*, a similarly-sized rodent also found in Tanzania (Malaisse & Parent, 1982).

[h] Fat content for Thomson's gazelle from Ntiaamoa-Baidu (1997). Other values and kilocalories derived from springbok, *Antidorcas marsupialis*, a species belonging to the same tribe (Antilopini) as Thomson's gazelle (Hoffmann & Wiklund, 2006).

[i] Lipid and protein values from data of *Chersian angulate*, an African tortoise in the same family as the leopard tortoise (Thompson & Henshilwood, 2014). Calorific estimate derived from Thompson and Henshilwood (2014).

Table C.6   **Nutrient Composition of *Q. quelea* Eggs**

Common Name Hadza Name *Genus species*	Moisture (%)	Lipids (%)	Protein (%)	Ash (%)	Energy (kcal/egg)
Red-billed Quelea eggs[a] Ule[b] *Quelea quelea*	—	0.1	0.25	—	2.02

[a] Mean values for lipids and protein from 50 *Q. quelea* eggs (Jones & Ward, 1976) with mean energy content for passerine eggs (order to which *Q. quelea* belongs) (Rahn *et al.*, 1985).

[b]*Ule* refers generally to 'eggs'.

Table C.7   **Nutrient Composition of Honey**

Hadza Name Bee Type *Genus species*	Moisture (%)	Lipids (%)	Protein (%)	Simple Sugars (%)	Ash (%)	Energy (kcal/100g)
Ba'alako[a] Stinging bee *Apis mellifera scutellata*	15.1	6.07	2.76	75.6	0.43	368
Kanoa[a] Stingless sweat bee *Trigona rispolii*	21.6	3.02	1.88	72.9	0.63	316
Nateko[a] Stingless bee *Trigona erythra junodi*	23.5	2.45	2.41	71.0	0.65	326
Unidentified Honey[b]	20.1	3.85	2.35	73.2	0.57	337

[a] All estimates derived from the data of Murray *et al*. (2001).

[b] All estimates derived from averaging of the three other honey estimates. Unidentified honey refers to honey records without reference to a specific honey name.

Table C.8   **Nutrient Composition of Agricultural Food Stuffs**

Agricultural Food Swahili Name	Lipids (%)	Protein (%)	Energy (kcal/100g)
Condensed Milk Kufupishwa maziwa	8.7	7.8	320.0
Maize (cooked) Mahindi	1.2	2.7	119.0
Maize stiff porridge Ugali wa mahindi or Sembe	1.2	2.7	123.8
Maize stiff porridge with milk[b] Ugali wa mahindi or Sembe	4.5	5.9	183.8
Maize with kidney beans Makande	7.0	3.6	156.5

[a] All values, except for maize stiff porridge with milk, from the Tanzania Food Composition Tables (Lukmanji *et al*., 2008).
[b] Estimates derived from the data of Lukmanji *et al*. (2008), using whole milk with 3.25% milk fat.

Appendix D: Food Data Limitations & Micronutrients

Limitations to food weight estimates

The practical methodology used from Rothman *et al.* (2012) for primate ecology was applicable precisely because it is non-invasive. Yet the trade-off for less invasiveness is less accuracy. Accuracy was maximised by collecting corresponding data in the field (like berries per handful). Nonetheless, the accuracy is inherently limited by visual biases of the researcher. In the case of food shared, these visual biases may also include unobserved food exchanges.

Limitations were also imposed by the dearth of data on published food weights for the female-targeted species. Though this study has attempted to amass as many applicable studies as possible, certain species may still have a wider variation than captured by previous studies (particularly those with very small sample sizes).

Limitations to nutritional estimates

An apparent limitation to the nutritional values is the small sample size of Hadza foods estimated to date (e.g. Murray *et al.*, 2001; Crittenden, 2009). Small sample sizes are particularly problematic when high variance is present. In the tuber data, for example, there is high variance across some estimates. As stated previously, data from Schoeninger *et al.* (2001) were not used for reasons shared by Crittenden (2009) and Blurton Jones (2016).

When analysing wet weight data, one of the most important factors is moisture content. Even if studies agree on overall protein or fat content, the moisture level determines the calorific outcome. Therefore, the same nutritional values with two very different moisture levels easily produce very different calorific values. For example, the moisture value of Galvin *et al.* (nd) for one of the tuber species (*V. pseudolablab*) was markedly different from that of Crittenden (2009). Although the difference may have arisen from methodological differences, it is possible that there may be a wider range of moisture levels depending on season and location. If this is the case, more samples are needed to determine the most representative moisture estimate for the true mean.

Besides variation in moisture content, there is also variation in nutritional estimates. Baobab, in particular, is noted as having considerable variation for its nutritional properties (Chadare *et al.*, 2009; De Caluwé *et al.*, 2009; Stadlmayr *et al.*, 2013). This variation matches its substantial phenotypic and genetic variation (De Smedt *et al.*, 2011; Kamatou *et al.*, 2011; Munthali *et al.*, 2012; Gebauer *et al.*, 2016). Though yet unidentified genetic or phenotypic correlations with nutritional properties may exist, Chadare *et al.* (2009) offers a list of potential explanations:

> "This variation may be due to the quality of the sample (mixture of samples, or samples obtained from markets or samples from individual trees), the provenance of the samples, the age of the sample, the treatment before analysis, the analytical methods used, the storage conditions, the processing method, a probable genetic variation, and the soil structure and its chemical composition" (p. 268-269).

Although Chadare *et al.*'s comments are specific to baobab, these comments are useful for considering limitations on nutritional studies generally.

Micronutrient content: Two cases

Although a breakdown of micronutrient content is beyond the scope of this study, it is worth noting two exceptional cases of micronutrients for the female-targeted foods.

The first exception is baobab. Despite baobab's high morphological, genetic and nutritional variability, there is one particular property that studies agree on: elevated vitamin C content (Rahul *et al.*, 2015). Baobab has the highest content known to any natural fruit, nearly 10 times the amount found in oranges (De Caluwé *et al.*, 2009). Though the content does still demonstrate some variability, Chadare *et al.* (2009) found that for the lowest vitamin C content reported, a pregnant woman would meet 84% of her recommended daily intake with only 40 grams of pulp. At the highest levels reported, she would have 141%.

The second exception is *Grewia* berries. Elhassan and Yagi (2010) found that *Grewia flavescens* (*mbilipe* berry) and *Grewia villosa* (*chukwayabe* and *hlukwayabe* berries) had high

levels of iron: 26.9 mg/100g and 29.6 mg/100g, respectively. According to the study, the result supported the traditional usage of *Grewia* in treatments for anaemia. Indeed, *G. tenax* has been linked to preventing anaemia, having a statistically significant association with haemoglobin levels (Ahmed *et al.*, 2012). Since *G. tenax* has a lower level of iron content (20.8 mg/100g) compared to *G. flavescens* and *G. villosa* (Elhassan & Yagi, 2010), it seems reasonable to assume that *G. flavescens* and *G. villosa* have the potential to be as effective as dietary preventions against anaemia.

Appendix E: Hadza Women's Toolkit

Hadza women's foraging behaviour is particularly relevant to models of past foragers because they use a simple toolkit. For men, big-game hunting was possible with complex technology (Marlowe, 2005a), like the bow and poisoned arrows, tools not available to Pleistocene hominins. Women's tools, on the other hand, represent simpler technology with a greater time depth. The following Appendix summarises the toolkit used by Hadza women and its evolutionary significance.

Digging sticks are a critical tool of women's foraging, being used in 42% of all forays studied by Marlowe (2010). With tubers growing at an average depth of 25 to 50 cm in soil that is hard, dry or rocky, Hadza women cannot simply use their hands for digging (Vincent, 1984, 1985). Instead, they fashion digging sticks with sharp, fire hardened tips (Woodburn, 1970; Vincent, 1985). [The women do not weigh or tip their sticks with horns or bones (Vincent 1985).] The total time to make the stick is just over four minutes (Vincent, 1985), and one stick lasts an average of eight digging trips (Vincent, 1985). Their functionality is not only limited to digging tubers; they are also used for levering away boulders (Blurton Jones, 2016), for self-defence (Marlowe, 2010) and were even once observed as aiding women appropriate a kill involving a leopard (O'Connell *et al.*, 1988).

Carrying tools are another important feature of women's foraging, necessary for holding food stuffs, water and infants. Such tools range from simple to more complex. For instance, from an empty baobab pod for carrying water to an elaborate basket that takes three to four days to weave (Marlowe, 2010). Slings are used the majority of time to carry infants (see review in Konner, 2005). They even feature in playtime, with young children using slings for dolls or infants (Crittenden, 2016).

As for stone tools, hammerstones are round rocks used for processing baobab and marula. Though pods may be cracked open without the hammerstone, this tool is necessary to process baobab's hard seeds (Murray *et al.*, 2001; Marlowe, 2010). Marlowe (2010) speculates that the Hadza may have used sharpened stones or flakes before iron was available, but the earliest observations of Woodburn (1964, 1970) demonstrate the reliance on iron knives for cutting and chopping.

Women's possession of iron knives appears to be a more recent phenomenon; Marlowe (2010) describes women as borrowing husbands' knives during his 1995 fieldwork. They use knives for chopping and sharpening their digging sticks, and have been observed to

chop open nests for honey (Wood *et al*. 2014). Today, the abundance of knives reflects their use as gifts from researchers (Marlowe, 2010; Blurton Jones, 2016). Nevertheless, some purposes are still served by teeth instead, like peeling tubers (Vincent, 1985; Berbesque *et al.*, 2012).

Evolutionary Significance

Digging sticks may have been an important tool for past hominins. Access to USOs has been hypothesized as important for *Australopithecus* and *Homo* and subsequent expansion into savannah habitats (Hatley & Kappelman, 1980; O'Connell *et al.*, 1999; Wrangham *et al.*, 1999; Laden & Wrangham, 2005; Berbesque & Marlowe, 2009). Such access may have been afforded by digging sticks, at least for the emergence *of H. erectus* (O'Connell *et al.*, 1999). D'Errico *et al*. (2012) review the archaeological evidence for digging sticks, including their documentation of a stick dated to approximately 39,000 BP in South Africa.

Additional support for digging tools and USOs as important to the early hominin diet is drawn from observations of chimpanzees and bonobos. Hernandez-Aguilar *et al.* (2007) reported wild chimpanzees using sticks for obtaining USOs in Tanzania. More recently, Roffman *et al.* (2015) observed captive and semi-captive bonobos using modified branches (both short and long sticks) for obtaining USOs. Interestingly, the chimpanzee data do not support tubers as fallback foods; the chimpanzees exploited the USOs during the wet season, long after the most likely period of shortages (Hernandez-Aguilar *et al.*, 2007).

With regards to carrying tools, the loads of foraged foods and infants are important factors in the evolution of bipedal humans. Carrying an infant in one's arms has a 16% higher energy cost than using a carry device (Wall-Scheffler *et al.*, 2007). Watson *et al.* (2008) explain that carrying an infant, a heavy asymmetric load, is not only energetically costly but also a complex behaviour with respect to balance. They interpret the findings of Wall-Scheffler *et al.* (2007) as suggestive of rapid development of carrying tools following the emergence of bipedalism.

Evidence of hammerstones dates back to the earliest evidence of stone tools. Recently, the earliest stone tools were dated to 3.3 million years ago in West Turkana, Kenya (Harmand *et al.*, 2015). This dating is 700,000 years earlier than the Oldowan industry, and almost 1 million years earlier than the oldest specimens of *Homo* in West Turkana (Prat *et al.*, 2005; Harmand *et al.*, 2015). The artefacts include hammerstones and Harmand *et al*. argue that the modes of knapping are similar to the nut-cracking techniques of chim-

panzees and other primates. Indeed, chimpanzees, bonobos and bearded capuchin monkeys have been observed to transport and use hammerstones in cracking nuts (Matsuzawa, 1994; Mercader *et al.*, 2002; Elisabetta *et al.*, 2013; Neufuss *et al.*, 2017).

Iron knives, on the other hand, have the least time depth of the Hadza women's tools. Woodburn (1970) describes the blades as obtained from Isanzu and other neighbours or beaten out by the Hadza themselves with traded iron. The presence of iron artefacts in the Eyasi Basin dates back to at least 1,800 years ago (Mabulla, 2007). How long ago Hadza may have switched from stone cutting tools to iron knives is not known. Stone axes and flakes have been dated to around 140,000 years ago (Mehlman, 1989; Mabulla, 2007).

Appendix F: Measuring Hadza Women's Menstrual Blood Loss

For measuring actual blood volume, the traditional methods are alkaline hematin (Hallberg & Nilsson, 1964; Newton *et al.*, 1977; van Eijkeren *et al.*, 1986) and pictorial techniques (Higham *et al.*, 1990; Wyatt *et al.* 2001). Both methods are ill-suited for the Hadza because they depend on the use of sanitary products. Two alternative options available are menstrual seals or cups and a modification to the pictorial technique. Besides being equally as invasive as sanitary products, menstrual seals and cups are rarely used for measurements of blood loss due to problems like spillage during removal (Wyatt *et al.*, 2001; Warrilow *et al.*, 2004). The first option is thereby unsuitable.

As for the second option, a possible modification to the menstrual pictogram of Wyatt *et al.* (2001), this new method would entail discarding tampon and pad visualisations and extending the pictogram representations for extraneous loss. Just as Hurskainen *et al.* (1998) relied on comparison to multiples of a visual item (the Finnish ten mark coin), so too may the Hadza researcher choose an equivalent visual representation within the environment. This visual representation would need to be a unit that is at once intuitive to the Hadza and also easily transferrable to blood volume.

Still, such a modification to the menstrual pictogram is rife with potential sources of error. Firstly, the method necessitates a high level of vigilance on the part of the Hadza woman for observing menstrual blood and on the part of the researcher for prompting oral communication about blood loss. Unlike patients in the clinical setting, the Hadza women would not be marking the pictogram themselves. As such, it would be imperative to constantly communicate the visual representations of blood for each day from each woman – a task which is both labour-intensive and time-intensive. Secondly, the method may be highly disruptive to the Hadza daily routine, calling attention to those women who are menstruating and disturbing their personal washing routines. Thirdly, the method itself would be difficult to validate.

Appendix G: Mixed Models Approach

The mixed models approach is applied in Chapter 3 and Chapter 5 to control for repeated measures. Two major alternatives to this approach were firstly, treating the observations as independent and not controlling for repeats and secondly, applying the repeated measures ANOVA. This Appendix discusses the limitations of these approaches and the advantages of applying the mixed models analysis.

Alternative 1: Not Controlling for Repeats

An alternative to both the repeated measures ANOVA and the mixed models approach would be to treat each measurement within a woman as independent. This would simplify the analyses by reducing any need to control for repeats. To be able to treat the measurements as independent, however, requires that these measurements are sufficiently different from one another.

Within-woman analyses: No significant differences were found between the repeat measurements of women for the amount eaten per foray. A paired t-test for women with two repeat measurements (n = 17, p = ns) was conducted for kilocalories consumed and revealed no significant differences. Additionally, a repeated measures ANOVA for women with three measurements (n = 10, p = ns) and women with five measurements (n = 10, p = ns) found no significant differences for kilocalories consumed. The repeat measures of women were not significantly heterogeneous, suggesting that they should not be treated independently.

The results of the within-woman analyses support the inclusion of repeated measures.

Alternative 2: Repeated Measures ANOVA

Given that the repeated measures should not be treated independently, data analysis required a mechanism for controlling repeats. The repeated measures ANOVA or mixed models analysis could provide such a mechanism. Because of the nature and type of repeats in the follows dataset, the mixed models approach has advantages over the repeated measures ANOVA.

Unbalanced repeat measures

If a repeated measures ANOVA were applied, then the number of repeats would need to be balanced. In other words, women would need to be followed for the same number

of days. This would greatly restrict the sample size. Mixed models, on the other hand, allow for the inclusion of an unbalanced number of repeat measures.

Furthermore, the conditions and temporal spacing of the repeat measures were not equivalent across women. In mixed models, no assumptions exist regarding the number of repeats or the time between repeats. As Verbeke and Molenberghs (2000) explain, an important strength of the mixed models approach is "that it does not assume that an equal number of repeated observations is taken from each individual or that all individuals should be measured on the same time points" (p. 120).

An additional analysis was conducted to test whether the inclusion of unbalanced or an uneven number of repeat measures across women was supported.

Between-women analysis: A one-way ANOVA was conducted to test whether the amount eaten varied in terms of the number of repeat measurements. The one-way ANOVA included four groups, women with one measure, with two repeat measures, with four repeat measures, and with five repeat measures. There was no significant differences in amount eaten between those women studied once, twice, four times or five times ($n = 152$, $p =$ ns). Figure H.1 demonstrates the distribution across the four groups tested.
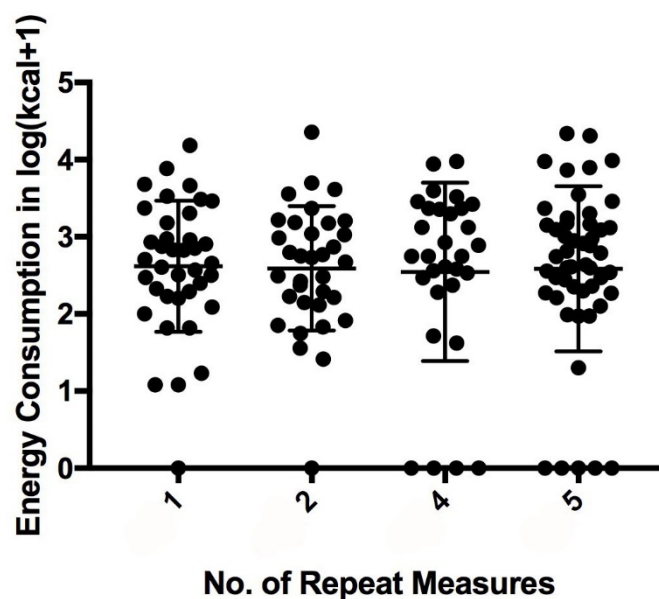

Figure H.1 Energy Consumption across Hadza Women
with Different Repeat Measurements ($n = 152$).

The results of the between-women analyses further supported the inclusion of unbalanced, repeated measures.

Missing data

Measurements must be balanced in a repeated measures ANOVA, and subjects must not have missing data. In contrast, maximum likelihood estimations allow mixed models to overcome missing data and use all available data. Subjects with missing data need not be dropped, as in repeated measures ANOVA.

Mixed models are fitted by maximum likelihood (ML) or restricted maximum likelihood (REML) methods. In R, the default setting is to fit the model by REML. The SPSS Technical Report (2005) summarises the advantage of mixed models: "ANOVA methods produce an optimum estimator (minimum variance) for balanced designs, whereas ML and REML yield asymptotically efficient estimators for balanced and unbalanced designs" (p. 1). The report states that mixed models are "generally preferred" (p. 12) since ANOVA only achieves its optimal performance with balanced data.

Appendix H: Translated Text

Translations for Chapter 4: The Hadza Woman's Menstrual Cycle

1. *"Kihadzabe ni atama tu basi na Kiswahili, damu"*
2. *"Sijui hata inatoka wapi, kwani wewe utaona, ikinanii, si hutaona"*
3. *"Maana ya damu si mtoto, kama naingia mtoto, naona atama hamna"*
4. *"Maana ya damu ni kupata mtoto kihadzabe,,ukisahau mwezi mmoja unajua kwamba umepata mtoto…ikipita miezi miwili unajua kwamba mtoto ndio unajua kwamba umepata"*
5. *"Maana ya damu kutoka kwa hadzane ni shauri ya wewe kutoka kwenye tumbo la mama yako, unazaliwa basi unapata atamako"*
6. *"Mi naona tu damu inatoka, naona sijui labda, nipo mgonjwa huko, mpaka mama naenda kuangalia nasema, aaah hii ni shauri ya mungu"*
7. *"Nimepata kuangalia natoka damu, nikasema hii ni kitu gani natoka, nakwenda sasa kwa mama nalia"*
8. *"Mama yangu hajaniambia kitu ameniacha hivo hivo. Wakati mimi napata atama peke yangu mimi naenda kumwambia, mama mimi nimeapata atama; aliniambia hivo ya wanawake"*
9. *"Niliona damu inatoka nikadhani wakati nalala kuna mtu alikuja kunichoma, ni-kashituka"*
10. *"Mi nilianza tu, nikasema sijui hii mbaya nikalia"*
11. *"Nilisikia mwili ni nzito, inawaka"*
12. *"Kama msichana umeanza, unaanza kuuma mgongo, kiuno unaanza umwaaa, kuja kustuka ukilala yote, unasikia aah tayari, ndio unapamba ushanga sisi, kama msichana unapamba ushanga yoteiwe nyeupe ndio umepamba ushanga ndio umekuwa msichana umekua"*
13. *"Aliniambia tu mwezi ikitoka tu utaona dalili yako ya ngozi ikibadilika basi"*
14. *"Aliniambia wakati unakua, unapata maziwa, basi unapata atama"*
15. *"Aliniambia kama mbaramwezi natoka najua atama natoka"*
16. *"Alisema ukisikia dalili kama hizi ndio atama inakuja; nasikia maumivu ya mwili, uchovu uchovu unajua leo atama inakuja"*
17. *"Kama ukisikia maumivu ya kiuno tayari mwanangu, tayari damu imetoka, umekua"*
18. *"Hiyo atama uliyoona umekua"*
19. *"ukikua mtoto wangu utaona atama, ukiona atama, unaona mtoto"*
20. *"Aliniambia fanya usafi; kufua atama na maji"*
21. *"Alinifundisha kusafisha […] ili nisinuke"*
22. *"Amenifundisha kwamba fanya hivi, fua nguo, fanya hivi, fua nguo"*

23. *"Aliniambia kama mtoto wangu ukipata atama, ikitoka atama, unaenda kufua, kuoga; ikitoka atama unafua nguo, unachota maji, unaleta nyumbani"*

24.. *"Alinifundisha kuhusu na atama sana, unafunga nguo wanaume wasione damu"*

25. *"Alinifundisha kusafisha atamako na sabuni porini"*

26. *"Nalala siku hizi, siku mbili, hii ya tatu tayari naisha"*

27. *"Asubuhi, jioni, usiku, siku tatu"*

28. *"Hamna, naingia mtoto peke yake hamna damu"*

29. *"Mimi wakati nilikuwa msichana, sijaona atama, mimi napata mtoto tu atama mimi sina"*

30. *"Bado, mimi sijapata, napata mtoto tu, atama sina"*

31. *"Ikitoka hii miezi ikizama, ikitoka hii miezi ukitoka damu inapita hii miezi, inatoka mingine unaona tena"*

32. *"Haiwezekani, mwanamke anapata atamako kwa baada ya mwezi tu"*

33. *"Nyingi, unakanyaga mpaka kwenye miguu"*

34. *"Siku moja, ndogo, siku mbili, ndogo, siku tatu, ndogo"*

35. *"Unasikia hapa moto kidogo kwa kiuno"*

36. *"Napata maumivu ya tumbo ni kali"*

37. *"Maumivu wakati wa damu, atama? Eeh, wanatumia dawa ya porini"*

38. *"Nasafisha nyumbani ndani ili watu wasione"*

39. *"Maji nachota mtoni, nakuja natawaza, naosha damu"*

40. *"Kama huna maji nakwenda chota"*

41. *"Unajisafisha usinuke"*

42. *"Kwa sababu kama hufui, unanuka harufu"*

43. *"Unanuka! Unatoka harufu, watu watasikia harufu"*

44. *"Kama hamna maji si utanuka! Nafuu kama maji kidogo iko unafua unaanika pale ndani, kama nakauka unavaa sasa, hapana ona wanaume"*

45. *"Unamtuma mtu akachote maji"*

46. *"Kama hamna maji, si ataendea mzee, anaenda kuchota maji, analeta"*

47. *"Mkojo ikiwa maji hamna wanatumia mkojo yake"*

48. *"Kama huna maji unachukua kitambaa unaweka"*

49. *"Unatumia kitambaa kuzuia atama"*

50. *"Nachukua na kanga mbili nafunga damu isitoke"*

51. *"Kitambaa kidogo naweka halafu nafunga halafu nachukua pokoroshobo ya wahadzabe ile ngozi unafunga basi unachukua kanga unafunga"*

52. *"Sisi wakati wa atama tunaoga maji na kufua nguo"*

53. *"Unaoga na sabuni, nafua nguo na sabuni"*

54. *"Hamna sabuni, unaenda kufua tu na maji"*

55. *"Nikiwa na sabuni ndio naosha lakini kama hamna nafua hivo hivo"*

56. *"Kama ipo sabuni kidogo, unasafisha na sabuni"*

57. *"Sisi tunachukua ile sabuni, ile matunda yake, ukifanya hapa kwenye maji, basi halafu, povu ikitoka kidogo, unachukua nguo yako yote, naweka sasa unasafisha"*

58. *"Sabuni kidogo unajipaka na mafuta basi ushamaliza"*

59. *"Maji nachukua maji nasafisha naweka kwenye jua inakauka nguo, naweka sasa"*

60. *"Nitatazama anga kwa sababu nikiona mbaramwezi imefika hivi labda nitaona atama"*
61. *"Kila siku naangalia mwezi tu"*
62. *"Naangalia mwezi kila siku, kama nimeenda ile mwezi anasema, nimeenda, kama sijaenda, sijaenda atamako"*
63. *"Mwezi ukawa katikati"*
64. *"Ikipita hivi au ikitoka hivi"*
65. *"Naangalia mwezi vile inatoka inakufa inatoka inakufa naangalia"*
66. *"Unaangalia kwa kujua kwamba atama kwenye umri wake imekatika, unakaaa unaangalia mwezi umepita bila atama, mwezi unapita bila atama, mwezi unapita bila atama hata kama ni miezi miwili bila atama unajua aah kumbe iko tumboni, umeshajua"*
67. *"Baada ya mbaramwezi kuisha, nitajua mwezi kama napita, atama hamna najua mimba inaingia"*
68. *"Naangalia mwezi. Naangalia kwamba mwanaume akifanya hivi ndio naangalia mwezi basi"*
69. *"Najua wakati wa mapenzi kama unapata atama unakataa"*
70. *"Kama atama ipo, hakuna kufanya kwa mwanaume, atama ni mbaya"*
71. *"Naoga siku nne, ya nne hii ndio naonana"*
72. *"Mimi sijajua; mama aliniambia nina mimba"*
73. *"Mimba amesema mzee wangu tumepata muda muda wakati tumekuwa"*
74. *"Najua tu, unaona damu inakatika; najua nina mimba"*
75. *"Nitajua kwa sababu ukipata mimba, atama haitoki"*
76. *"Nitajua tu kwani nina uwezo wa kujua si utajua kwani imeingiaje"*
77. *"Najua mwili ukiwa unang'aa, unataka kuja kuja"*
78. *"Nikiwa na mimba najua kama matiti imekuwa, ni kubwa sana"*
79. *"Wakati naona ile mwili wa wanawake"*
80. *"Kujua ni mungu tu, naona tumbo ni kubwa"*
81. *"Hesabu sasa sijui, kwa sababu wahadzabe hawajasoma"*
82. *"Mi sijui maana sijasoma"*
83. *"Hawahesabu, hawajui hata kuhesabu, hatuhesabu sisi"*
84. *"Wanahesabu, miezi moja, miezi mbili, tatu bila atama"*
85. *"Kama unamaliza mwezi mmoja anajua kama damu imekatika unajua ni mtoto tayari tumboni"*
86. *"Mwezi mmoja ukipita ikisimama basi najua nina mimba"*
87. *"Kama napita mwezi mbili nasema iko mimba"*
88. *"Wanawake wahadzabe wanajua kwa hali ya mwezi, mwezi mmoja ikipita na mwezi mbili ikipita ndio atama imefunga, mtoto yupo"*
89. *"Ukisahau atama miezi miwili ndio unajua una mimba"*
90. *"Unaangalia miezi mitatu au nne kama imepita hivi hivi bila atama unajua iko na mtoto tumboni"*
91. *"Mimi nitaangalia mwezi kama inapita miezi mitatu najua mimba ipo"*
92. *"Najua siku ya kuja mimba"*
93. *"Atamako kwa siku moja, naingia mimba baada ya kuisha atamako"*
94. *"Leo naweza nikasema naenda atama nikafunga, nikasema mbona hali siendi? Nategemea mwezi hii mpaka nakwisha, nasema napata mtoto"*

95. *"Yeye saa ya kubalehe alikuwa hana nafasi ya kuingia mimba ama itakuwa tofauti kabisa"*

96. *"Lazima atamako itangulie, ikitangalia atamako ndio mtoto anaingia"*

97. *"Kama mnalala na mwanaume tayari, hiyo damu inaenda inachanganya na damu ya mwanaume inakuwa mtoto"*

98. *"Mtoto akikaa chini na kutembea basi, napata atama"*

99. *"Huwezi kupata haraka atama mpaka nakuwa kubwa basi ndo unakwenda atama"*

100. *"Yaani kama nina mtoto sipati atama, kama mtoto akikua kuwa kubwa sana kama hii ndo napata atama"*

101. *"Wanazungumza sasa tumemaliza atama. Wanafurahi, wamezeeka"*

102. *"Kama umeshazeeka akina mama, kama umeshakua, huwezi kwenda atama tena. Umefunga moja kwa moja kizazi, hamna kwenda, moja kwa moja"*

Translations for Chapter 5: Foraging Behaviour & Reproductive Status

1. *"Ni ngumu kuchimba mzizi ukiwa na mimba"*

2. *"Nikiwa na mimba siwezi kuchimba mizizi"*

3. *"Wakati wa mimba huwezi kuchimba mizizi sana"*

4. *"Nikiwa kwenye mimba ni ngumu kuchimba kwa sababu nashindwa kuinama; mimba imekua"*

5. *"Ukiwa na mimba kuinama hivi sio rahisi"*

6. *"Ukichimba, ukiinama hivi, tumbo si kubwa si ataumia mtoto"*

7. *"Wakati kama unaye mimba, utapumzika, unakaa, kwa sababu si umechoka, unakaa"*

8. *"Ukiwa na mimba, ukichoka sana; huwezi kuchimba"*

9. *"Ni ngumu zaidi nikiwa na mimba sana"*

10. *"Si akikua mimba si kazi kufanya ni shida"*

11. *"Kunyonyesha ni rahisi kuchimba mzizi lakini kwa mimba ikikua sana ni ngumu"*

12. *"Kama ipo kidogo unaenda kuchimba mzizi, kama anakua ni ngumu sana, unakaa nyumbani"*

13. *"Ukiwa na mimba ya miezi saba unashindwa kwenda kuchimba, kama miezi mitano unaweza kuchimba tu"*

14. *"Kwa sababu mtoto anakamata nanii yako ya kuchimba, shida"*

15. *"Ukiwa unanyonyesha unachimba; siyo ngumu ukiwa"*

16. *"Kama unanyonyesha unamteremsha unamlaza tena unachimba unatoa, unachoma, unabeba, unachukua mtoto unabeba hapa unaenda nyumbani"*

17. *"Ukiwa umeezeka basi huwezi kuchimba"*

18. *"Ni ngumu lakini utajikaza tu kuchimba"*

19. *"Ni ngumu, unachimba kidogo hamna"*

20. *"Siyo ngumu, unachimba tu"*

21. *"Unachimba muda wowote, unaweza kupumzika kama lisaa limoja"*

22. *"Kwa sisi wahadzabe hakuna shida, siyo ngumu"*

23. *"Siyo ngumu, hata kama nina mtoto ninanyonyesha lazima nitachimba mzizi"*

24. *"Hamna siyo ngumu, hata kama una mimba unachimba tu unatoa"*

25. *"Kama unakuwa na mimba, unakaa nyumbani, naleta chakula mzee"*
26. *"Ikikuwa sana nashindwa kuchimba, majirani wananigawia"*
27. **"***Kama una mzigo, kama amekua unashindwa kufanya kazi, kuchimba unashindwa kazi kukaa tu, anakwenda kuchimba msichana kama ipo watatu wanaenda kuchimba wasichana wanaleta //ekwa, mama hii hapa […] unakula vizuri unakaa sasa moja kwa moja hamna kusumbuka"*
28. **"***Kama unazeeka kama mzee hakuna kuchimba unakaa nyumbani, wanaleta watoto, wasichana wako, wanachimba wanaleta kuja kukwambia mama, unakula unakaa umezeeka"*
29. *"Siyo ngumu lakini ni rahisi, nachimba, mume wanga natafuta manako"*
30. *"Kama niko kwenye mimba ni ngumu nakaa chini nachoka"*
31. *"Ukiwa na mimba sana, kuchuma matunda utashindwa"*
32. *"Hata ukiwa na mimba lakini ukiwa kama sasa hivi unafanya kazi ikikua sana haiwezekani"*
33. *"Kama mimba kubwa sana huwezi kupanda kwenye miti"*
34. *"Huwezi wakati wa mimba sana huwezi kuchuma sana matunda sababu ya mimba"*
35. *"Kunyonyesha nachuma zaidi kidogo"*
36. *"Ni rahisi ukiwa unanyonyesha"*
37. *"Nikiwa nina mtoto tumboni siwezi kuchuma mdabi, siyo ngumu kwa mzee. Nikiwa nanyonyesha ndio naanza kuchuma mdabi"*
38. *"Ni ngumu sana, haya kuchukua kitu cha mtini hawezi"*
39. *"Ukiwa na mzee ngumu"*
40. *"Ukiwa mzee utashindwa kuchuma"*
41. *"Hata ukiwa na mimba unachuma"*
42. *"Siyo ngumu, unachuma, unajaza sufuria unaweka kichwani, mtoto mgongoni au kama una mimba unaweka mgongoni matunda"*
43. *"Nafanya, sasa kama sifanyi kazi, nani atafanya"*
44. *"Atakuchumia mzee kama una mimba"*
45. *"Ni ngumu, mpaka ukae chini wakukatie na panga wakushushie"*
46. *"Kama una mimba kabisa, […] unashindwa kutembea wanakwenda wasichana kwenda kuchuma na leta nyumbani , umechoka, unakaa"*
47. *"Kama umezeeka kama mzee huwezi kuchuma, nakwenda kuchuma, wasichana na baba yao kwenda kuchuma naleta, wewe unakaa nyumbani unaendelea kula"*
48. *"Ah ah ah ah, mpaka inakwisha mwishoni mwishoni ndio unafanya kazi"*
49. *"Nakaa nyumbani hadi atama inaisha, ndio nafanya kazi"*
50. *"Unafanya kazi zako vizuri, hamna shida"*
51. *"Kazi ya? Ningeweza fanya nikiwa kwenye atama"*
52. *"Unafanya tu, unaenda kuchimba"*
53. *"Unaenda kuchimba mzizi au kama ipo mbuyu unaponda kidogo"*
54. *"Mpaka napona, basi naenda kuchimba mzizi"*
55. *"Huruhusiwi kuchimba"*
56. *"Kwa sababu huruhusiwi kugusa kitu yoyote, unakaa tu ndani hadi iishe"*

57. *"Naenda kuchimba mizizi yangu, hamna shida"*
58. *"Naenda kuchimba mzizi naleta"*
59. *"Kama kawaida, unachimba unatoa nyingi kama kawaida, unakuja kuwalisha watoto wako kama kawaida, hamna tatizo lolote kwa atama"*
60. *"Huwezi kuchuma matunda"*
61. *"Lakini kuchuma mdabi sichumi"*
62. *"Nachuma matunda, vinginevyo mdabi hatuchamagi tukiwa tuko kwenye atama"*
63. *"Kama wanaume hamna wingi si nakwenda"*
64. *"Unatembea kwa wanawake au kama yuko wanaume pale ataona atama!"*
65. *"Wanakwenda kwa maji kusafisha nguo"*
66. *"Nachota, hata kwenda kwenye [….] atama kama napewa ile nguo yangu nzito"*
67. *"Hamna wanatembea, damu kidogo, tunabaki hapa"*
68. *"Eh, mama anaenda kunanii kuchuma unaletewa nyumbani unakula"*
69. *"Kuna baadhi yule atakayeona sasa hivi atama atakuwa nyumbani, hawezi akatembea tembea"*
70. *"Kwa nini nitembee na atama?"*
71. *"Nakaa, kama natembea atama inatoka"*
72. *"Si siwezi kutembea si nimetokwa na damu, nikitembea damu ina dondoka"*
73. *"Shauri ya atamako, nikitembea inazidi, ukikaa nyumbani atamako hapana zidi, anaisha haraka"*
74. *"Sasa nikitoka nyumbani, si itakuwa hali si itakuwa mbaya"*
75. *"Kama unatembea damu labda inatoka naona watu"*
76. *"Maumivu hamna, damu itadondoka"*
77. *"Kama nitaamua kukaa naweza nikakaa kama naamua kutembea natembea, kwani inazuia atama"*
78. *"Kwa sababu ni miiko […] mpaka umalize"*
79. *"Miiko ya kwetu mzee asishike mshale ndio mbaya, lakini tsapale ya kuchimba, uamuzi wa kuchukua tsapale nachimba nakwenda, sikai, natembea"*
80. *"Mimi nabaki kwa sababu hiyo ni aibu, kabila letu, unatoka unatembea tembea unaan-galia mwanaume ni aibu"*
81. *"Msichana kama ipo mbili wasichana na kijana wanasaidiana"*
82. *"Hamna, naenda peke yangu kutafuta chakula porini naleta"*
83. *"Mwenzangu, kama anatengeneza chakula ananiletea"*
84. *"Naenda kuchimba mzizi naleta"*
85. *"Labda kama mzee wangu anaenda kukata hata kama matunda ananiletea hata kama ni asali ananiletea"*
86. *"Watoto ile wakubwa wakubwa, kama ile watoto wangu ndogo, ubuyu si nyingi basi naenda kuokota okota"*
87. *"Jirani yangu mimi ipo Sengele, leo hapa jirani hamna"*
88. *"Jirani, mfano wewe na Emily; Emily anakuja analeta chakula"*
89. *"Ile kama napata mimba nakuwa nakua hivi nakaa nyumbani"*
90. *"Sifanya sana, kidogo"*