Title: Physical behaviours and their association with adiposity in men and women from a low-resourced African setting

Running Title: Physical behaviours and adiposity

Manuscript type: Original research

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Key words: Physical activity, sedentary, moderate-to-vigorous physical activity, obesity, low and middle-income countries

Abstract word count: 199

Manuscript word count: 3796

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Resubmission date: 8th April 2022

Abstract

Background: We firstly explored the associations between physical behaviours and total and regional adiposity. Secondly, we examined how reallocating time in different physical behaviours was associated with total body fatness in men and women from a low-income South African setting.

Methods: This cross-sectional study included a sample of (men (n=384) and women (n=308) aged 41-72 years. Physical behaviours were measured using integrated hip and thigh accelerometry to estimate total movement volume, and time spent in sleeping, sitting/lying, standing, light PA (LPA) and moderate-to-vigorous PA (MVPA). Total-body fat mass (FM%) and regional adiposity were measured using dual-energy X-ray absorptiometry.

Results: The associations between total movement volume and measures of regional obesity were mediated by total body adiposity. In men, reallocating 30 minutes of sitting/lying to 30 minutes of MVPA was associated with 1.0% lower FM. In women, reallocation of 30 minutes of sitting/lying to MVPA and 30 minutes of standing to MVPA were associated with a 0.3% and 1.4% lower FM, respectively.

Conclusions: Although the association between physical behaviours and FM differed between men and women the overall public health message is similar; reallocating sedentary time to MVPA is associated with a reduction in FM% in both men and women.

INTRODUCTION

The increasing prevalence of overweight and obesity in sub-Saharan Africa is of public health concern, with the highest prevalence and rate of increase shown in South Africa [1,2]. The most recent national survey from South Africa reported that 68% of women and 31% of men are living with overweight or obesity, with a clear sex difference acknowledged [1,3]. The increasing prevalence of obesity in South African men and women is particularly alarming due to its association with non-communicable diseases such as type 2 diabetes [4].

Recent evidence from a National Population based survey has shown that the prevalence of self-reported physical inactivity in South Africans is as high as ~57% [5], and it has also been shown that it is associated with BMI and central obesity [6]. Indeed, higher levels of total physical activity (PA), at any intensity, and less time spent in sedentary behaviours, are associated with substantially reduced risk for the development of obesity and non-communicable diseases [7,8], with evidence of a non-linear dose-response pattern in adults [9]. Accordingly, the new World Health Organization (WHO) guidelines recommend that adults should limit sedentary time and replace it with time being physically active, acknowledging that any PA intensity (including light physical activity; LPA) provides health benefits associated with reduced morbidity and mortality risk [10,11]. As such, research that encapsulates the full 24-hour behaviour profile can inform guidelines on how to replace known detrimental behaviours such as sedentary time with other activities such as moderate-to-vigorous physical activity (MVPA).

Socioeconomic status is associated with physical behaviour patterns in men and women [12,13]. A pooled analysis of 358 population-based surveys showed that the prevalence of inactivity was higher in high-income countries (HICs) compared to low-to-middle income (LMICs) Sub-Saharan African countries (38.8 vs. 21.4%). Within sub-Saharan Africa, a greater proportion of women are inactive than men (24.8 vs. 17.9%) [12]. People living in HICs accumulate MVPA through leisure time activities, whereas those living in LMICs accumulate MVPA and LPA through occupational and transport-related activities [14,15]**.** Differences in these physical activity patterns may lead to differential health effects [16] and need to be considered when addressing population-specific physical activity needs and requirements in LMICs.

Quantifying physical behaviours in daily life is difficult using self-report as this approach may be prone to over-reporting and recall bias [17]. Using wearable devices to capture physical behaviours continuously across 24-hours enables more detailed examination of time composition and displacement of physical behaviours by other physical behaviours [18]. This approach enables evidence-based recommendations on favourable reallocations of time between sedentary behaviour and different physical activity intensities, which has the potential to improve research translation of behaviour into applied public health messaging. However, the generalisability of findings are limited due to all previous evidence being produced in HICs [18-20] with no current evidence available in LMICs where high levels of obesity and inactivity are evident. In addition, most population-based studies do not adjust for sleep time, which is recognised as a major limitation of the current evidence [21]. Moreover, most studies use proxy measures for total and abdominal fat distribution such as body mass index (BMI) and waist circumference [22], which does not allow differentiation between fat mass, muscle mass, visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), which are all closely associated with non-communicable disease risk [23,24]. Accordingly, our study firstly aimed to explore the associations between total movement volume and measures of total and regional adiposity. Secondly, we aimed to examine how reallocating time in different physical behaviours was associated with total body fatness in men and women from a low-income South African setting.

SUBJECTS AND METHODS

Design, study population and setting

This cross-sectional study includes the Middle-Aged Soweto Cohort (MASC) of Black South African men and women (n=1029), who were part of a longitudinal study designed to investigate the determinants of type 2 diabetes risk in middle-aged black South African men and women[25]. Participants with complete accelerometry and dual–energy X-ray absorptiometry (DXA) data were included and resulted in a final sample of 692 participants (384 men; 308 women)[26]. During the first clinic visit participants completed sociodemographic questionnaires, human immunodeficiency virus (HIV) testing, venous blood collection, and DXA. Participants were fitted with two accelerometers and returned the equipment and sleep diaries to the clinic after 7 days of wear. The study was conducted in accordance with the declaration of Helsinki and was approved by the Human Research Ethics Committee (HREC) of the University of the Witwatersrand (No. M160604 and M160975). Signed consent was obtained from all participants prior to their participation in the study. All testing procedures were conducted at the South African Medical Research Council/Wits Developmental Pathways for Health Research Unit at the Chris Hani Baragwanath Hospital in Soweto, Johannesburg, South Africa. All data was collected between January 2017 and August 2018.

Body composition and body fat distribution

Weight was measured to the nearest 0.1 kg (Model: TBF-410, TANITA, Illinois, USA) and height was measured to the nearest 0.1 cm (Holtain, Wales, UK) for the calculation of body mass index (BMI, weight/height $(m)^2$). DXA (Hologic QDR 4500A, Bedford, USA) was used to measure whole body composition and fat distribution and was analysed with APEX software version 13.4.2.3. The head was excluded to reduce the possibility of artefacts, and variables included subtotal (total body minus head) fat mass (FM), trunk fat mass and leg fat mass (reported in kg and % sub-total fat mass, FM%). Fat mass index (FMI) was calculated as sub-total fat mass kg/height $(m)^2$. Abdominal visceral (VAT) and subcutaneous adipose tissue (SAT) were estimated from DXA [27].

Physical activity behaviours

Participants were fitted with an ActiGraph (GTX3+, ActiGraph LLC, Pensacola, Florida) and ActivPAL (PAL Technologies Ltd, Glasgow, Scotland) on the right hip and mid anterior right thigh, respectively. Participants were requested to wear both accelerometers simultaneously for seven consecutive 24-hour days whilst recording their sleep times (nocturnal and napping) in a diary. Following monitor download, the raw triaxial signals from both accelerometers were calibrated to local gravity, periods of non-wear were removed, and activity-related acceleration (Euclidian norm minus one; ENMO) and thigh pitch angles were derived at minute level. The signals from the two monitors were combined and self-reported sleep times were overlaid onto these time-series. Data was summarised at participant level to derive total movement volume, and the magnitude and angle of the signals were used to derive time spent in postures and intensities of activity [26]. The variables reported are total movement volume (ENMO expressed as milligravitational units (mg)) and time (min/day) spent in sleeping, sedentary (awake sitting or lying), standing, LPA, and MVPA behaviours.

Sociodemographic questionnaire, HIV and menopausal status

Interviewer-administered questionnaires were completed and captured onto REDCap [28]. Data collected included age, current employment (employed/not employed), smoking (current smoker/non-smoker) and alcohol use (consume/do not consume). All participants who did not know their human immunodeficiency virus (HIV) status underwent a HIV rapid test (one Step HIV ½ Whole Blood/Serum/Plasma Test: Wondfo Biotech, Co., Ltd, Guangzhou, China), with pre and post-test counselling by a trained HIV counsellor. If the participant was HIV positive, they continued in the study and were referred to a local clinic for follow-up testing and counselling. Women were classified into either pre-, peri- and post-menopausal categories using date of last menstrual period [29]. Women who were on hormonal contraceptives, hormone replacement therapy or who had a hysterectomy were not classified (n=48).

Statistical Analysis

Descriptive statistics

All normally distributed and skewed continuous data are reported as mean ± standard deviation (SD) and median (25th and 75th percentile), respectively and categorical data are presented as n (%). Differences in PA across FM% were observed in men and women, thus PA patterns and sociodemographic characteristics were stratified by sex and assessed between groups separated into quartiles of total body FM%. A Chi-squared test was used to compare differences across quartiles of FM% for potential covariates such as HIV status, employment, smoking, alcohol consumption and menopausal status. As all data were skewed, differences between FM% groups were analysed using Kruskal-Wallis test with Bonferroni correction for pairwise comparisons. Spearmans correlations were used to observe the associations between total body FM% and total movement volume in both men and women. Statisical analysis was completed using IBM SPSS statistics (Version 25, Statistical Package for the Social Sciences, Chicago, IL, USA). Significance was set at $p<0.05$.

Regressions and isotemporal substitution

Quantile regression at the median (50th percentile) was used to determine the association between physical behaviours and adiposity variables due to the non-normal distribution of the residuals in an OLS linear regression model. All regression models were performed in men and women separately. Firstly, the dependent variables of total (FMI and FM%) and regional (trunk (kg), leg (kg), VAT and SAT) adiposity were regressed against total movement volume as the independent variable, adjusting for age, employment status, smoking and HIV status (Model 1), variables previously shown to be associated with total PA and/or MVPA [30,31]. Model 2 further adjusted for FMI, to understand if the association between regional adiposity and total movement volume was independent of total body adiposity. Menopausal status (women only) and alcohol intake did not significantly contribute to the regression models and were removed as covariates. Data are reported as coefficients and 95% confidence intervals (95% CI).

Secondly, isotemporal substitution was used to assess the association between total adiposity (FMI and FM%) and the theoretical effect of reallocating 30 minutes in one physical behaviour (sleep, sitting/lying, standing, LPA and MVPA) with the same amount of time spent in another behaviour. Accordingly, all physical behaviours that encompass the full 24 hour day were included in the model and the coefficients represent the estimated effects of substituting one physical behaviour category for a single excluded physical behaviour category. Fat mass (FM%) and FMI were the only variables used in the isotemporal substitution as based on the regression models described above the relationships with total physical activity and regional adiposity were driven by total body fatness. Separate regressions were completed in men and women and the coefficients (95% confidence intervals; CI) reported represent the replacement of 30 minutes of sitting/lying with 30 min of standing, LPA or MVPA; 30 minutes of standing with 30 minutes of LPA or MVPA; and 30 min of LPA with 30 minutes of MVPA. This analysis was conducted using quantile regression at the 25th, 50th and 75th percentile of total body fatness (FM% or FMI), adjusting for age, employment, smoking and HIV status.

RESULTS

Physical activity and sociodemographic characteristics across quartiles of total body fat mass (%)

The prevalence of overweight and obesity were higher in women (88.7%) than men (47.9%). On average men and women spent similar amounts of time sitting/lying (10.8 vs. 10.1 hour/day) and in LPA (108 vs. 118 min/day), but men accumulated more time in MVPA than women (52 vs. 32 min/day). The PA patterns and sociodemographic characteristics of men (Table 1) and women (Table 2) are presented according to quartiles of FM%. Differences in measures of body fat distribution (trunk and leg fat, VAT and SAT) were evident in both men and women across quartiles of FM%. In particular, when compared to the lowest quartile of FM%, men in the upper quartile had higher central (kg and %FM) and lower peripheral fat mass (%), while the women in the upper quartile of FM% showed higher central VAT and SAT and no difference in peripheral fat. Men in the higher FM% quartiles were older and less likely to smoke or have HIV compared to those in the lower FM% quartiles. Men in the lowest FM% quartile spent less time sitting/lying and more time in MVPA and higher total movement volume compared to men in FM% quartiles 3 and 4. In women, there are no differences in sociodemographic characteristics between FM% quartiles. Women in the lowest FM% quartile had higher total movement volume and spent less time sitting/lying, and more time standing and in MPVA, compared to women in the highest FM% quartile. There were no differences in LPA between the quartiles of FM% in either men or women.

Association between total movement volume and total and regional adiposity

The associations between total movement volume, and total and regional adiposity in men and women are presented in Table 3. In men, total movement volume was inversely associated with total body fatness (FMI and FM%) and all absolute measures of regional adiposity (Model 1). Similar, but weaker associations were shown for women, except for SAT which was not associated with total movement volume (Model 1). When adjusting for FMI, the associations between regional adiposity and total movement volume (Model 2) were no longer significant in both men and women. The correlation between total movement volume and FM% in both men (Rho=-0.189; $p<0.001$) and women (Rho=-0.195; $p=0.001$) is represented graphically in Figure 1.

Isotemporal substitution was used to explore the reallocation of physical behaviours in participants with lower (25th), median (50th) and higher (75th) percentiles of total body fat mass (%) (Figure 2). This approach was chosen due to the large variability in total body fat mass and PA profiles in both men and women. In men, reallocating sitting/lying time to standing or LPA was not associated with FM%. However across all percentiles of FM%, reallocating 30 min of sitting/lying time to MVPA was associated with lower FM% (50th; β= -1.0 [95% CI: -1.6 to -0.4]). In men, there were no significant associations when reallocating time spent standing to LPA, while the reallocation of 30 min standing time to MVPA was associated with lower FM% at the lowest (25th; β= -0.8 [95% CI: -1.6 to -0.03]) and median (50th; β= -1.0 [95% CI: -1.7 to -0.3]) percentiles of FM%. The reallocation of 30 mins of LPA to MVPA was associated with 0.9% lower FM% only in the men at the median percentile of FM% (50th; β= -0.9 [95% CI: -1.6 to -0.2]).

In women, the association between the reallocation of physical behaviours and FM% was predominantly observed in participants in the higher percentile of FM%. The reallocation of 30 min of sitting/lying time to standing (50th; β= -0.3 [95% CI: -0.5 to -0.003]; 75th; β= -0.3 [95% CI: -0.5 to -0.1]) or MVPA (75th; β= -1.4 [95% CI: -2.2 to -0.2]) were associated with lower FM%. Interestingly, reallocating 30 min of sitting/lying to LPA, and standing to LPA, was associated with a 0.4% (75th; β= 0.4 [95% CI: 0.03 to 0.8]) and 0.7% (75th; β= 0.7 [95% CI: 0.3 to 1.1]) higher FM, respectively. The reallocation of 30 min standing to MVPA and 30 min LPA to MVPA were associated with a 1.1% (75th; β= -1.1 [95% CI: -1.9 to -0.3]) and 1.8% lower FM% (75th; β= -1.8 [95% CI: -2.8 to -0.8]), respectively. Isotemporal substitution outcomes were similar when using FMI in both men and women and results are shown in Table S1.

DISCUSSION

This study reports novel data on the association between objectively measured physical behaviours and DXA-derived measures of adiposity in middle-aged and older men and women (aged between 41-72 years) from a low-resourced African community. We firstly showed that the association between total PA and regional adiposity was mediated by total body fat mass in men and women. Secondly, we highlight that the strongest association with lower FM% was for the reallocation of sedentary time to MVPA. Thirdly, LPA likely reflects transport and/or occupational related activities that represent requirements of daily living in a low-income setting, and these activities were not associated with total adiposity in both men and women. Although, the association between PA behaviours and FM differed between men and women, the overall public health message is similar; that reallocating sedentary time to MVPA is the behaviour change that is most strongly associated with a lower FM% in both men and women.

In South Africa, 68% of women and 31% of men are living with overweight or obesity, with the mean BMI of our cohort (men 24.5 kg/m^2; women 32.6 kg/m^2) representative of the national average [1-3]. We have shown that a lower level of total PA is associated with higher FM% in both men and women. Further, that the association between DXA-derived abdominal VAT and SAT, and objectively measured total PA is mediated by total body fat mass. In comparison, similar results have shown that the relationship between daily physical activity energy expenditure and abdominal VAT and SAT is mediated by BMI in an adult Inuit population from Greenland [19]. Whole-body fat oxidation rates increase with prolonged exercise or PA, and exercise training leads to a reduction in total adiposity, even in the absence of weight loss [32]. Further, a reduction in VAT has shown to be associated with an overall weight reduction in response to aerobic exercise interventions [32,33].

Accordingly, the reallocation of physical behaviours in the current study were explored in association with total body adiposity. A meta-analysis in youths identified that the greatest magnitude was observed when replacing 60 minutes of sedentary time with 60 minutes of MVPA was associated with a 4.5% reduction in FM [34] and 15-year follow-up of middle-aged men and women from a high-income setting report that and that replacing sedentary time with MVPA reduced CVD mortality [35]. In support of these findings, our study shows that replacing 30 minutes of sedentary or standing time with the same amount of time in MVPA in men was associated with ~1% lower FM. We also showed that the benefit of time reallocation from sedentary or standing to MVPA was only evident in women with a higher FM% (median FM, 50.2% and BMI, 38.2 kg/m^2). These women had the lowest levels of total

PA, standing and MVPA (less than 30 min per day) and the highest sedentary time (~10.8 hours/day), and therefore it may be that these women benefit the most from increasing PA, in particular MVPA. In comparison, although the men in the highest FM% quartile also had the lowest MVPA and higher sedentary time there were differences in total PA, sedentary time and MVPA across the different levels of adiposity. These results highlight key physical behaviours that need to be targeted for a reduction in adiposity in ageing adults.

The inverse association between MVPA and FM% may also suggest potential for a reduction in the risk for developing obesity-related non-communicable diseases such as diabetes and heart disease [36]. Specifically, longitudinal analyses in healthy adults from middle-to-upper socioeconomic strata have shown that over a ~2 year follow-up period, for every 1% increase in total body fat mass there was a 4%, 5% and 10% higher risk of developing hypertension, metabolic syndrome and hypercholesterolemia, respectively [36]. Although we also show that greater MVPA was associated with lower FM%, our study reports appropriate levels of MVPA (~52 min/day in men and 32 min/day in women), but this is in addition to a high sedentary time of 10.7 and 10.1 h/day in men and women, respectively. A recent systematic review and meta-analysis has shown that high levels (~60–75 min/day) of moderate intensity PA eliminates the risk of mortality that is associated with high sitting time (>8 h/day) [37]. Even though the majority of men and women in the current study will be meeting international physical activity guidelines this may not be sufficient to attenuate the effects of their excessive sedentary time on overall risk of morbidity and mortality. The current WHO guidelines acknowledge the interaction between sedentary behaviour and MVPA [38]. Although these guidelines support the implementation of public health programmes and policies aimed at increasing MVPA and limiting sedentary behaviour, there is still no consensus on time limits of sedentary behaviour, what constitutes as too much sedentary behaviour and how this may differ according to physical activity levels [38]. Physical activity levels vary greatly in Africa, with participation in leisure time activity consistently low [39]. Rather MVPA is performed through manual labour work-related activities and LPA is dominated by transport and work-related activities and reflect a behaviour that is a necessity rather than a choice [39,40]. Indeed, interventions designed to alter movement patterns and behaviours need to conducted in collaboration with communities to ensure a context specific approach for uptake and sustainability.

Interestingly, we show that replacing any behaviour with LPA was not associated with FM% in the men, and in women with a high BMI (~37.1 kg/m^2) it was associated with an increase in FM%. Physical activity is influenced by a complex interaction of biological, social and environmental factors [40,41]. As such, the determinants and patterns of physical activity, and its relative contribution to the burden of non-communicable diseases and obesity, will likely differ within and between African countries at varying stages of economic development and diverse sociocultural contexts [15,42,43]. Unsurprisingly, when comparing the physical behaviour profile across the quartiles of total body fatness in both men and women, those with highest FM% participated in less MVPA and were more sedentary. Moreover, compositional analysis has reported that for a reduction in body fat, 8-min/day of sedentary time is required to be reallocated to MVPA; however, when reallocating sedentary time to LPA, more than 10 times the volume (>80 min/day) is required for the same effect [44] and a larger sample size may be required in the current study to identify an association between LPA and FM% in both men and women. This highlights the importance of physical activity intensity and the substantial benefits of reallocating sedentary time to MVPA, rather than LPA. Accordingly, our results, alongside previous studies [34,44] reinforces the importance of reallocating time to MVPA for future interventions in middle-aged and older adults aimed at reducing fat mass. Regardless, the recommendation from the WHO suggests that any activity (including LPA) is better than none. This is based on data showing that replacing sedentary time with LPA has a beneficial effect on both all-cause mortality and CVD mortality [35] and that overall volume of PA is strongly associated with mortality, regardless of intensity [45].

Although the current study is cross-sectional and causal conclusions are not possible, we present novel data on the relationship between objectively measured physical activity and DXA-derived measures of total body fatness and regional adiposity in men and women from a low-resourced African setting. Currently, there are recognised global transformations in addressing obesity, food practices, mental health, the physical environment and physical activity patterns, but this does not ensure that universal interventions will be effective across populations, with many arguing that contextual factors matter [40,41,46]. Accordingly, the design and success of physical activity promotion strategies requires community collaboration for an improved understanding of the physical activity patterns and domains of African populations and their multiple determinants; with the development of context relevant interventions and longitudinal analysis required. Regardless, our recommendations for middle-aged and older adults are similar to the new WHO guidelines, which recommend a reduction in sedentary time for the reallocation into any PA behaviour, in particular MVPA.

Acknowledgements: We are grateful to the participants, as well as the DPHRU field staff.

Funding: The study was funded by the South African Medical Research Council (SAMRC) with funds received from the South African National Department of Health, the UKMRC (via the Newton Fund), and GSK Africa Non-Communicable Disease Open Lab (via a supporting Grant project no: ES/N013891/1). SB, KWe and AS were supported by the UK Medical Research Council (MC_UU_12015/3) and the NIHR Cambridge Biomedical Research Centre (IS-BRC-1215-20014). Supplementary funds were also received from the South African National Research Foundation (NRF; Grant no: UID:98561). Any opinion, finding and conclusion or recommendation expressed in this material is that of the author(s) and the NRF does not accept any liability in this regard.

Author's contributions: AEM, JHG and LKM conceived the study. NCK, MS, JHG and LKM were involved in data collection. AS, KW and SB processed the physical activity data. All authors were involved in interpreting the results and drafting the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Competing Interests: The authors declared no competing financial interests in relation to the work described.

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Table 1: Physical activity and sociodemographic characteristics across quartiles of fat mass in men.

Variables	Total (n=384)	Quartiles of fat mass (%) Quartile 1 (n=96)	Quartile 2 (n=97)	Quartile 3 (n=96)	Quartile 4 (n=95)	P value
Age (years)	53 (48-59)	51 (47-57)	51 (48-57)	55 (50-61) *	55 (49-61) *#	**0.001**
Fat mass (%)	26.0 (20.2-30.6)	16.4 (14.9-18.3)	23.5 (22.1-25.0)	28.1 (27.1-29.3)	33.4 (32.0-35.1)	**-**
Fat mass (kg)	17.3 (11.3-22.8)	8.6 (7.4-10.1)	14.8 (12.5-16.7)	20.0 (17.6-21.8)	28.0 (24.7-32.6)	**<0.001^**
Fat Mass Index (kg/m^2)	5.8 (3.8-7.9)	2.9 (2.5-3.4)	5.0 (4.3-5.6)	6.8 (6.2-7.5)	9.6 (8.6-10.8)	**<0.001^**
Trunk Fat (kg)	7.9 (4.9-11.1)	3.7 (3.3-4.2)	6.7 (5.4-7.8)	9.5 (7.9-10.6)	13.8 (11.4-16.3)	**<0.001^**
Trunk Fat (%)	46.2 (43.0-49.7)	43.4 (40.8-46.6)	44.7 (42.1-47.8)	47.7 (43.9-51.0) *#	49.2 (46.2-51.3) *#	**<0.001**
Leg Fat (kg)	7.0 (4.9-9.1)	3.7 (3.1-4.4)	6.2 (5.4-7.1)	7.8 (6.9-9.0)	11.0 (9.5-13.0)	**<0.001^**
Leg Fat (%)	41.3 (38.1-44.4)	43.2 (40.3-46.0)	42.7 (38.8-44.9)	40.7 (37.1-43.6) *#	39.2 (37.0-41.9) *#	**<0.001**
VAT (cm^2)	71.9 (48.2-110.6)	41.3 (34.2-47.8)	63.8 (50.2-81.1)	91.1 (68.4-114.6)	126.5 (102.3-157.2)	**<0.001^**
SAT (cm^2)	184.5 (88.3-262.4)	59.1 (44.5-70.9)	138.5 (101.3-178.4)	220.4 (189.5-255.0)	335.6 (281.7-390.3)	**<0.001^**
BMI (kg/m^2)	24.5 (20.8-28.3)	19.6 (17.8-21.0)	22.7 (21.0-25.3)	25.9 (23.9-27.9)	30.6 (27.8-33.6)	**<0.001^**
Height (m)	1.71 (1.67-1.75)	1.71 (1.67-1.77)	1.71 (1.67-1.75)	1.71 (1.67-1.75)	1.71 (1.66-1.74)	**0.551**
Weight (kg)	71.4 (60.5-82.5)	58.0 (52.5-62.0)	68.8 (60.5-74.0)	76.7 (68.7-81.8)	87.7 (80.4-101.20)	**<0.001^**
Employed, n (%)	151 (39.3)	31 (32.3)	40 (41.2)	40 (41.7)	40 (42.1)	0.446
Smoker, n (%)	197 (51.3)	71 (94.0)	63 (65.0)	38 (39.6) *#	25 (26.3) *#	**<0.001**
HIV positive, n (%)	83 (21.6)	30 (31.3)	27 (27.8)	13 (13.5) *	13 (13.7) *	**0.002**
Consumes Alcohol, n (%)	283 (73.7%)	72 (75.0)	76 (78.4)	71 (74.0)	64 (67.4)	0.371
Sleep (h/day)	7.07 (6.18-7.93)	7.32 (6.45-8.25)	6.9 (6.13-7.94)	7.09 (6.30-7.98)	6.85 (5.87-7.64)	0.115
Sitting/lying (h/day)	10.7 (9.4-12.06)	10.41 (9.42-11.58)	10.8 (9.37-12.06)	10.45 (9.10-11.8)	11.3 (9.7-12.61) *	**0.042**
Standing (h/day)	3.23 (2.26-4.31)	3.15 (2.11-4.20)	3.04 (2.12-4.00)	3.415 (2.61-4.40)	3.20 (2.18-4.33)	0.309
LPA (h//day)	1.79 (1.34-2.31)	1.76 (1.29-2.24)	1.84 (1.40-2.35)	1.77 (1.31-2.87)	1.89 (1.34-2.29)	0.962
MVPA (min/day)	51.9 (27.9-78.5)	58.1 (35.6-98.2)	56.3 (33.6-79.7)	42.5 (18.1-70.8) *	45.3 (21.4-71.6) *	**<0.001**
Total movement volume (mg)	14.3 (11.1-17.5)	15.5 (11.4-20.1)	14.6 (11.7-18.9)	12.8 (10.4-16.3) *	13.9 (11.1-15.9) *	**0.005**

All data are reported as median (25th-75th percentile). Abbreviations: Body Mass Index, BMI; Visceral Adipose Tissue, VAT; Subcutaneous Adipose Tissue, SAT; Light Physical Activity, LPA; Moderate-Vigorous Physical Activity, MVPA; Human Immunodeficiency Virus, HIV; milligravitational units, mg.

Significantly different to Quartile 1 *; Significantly different to Quartile 2 #; All groups significantly different ^.

Table 2: Physical activity and sociodemographic characteristics across quartiles of fat mass in women.

		Quartiles of fat mass (%)				
Variables	**Total (n=308)**	**Quartile 1 (n=77)**	**Quartile 2 (n=78)**	**Quartile 3 (n=73)**	**Quartile 4 (n=80)**	**P value**
Age (years)	53 (49-58)	53 (49-57)	53 (48-58)	53 ± 6	54 (50-59)	0.481
Fat mass (%)	45.3 (41.4-48.4)	38.9 (36.6-40.1)	43.6 (42.8-44.6)	46.7 (46.1-47.5)	50.2 (49.4-51.8)	-
Fat mass (kg)	34.9 (27.6-43.1)	23.5 (20.1-28.1)	32.8 (28.8-36.4)	37.5 (34.5-43.4)	46.4 (39.8-50.8)	**<0.001^**
Fat Mass Index (kg/m^2)	14.0 (11.2-16.7)	9.5 (8.1-10.8)	12.8 (11.6-14.5)	15.5 (14.3-16.7)	18.7 (16.2-20.4)	**<0.001^**
Trunk Fat (kg)	15.4 (11.8-18.5)	10.2 (7.2-12.6)	14.5 (12.8-16.9)	17.0 (14.9-18.7) *#	20.1 (16.9 (22.2) *#	0.004
Trunk Fat (%)	43.1 (39.2-47.0)	42.4 (37.3-46.7)	44.0 (41.5-48.5)	44.4 (40.2-48.0)	41.7 (38.6-44.8) #	**<0.001**
Leg Fat (kg)	14.9 (12.0-18.7)	11.0 (9.2-12.2)	13.5 (12.5-15.5)	16.3 (14.2-18.9)	20.6 (17.2-25.1)	**<0.001^**
Leg Fat (%)	44.5 (40.4-47.9)	45.8 (41.2-50.4)	42.4 (38.3-46.8) *	43.5 (38.1-46.8) *	45.7 (42.6-50.3) #	**<0.001**
VAT (cm^2)	101.6 (69.4-130.9)	63.9 (43.9-88.8)	109.0 (78.0-125.4)	104.7 (84.9-136.3) *	123.8 (95.6-159.6) *#	**<0.001**
SAT (cm^2)	462.4 (352.8-562.1)	292.8 (233.2-356.0)	436.6 (369.8-484.0)	509.9 (457.1-573.5) *#	607.0 (499.4-651.0) *#	**<0.001**
BMI (kg/m^2)	32.6 (28.2-37.1)	26.3 (23.1-28.7)	31.3 (28.4-35.0)	34.9 (33.5-37.5)	38.8 (34.3-41.8)	**<0.001^**
Height (m)	1.58 (1.54-1.63)	1.59 (1.55-1.62)	1.58 (1.55-1.63)	1.58 (1.53-1.63)	1.58 (1.54-1.61)	**0.284**
Weight (kg)	80.0 (70.8-94.9)	66.8 (57.1-75.6)	78.2 (70.2-87.3)	84.3 (78.4-98.2) *#	96.9 (84.3-105.7) *#	**<0.001**
Employed, n (%)	128 (41.6)	35 (45.5)	30 (38.5)	37 (50.7)	26 (32.5)	0.112
Smoker, n (%)	21 (6.8)	10 (13.0)	5 (6.4)	4 (5.5)	2 (2.5)	0.066
HIV positive, n (%)	62 (20.1)	22 (28.6)	15 (19.2)	14 (19.2)	11 (13.8)	0.138
Consumes Alcohol, n (%)	92 (28.9)	30 (39.0)	18 (23.1)	19 (26.0)	25 (31.3)	0.148
Post-menopausal, n (%)	159 (51.6)	42 (54.6)	39 (50.0)	38 (52.1)	47 (58.8)	0.094
Sleep (h/day)	6.90 (6.13-7.66)	6.98 (6.01-7.84)	6.84 (6.21-7.68)	418.5 (381.3-457.4)	410.5 (361.0-451.4)	0.873
Sitting/lying (h/day)	10.07 (8.98-11.64	9.32 (8.67-10.72)	9.89 (8.70-11.28)	10.20 (9.00-11.75)	10.99 (9.82-11.94) *#	**<0.001**
Standing (h/day)	4.22 (3.22-5.45)	4.40 (3.64-5.62)	4.60 (3.60-5.66)	4.08 (3.09-5.34)	3.76 (2.63-4.92 *#	**0.011**
LPA (h/day)	1.95 (1.47-2.49)	2.09 (1.68-2.72)	1.73 (1.42-2.48)	1.89 (1.44-2.44)	113.6 (81.2-149.9)	0.098
MVPA (min/day)	31.7 (16.8-47.3)	36.8 (25.7-60.0)	30.8 (15.2-45.6)	33.7 (19.1-47.9)	26.3 (11.9-40.8) *	**0.002**
Total movement volume (mg)	12.2 (10.0-14.5)	13.5 (11.1-15.9)	11.7 (9.9-13.7) *	12.3 (9.9-14.2)	11.3 (9.2-13.7) *	**0.001**

All data are reported as median (25th-75th percentile). Abbreviations: Body Mass Index, BMI; Visceral Adipose Tissue, VAT; Subcutaneous Adipose Tissue, SAT; Light Physical Activity, LPA; Moderate-Vigorous Physical Activity, MVPA; Human Immunodeficiency Virus, HIV; milligravitational units, mg.

Significantly different to Quartile 1 *; Significantly different to Quartile 2 #; All groups significantly different ^.

Table 3: The association between total movement volume (ENMO) and total and regional adiposity in men (n=384) and women (n=308).

	MEN			WOMEN		
Model 1	**β**	**95%CI**	**p-value**	**β**	**95%CI**	**p-value**
Fat Mass Index (kg/m^2)	-0.1	-0.2, -0.1	<0.001	-0.3	-0.5, 0.1	0.003
Fat Mass (%)	-0.3	-0.4, -0.1	<0.001	-0.2	-0.5, -0.0	0.047
Trunk Fat (kg)	-0.2	-0.2, -0.1	<0.001	-0.3	-0.5, -0.1	0.004
Leg Fat (kg)	-0.1	-0.2, -0.1	<0.001	-0.3	-0.5, -0.1	0.003
VAT (cm^2)	-1.4	-2.3, -0.5	0.003	-3.2	-5.1, -1.2	0.002
SAT (cm^2)	-4.3	-6.2, -2.3	<0.001	-4.5	-11.1, 2.0	0.175
Model 2	**β**	**95%CI**	**p-value**	**β**	**95%CI**	**p-value**
Trunk Fat (kg)	-0.0	-0.0, 0.0	0.657	0.0	-0.1, 0.1	0.868
Leg Fat (kg)	0.0	-0.0, 0.0	0.211	-0.0	-0.1, 0.1	0.829
VAT (cm^2)	-0.1	-0.5, 0.2	0.464	-0.9	-2.5, 0.7	0.282
SAT (cm^2)	-0.0	-0.6, 0.6	0.995	1.9	-0.6, 4.3	0.130

Beta coefficients are difference in median (95% CI) adiposity measure per 1 mg difference in total physical activity.
Model 1: adjusting for age, employment, smoking and HIV status
Model 2: adjusting for age, employment, smoking, HIV and FMI
Abbreviation: VAT, Visceral adipose tissue; SAT, Subcutaneous adipose tissue

Figure Legends

Figure 1: Spearmans correlations between total movement volume and fat mass in men (a) and women (b).

Figure 2: Coefficients (95% CI) represent the association between time (30 minutes) reallocation of physical behaviours in participants with lower (25th) median (50th) and higher (75th) percentiles of total body fat mass (%). All regressions are adjusted for age, employment, smoking status and HIV status. Significant coefficients $p<0.05$ in men * and women $^{\#}$.