# A systematic review of the impact of the first year of COVID-19 on obesity risk factors: A pandemic fuelling a pandemic?

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lay summary: Systematic review demonstrating the impact of the first year of COVID-19 on key obesity risk factors, including diet, physical activity, depression and financial stress.

Conflicts of interest: NFD, CB, TC and FF have none to declare

We declare no external funding for the preparation of this manuscript

Running head: The impact of COVID-19 on obesity risk factors

Obesity is increasingly prevalent worldwide. Associated risk factors including depression, socioeconomic stress, poor diet and lack of physical activity have all been impacted by the COVID-19 pandemic. This systematic review aims to explore the indirect effects of the first year of COVID-19 on obesity and its risk factors. Literature research of PubMed and EMBASE was performed from 1st January 2020 to the 31st December 2020 to identify relevant studies pertaining to the first year of the COVID-19 pandemic- PROSPERO (CRD42020219433). All English-language studies about weight change and key obesity risk factors (psychosocial and socioeconomic health) during the COVID-19 pandemic were considered for inclusion. Of 805 full-text articles that were reviewed, 87 were included for analysis. The included studiesobserved increased food and alcohol consumption; increased sedentary time; worsening depressive symptoms and increased financial stress. Overall, these results suggest that COVID-19 has exacerbated the current risk factors for obesity and is likely to worsen obesity rates in the near future. Future studies, and policy makers, will need to carefully consider their interdependency to develop effective interventions able to mitigate the obesity pandemic.

**Keywords:** COVID-19, Obesity, depression, physical activity, financial stress, diet

**Introduction**

With over 268 million infections and 5.2million deaths worldwide(1), COVID-19 is one of the most serious infectious disease outbreaks in recent history. Even before the declaration of pandemic status by the World Health Organization (WHO) on 11 March 2020, many countries had begun to impose social distancing measures (SDM) in an attempt to reduce disease incidence. Understandably, the attention of scientists has focussed on how to limit the short-term consequences of COVID-19, which were mitigated by SDMs until vaccines were released. As a result, the scientific community has prioritized the research on the determinants of mortality and morbidity of COVID-19 over the long-term implication of the virus and the necessary countermeasures, such as SDMs.

Obesity is defined by the WHO as abnormal or excessive fat accumulation that presents a risk to health, marked by a body mass index (BMI) greater than 30kg/m2, and has reached epidemic proportions (2). Statistics suggest that the prevalence continues to follow an increasing trajectory with over 650 million adults having obesity in 2016 (3). Various models are attempting to predict the future burden of obesity, with projections ranging from 44% to over 50% of the population (4,5), though all agree that it is likely to encompass a significant proportion of the population. Many chronic illnesses are adversely affected by carrying excess body fat, with obesity being linked to cancers, cardiovascular disease, hypertension and osteoarthritis as well as a strong association with metabolic syndrome (6).

Among the factors that can increase the risk of obesity, some seem to play a more prominent role than others. For example, depression has repeatedly been shown to have bidirectional associations with obesity and overweight (7). The effect of depression on obesity is likely multifactorial, involving neuroendocrine disruption with a chronic state of elevated cortisol (8); lifestyle changes with reduced desire to exercise and increase in emotional eating (9); and in some cases the use of antidepressants (10). Socioeconomic status has long been linked inversely to bodyweight (11) and again is multifactorial with effects mediated through fewer opportunities for physical activity and healthy food, education and poorer mental health. Not only is low physical activity a risk factor for obesity, but also an important modulator of risk conferred by excess weight (12), and so the potential effect of lockdowns on sedentary behaviour may act as a multiplier for poor outcomes.

As a result of such health implications, obesity imposes a considerable economic burden right from the individual through to national levels (13). In addition to direct effects on excess care needs, costs are also incurred through time off work, lower productivity at work and associated disabilities. These costs have previously been estimated on a global scale to be 2.8% of global gross domestic product (GDP) at US $2 trillion (14), since which time the proportion of the population having obesity has continued to rise.

The direct implications of COVID-19 on health and wellbeing are well-discussed elsewhere - what remains to be seen is whether this pandemic is exacerbating the growing obesity pandemic. A systematic review and meta-analysis by Bakaloudi et al. suggest an overall global trend of weight gain during the first COVID-19 lockdown (15). To date, no studies have assessed the indirect impact of the COVID-19 pandemic, such as its SDMs, on obesity risk factors that could explain this trend. Therefore, the objectives of this paper are to fill this gap by describing the effects of the COVID-19 pandemic and the needed countermeasures on obesity risk factors to explore underpinning mechanisms of the general trend of weight gain during the COVID-19 pandemic.

**Methods**

**Search strategy and study selection**

Literature research of PubMed and EMBASE was performed from 1st January 2020 to the 31st December 2020 to identify relevant studies pertaining to the first year of the COVID-19 pandemic. The study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (16). The protocol details were registered prospectively on PROSPERO (CRD42020219433).

The following keywords were used in the search criteria: *("Sars-Cov-2" OR "covid-19") AND ("quarantine" OR "lockdown" OR "BMI" OR "body mass index" OR "obese" OR "obesity" OR "overweight" OR "weight gain" OR "physical activity" OR "depression" OR "depressive symptoms" OR "redundancy" OR "redundant" OR "low income" OR "sedentary behaviour").* The search was limited to the English language, full-text availability and human subjects. The abstracts of the resulting studies were manually searched to identify relevant studies, with NFD, CB, and TC applying inclusion/exclusion criteria to the full text to select the final studies.

**Inclusion and exclusion criteria**

All English-language studies about weight change and key obesity risk factors (psychosocial and socioeconomic health) during the COVID-19 pandemic were considered for inclusion. Studies had to be comparative (baseline vs during the pandemic) with cross-sectional and longitudinal studies considered. At least one of the following factors had to be included i) weight (either anthropometry or self-report) ii) dietary habit iii) physical activity iv) depressive symptoms or v) financial status. In cases of depression, a validated depression measure had to be used (such as PHQ-9) with any unvalidated questionnaires excluded (17–19). Qualitative studies, case reports and reviews were excluded. Papers including pregnant women were also excluded due to the confounding effect of pregnancy over the outcomes of interest.

**Data extraction**

Data extraction was performed independently by NFD, CB and TC with any ambiguity resolved via consensus. Each included study had the following extracted: i) Study ID (author name and date) ii) Country iii) Study type iv) Sample size v) Sample characteristics (age, sex and occupation of sample) vi) assessment tool and vii) outcome.

**Data synthesis and quality assessment**

Results were summarised via a narrative review, a quantitative synthesis was not attempted due to the heterogeneity of the samples and methodology between studies in the measurement of the relevant factors (e.g. depression). Study quality was assessed using a modified Newcastle Ottawa Scale (20) which were performed by NFD, CB, TC and any ambiguity was resolved via consensus (see Supplementary Material). The score used was based on the selection of the study sample using four criteria, the comparability of the outcome groups and assessment of the outcome. The final score ranged from 0-10 points, with 0-4 considered unsatisfactory, 5-6 considered satisfactory, 7-8 considered good quality and 9-10 points considered very good (20).

**Results**

The electronic search conducted identified 3773 studies (EMBASE: 1383; PubMed 2390). After removing duplicates, 3154 studies were screened using a two-step approach. First, the title and abstract of each paper were screened followed by a full-text screening if the inclusion-exclusion criteria were met. Based on screening the title and abstract, 805 (PubMed: 626 EMBASE: 179) potentially eligible studies were identified. Full-text screening resulted in a total of 87 studies that were included in the systematic review (Figure 1). A summary of the characteristics of included studies is presented in Tables 1-5.

**Characteristics of included studies**

Of the 87 studies included, fourteen looked at the impact of COVID-19 on BMI directly (21–34), eighteen looked at physical activity during the pandemic (31,35–51)eleven looked at the financial impact (52–62), twenty-seven at diet (23,26,33,50,61,63–84)and seventeen at depression (57,85–100). None of the 87 studies investigated the link between the obesity risk factors and obesity itself. The majority of studies were conducted in the USA (n=17), China (n=13), Spain (n=12), Poland (n=8) and Italy (n=8). The sample size ranged from 164,101 (100) to 18 participants (40). In terms of quality assessment there were a total of two unsatisfactory studies (51,91), thirty-six satisfactory (21,23,25,26,28,33,36,37,38,40,41,43,44,47,48,52,53 54,55,56,57,59,60,61,62,63,64,67,68,71,77,78,81,82,83,92), forty-two good quality (22,24,27,29,30,31,32,34,39,42,45,46,49,50,57,58,61,65,66,69,70,72,73,74,76,79,80,84,85,86,87,88,89,90,93,94,95,96,97,98,100), two very good quality (35,99)

Tables 1-5 shows further details on the characteristics of the included studies.

**Relation between COVID-19 and weight**

A summary of the weight changes reported during COVID-19 is summarised in Table 1. A total of fourteen studies looking at the impact of COVID-19 on weight directly were included(21–30,32–34,75). Overall there was a general trend of weight gain during the pandemic, with twelve studies reporting this. While three studies included student populations (29,32,34) and one study looked at diabetic patients (28), the majority of the studies focused on the general population (22–24,26,27,31). Different results were seen in Spain, in which one study reported no change in weight in the Spanish general population (33). This study by Lopez-Moreno et al., focused on BMI change, whereas the other three studies (21,30,31) used self-reported weight.

**Obesity risk factors and COVID-19:**

**Relation between COVID-19 and physical activity:**

A summary of the changes in physical activity during the first year of COVID-19 is summarised in Table 2. A total of eighteen studies were included that looked at the relationship between COVID-19 and changes in physical activity and sedentary behaviour (24,36,45–52,37–44). All the eighteen studies were longitudinal and used self-reported measurements except for Wang et al. who used an accelerometer sensor to record daily step counts (35). A total of sixteen studies reported a reduction in physical activity during COVID-19, with one study showing an increase in activity (46) and one showing no change at all (40). A study of German schoolchildren aged between 4 and 17 years found an increase in active days per week, with an 11.1% increase in adherence to WHO physical activity guidelines (46). A study of high school students found no significant increment in physical activity between during COVID-19 and pre-restriction baseline, however highly active students increased their activity levels relative to baseline (47).

**Relation between COVID-19 and Diet**

Twenty-seven studies were included that investigated the impact of COVID-19 on dietary patterns, summarised in Table 4.

Favourable changes in dietary behaviour

A total of five studies reported an increase in home-cooked meals during the pandemic (23,61,68,74,80). Three studies reported an overall reduction in the frequency of fast food (26,74,79). Of the studies looking at alcohol consumption, only one study found a decrease in alcohol consumption during the pandemic in the Spanish general population (77). This decline in alcohol was correlated with higher adherence to the Mediterranean diet.

A cross-sectional study of the general population in Italy found an increase in the consumption of fruit, vegetables, nuts, legumes and a significant decrease in junk food consumption (66). Secondly, a Spanish cross-sectional study focusing on patients with Type 2 diabetes mellitus found a significant increase in vegetable consumption during the pandemic (69). Third, a study looking at healthy Chinese adults found an increase in vegetable, fruit and milk consumption (70) relative to before the pandemic. The last change reported by the studies was a reduction in overall food consumption during the pandemic (26,82). A longitudinal study of adults older than 62 years in the Netherlands found that 12% of the sample were eating less than usual. However, this change in dietary habits was not reflected by a statistically significant reduction in weight (64).

Unfavourable changes in dietary behaviour

A total of seven studies reported an increase in alcohol consumption (23,26,68,72,73,76,78). Three of the studies were of the Polish general population (23,26,68), with the remainder reporting from Spain (72), the USA (73), China (78) and Brazil (76). A total of ten studies found an increase in quantity of food consumption during COVID-19 (23,26,50,63,65,67,71,80,83,84). In particular, the most common change during the pandemic was an increase in snacking frequency, which was reported in eleven studies that included patients from a wide range of geographical areas ranging from Europe to Asia and including North America (23,26,33,61,64,69,70,74,81,83,84).

**Relation between COVID-19 and Socioeconomic status**

Eleven studies were included in this review that investigated the impact of COVID-19 on financial status, summarised in Table 4. Out of these studies, one reported a statistically significant worsening of financial wellbeing amongst 5,550 benefits-eligible university staff (94). The remaining studies did not report a p-value or 95% CI but reported a detrimental impact of COVID-19 on financial status, resulting in either reduced income (53,54,58,60,62)or job loss (56,57,59–62). Two of the papers showed that COVID-19 resulted in alarming the participant and increasing their fear of job insecurity (55,62), with Wilson et al. reporting 31.9% of participants had financial fears during the pandemic and only 19.6% of the sample having no concerns at all (55).

**Relation between COVID-19 and Depression**

Seventeen of the studies included in this review investigated the relationship between COVID-19 and depression, summarised in Table 5. Only validated depression scales were used, of which three studies used the Depression, Anxiety and Stress Scale (DASS) (85,94,97), eleven studies used the Patient Health Questionnaire (PHQ) (57,86,88,90–93,96,98–100), one study used the Children's Depression Inventory – Short Form (CDI‐S) (51), one study used the Centre for Epidemiological Studies-Depression (CES-D) (101) and one study used the Beck Depression Inventory (BDI) (89).

Ten studies reported a statistically significant increase in depressive symptoms during the pandemic (59,89,91,93–96,99,100,102). Two of the studies looked at the general population in the USA (57) and Austria (88). Three of these studies investigated clinical staff including obstetricians and midwives (96), nurses (98) and physicians (91). Four studies looked at a younger cohort of participants including school children (85) and students (86,87,100). Finally, one of the studies looked at the impact of COVID-19 on the LGBT population in the US and found a significant increase in depressive symptoms, particularly in those with a negative baseline screen (92). Although the p-value was not reported in six studies (89,90,93,97,99,100), five of them reported a trend of increased depression scores during COVID-19 (89,90,93,97,99,100). Only one study found no increase in depressive symptoms during COVID-19 and looked at US physician trainees (94).

Discussion

This systematic review of over 350,000 participants from across the globe attempted to describe the indirect impact that the SDMs due to the COVID-19 pandemic had on population bodyweight by altering the most important risk factors, namely diet, physical activity, mental health and financial status. Although the impact of the countermeasures used to curb the COVID-19 pandemic was evident on obesity risk factors**,** none of the studies included in our research explored the direct impact of the risk factors on obesity itself.

The general trend seen in included studies was a worsening in the obesity risk factors. There were however notable exceptions. A German study of schoolchildren found an improvement in physical activity (46) due to recreational sporting activities. This discrepancy is likely due to contextual factors such as how stringent the SDM measures were in the specific countries. For example, in China outdoor physical activity was banned during the first wave of COVID-19 (46).

Differences were also seen in dietary changes, with some studies showing an improvement in diet. However, those studies showing improvements in diet were looking at very different subgroups of the population (66,69,70) including the elderly or those with underlying medical conditions. The age of participants appears to have an impact, with the largest sample size studies (25,34)showing a significant weight increase in those under age 25. The same was seen in a US sample of students (35). This may reflect the widespread reduction in activity and greater sedentary time in this group of people across multiple nations (36,38,43,46,50). It may also suggest a disproportionate impact of SDM’s on the younger population. However, a comparable group of undergraduate students in Italy (30) did not show an increase in weight, arguing for a potential cultural role.

The proximity to covid exposure may have played a role in the likelihood to report increased stress or depressive symptoms, as was seen in several cohorts of healthcare workers (89,91,99). These studies did however tend to occur earlier in the course of SDMs which could also have played a role as uncertainty was at its greatest early on in the pandemic.

The COVID-19 pandemic, and its related SDMs, lead to a worsening of obesity risk factors in the majority of studies – albeit some beneficial effects were observed in the dieting domain, such as higher consumption of home-cooked meals and healthy food (e.g. vegetables). On the other hand, the overall food and alcohol consumption showed an increasing trend, which could have been either the result or the cause of poorer mental health (103).

An unavoidable consequence of the SDMs and, in the most extreme cases, of the national lockdowns was financial hardship and job loss. A large body of evidence suggests that financial stress is linked to mental illness, which then could have fuelled the obesity risk factors mentioned previously (104). Another element adding an extra level of complexity is the bi-directional relationship between financial hardship, mental illness and the other obesity risk factors, which makes it problematic to draw a conclusion on which is the leading factor during stressful circumstances, such as a pandemic.

There are several notable papers in the literature that have been published during the writing of this report which go some way to supporting our conclusions. Jia (105), Browne et al. (106) and Knebush et al. (107) all discuss similar findings with the interaction between the coronavirus pandemic and obesogenic risk factors. Jia (105) highlights the multifactorial impact of the pandemic on the obesogenic environment in adolescents, including increased sedentary time and dietary changes. Upstream factors such as changes in food environments and interaction with the built environment might help to explain some of our findings; however, as noted by Jia more modern measurement techniques are needed to better quantify this. An important issue raised is the difficulty in following up cohorts during periods of lockdown and how this will affect future data trends.

Browne et al. (106) also considers the change in the obesogenic environment affecting children during the COVID-19 pandemic. Increased stress has arisen from changes to home and school environments, in concert with less engagement in physical activity and increased familial financial stress. As we have found the case to be in adults, this review suggests that COVID-19 has exacerbated the obesity pandemic in children. An additional consideration in this paper was the deleterious impact of weight stigma which can further increase the psychological and physical sequelae of obesity.

Knebush et al. (107) again note similar patterns of reduced physical activity, increased screen time and dietary changes. School closures have had a marked impact on each of these risk factors at critical points in a child’s development.

These papers all highlight a similar pattern of an increasingly obesogenic environment that children have been subjected to during multiple SDMs throughout the pandemic. Of interest will be the effect of this in years to come as these children become adults, perpetuating the trend for increasing weight.

A BMJ feature (108) highlights the voice of Christina Marriott, chief executive of the Royal Society of Public Health, on the topic of obesity in the COVID-19 pandemic, who states that there has not been sufficient action to address the root causes of obesity. For this to happen, the complex relationship between the obesity risk factors should be explored in quantitative studies. Our review acts to emphasise the areas in which further data is required. In addition to this, there is a clear need for cost-effective policies able to mitigate the impact on obesity of stressful circumstances, such as a pandemic.

**Strengths and Limitations**

Our research is the first to attempt to summarize the multifactorial implications that the SDMs due to the COVID-19 pandemic had on obesity. A very broad search strategy was adopted to capture as thorough a picture as possible, aiming to include papers noting an association between COVID-19 SDMs, obesity, and risk factors together. None of the studies included in our research investigated the link between (a) SDMs, (b) obesity risk factors and (c) obesity itself. The absence of studies linking (a) to (b) and, thus, (c), lead us to focus our review on the impact of SDMs on obesity risk factors. As a consequence, our review cannot provide a conclusion on which elements have driven the increment in BMI during the COVID-19 pandemic (15). While this is the most important weakness of our study, our broad literature review allowed us to identify the studies on the effects of the pandemic on obesity and its risk factors.

Although our contribution is not sufficient to draw a conclusion, it represents a necessary step to develop new studies able to determine the key drivers of obesity in stressful circumstances, such as a pandemic. Besides the absence of evidence necessary to draw a conclusion, many of the included studies focussed either on self-reported body weight or BMI. Whilst these are widely used and validated measures of identifying individuals at risk of overweight or obesity, they do not account for factors that more reliably and objective link to health outcomes, such as total body fat percentage.

Another limitation of our review is the high proportion of cross-sectional studies, which makes it problematic to establish a causal clink. Likewise, the high heterogeneity in methodology, samples and socio-economic characteristics made comparisons difficult. Many of the studies had a significantly higher response rate in females, which may somewhat limit the application of our conclusions to the general population. Several studies also focussed on specific groups, many of which used healthcare workers or students. Once again this may limit the generalisability of conclusions.

These limitations are acknowledged in our quality assessment of the included studies. However, given the circumstances in which many of these studies were carried out, amid national lockdowns, in-person data collection was often unfeasible and so the majority of studies were affected by this measurement issue.

While this review does not provide a conclusive answer on the driver of obesity during the COVID-19 pandemic, it provides useful information to direct future research aiming at strengthening the link between stressful circumstances and a rise in risk factors for obesity and weight gain. This is important as establishing a link enables us to effectively target the risk factors in preventative public health measures. There is a need for longitudinal studies to elucidate the nature of the association.

**Conflict of interest:** authors report no conflicts of interest

**Acknowledgements:** F.F. conceived the idea of the study. N.F.D and C.B. designed the literature searches. N.F.D, C.B and T.C reviewed all abstracts and full-text articles. N.F.D and C.B. wrote the first draft of the manuscript. All authors read and approved the final version.

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**Table 1: Characteristics of included studies investigating the relationship between COVID-19 and weight**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study ID | Country | Study Type | No of participants | Sample characteristics | Assessment Tool | Outcome |
| Fernandez-Rio et al. 2020 (21) | Spain | Cross-sectional | 4379 | **Age:** 16-84    **Sex (F):**  2671(60.9%)    **Occupation/characteristic:** General population | Self-reported weight | No weight changes: 52.88%  Weight increase: 25.82%  Weight decrease:  21.27%  *P value NR* |
| de Luis Roman et al. 2020 (30) | Spain | Cross sectional | 284 | **Age**: 60.4 ± 10.8y  **Sex (F):** 211 (74.3%)    **Occupation/characteristic:** Obese outpatients | Self-reported weight | 36.3% reported weight gain    Increase in self-reported body weight was 1.62±0.2kg over 7 weeks of confinement  *P value NR* |
| Martinez-de-Quel et al. 2020 (31) | Spain | Longitudinal | 161 | **Age:** 35.0±11.2  **Sex (F):** 60 (37%)  **Occupation/characteristic:** General population | Self-reported weight | Significant increase in weight (p= 0.012) during lockdown |
| Lopez-Moreno et al. 2020 (33) | Spain | Cross sectional | 675 | **Age:** 39.1±12.9  **Sex (F):** 472 (70%)  **Occupation/characteristic**: General population | BMI | No significant change in BMI pre and post COVID (p=0.758) |
| Mason et al. 2020 (34) | USA | Longitudinal | 1820 | **Age:** 19.72±0.46  **Sex (F):** 1128 (62%)  **Occupation/Characteristic:** High school students | BMI | Overall significant increase in weight during COVID relative to baseline (p<0.001) |
| Yang et al. 2020 (29) | China | Cross sectional | 10082 | **Age:**  High school students: 17±1.2  Undergraduate students: 20.6±1.8  Graduates:  24.6±3.5  **Sex: (F):** 7229 (71.7%)  **Occupation/ characteristic:** Students | BMI | BMI significantly increased overall during COVID (P <0.001) in all subgroups  Prevalence of overweight/obesity significantly increased generally (p <0.001) and in high school (p <0 .01) and undergraduate students (p <0 .001). |
| Jia et al. 2020 (32) | China | Cross sectional | 10082 | **Age:** 19.8±2.3  **Sex (F):**7229 (71.7%)  **Occupation/characteristics:** Students | BMI | BMI significantly increased from 21.8 to 22.1 kg/m2 (p<0.001).  Significant increase in prevalence of overweight participants, (21.4% vs 24.6%, p<0.001) and obesity (10.5% vs 12.6%, p<0.001) |
| Pellegrini M et al. 2020 (24) | Italy | Observational Retrospective | 150 | **Age:** 47.9±16  **Sex (F):** 116 (77.3%)  **Occupation/characteristic:** Obesity outpatients | Self-reported weight | Significant increase in mean self-reported weight gain during COVID ≈1.5 kg (*p* < 0.001) |
| Gallè F et al. 2020 (25) | Italy | Cross-sectional | 1430 | **Age:** 22.9 +-3.5  **Sex (F):**  936 (65.5%)  **Characteristics:** Italian undergraduate students | BMI | No significant change in BMI (p=0.96) during COVID |
| Grabia et al. 2020 (28) | Poland | Cross sectional | 124 | **Age**: 23, (LQ-UQ 17-35)  **Sex (F):** 103 (83%)  **Occupation/characteristic**: Diabetic patients | Self-reported weight | Change in body mass  (P<0.001)  Increased during COVID:  49%  ≤5kg: 31%  >5kg:11%  No change  28%  Reduced  30% |
| Sidor A, & Rzymski P. 2020 (23) | Poland | Cross-sectional | 1097 | **Age:** 27.7 ± 9.0 (18-71)  **Sex (F):** 1043 (95.1%)  **Occupation/characteristics:** General population | Self-reported weight | Increase in weight: 29.9%  Decrease in weight: 18.6%  Those with high BMI at baseline experienced greater weight gain (p<0.05), as did those older in age (p<0.05) |
| Błaszczyk-Bębenek E et al. 2020 (26) | Poland | Cross-sectional | 312 | **Age:** 41.12 ± 13.05  **Sex (F):** 200 (64.1%)  **Occupation/characteristics:** Age >18yo, not pregnant, no diseases requiring a specific diet | Self-reported weight | Statistically significant increase in weight during confinement (Δ 0.56 ± 2.43 kg; p < 0.0001). |
| Ismail et al. 2020 (22) | Middle east and North Africa | Cross sectional | 2970 | **Age:** 18+  **Sex (F):** 2126 (71.6%)  **Occupation/characteristics:** General population | Self-reported weight | No weight changes: 43.9%  Weight increase: 30.3%  Weight decrease: 16.9%  *P value NR*  Significant association between physical activity and reported change in weight (p<0.001). |
| Pišot et al. 2020 (27) | 9 European countries (Croatia, Italy, Serbia, Slovakia, Spain, Greece, Bosnia and Kosovo) | Cross sectional | 4108 | **Age:**32.0 (13.2)  **Sex (F):** 2581 (62.8%)  **Occupation/characteristic**: General population | Self-reported weight | Increase of 0.3 (±2.2) kg during COVID-19 pandemic measures (P < 0.0008) (n=2208) |

\*p value NR: not reported

**Table 2: Characteristics of included studies investigating the relationship between COVID-19 and physical activity**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study ID** | **Country** | **Study Type** | **Sample size** | **Sample characteristics** | **Assessment Tool** | **Outcome** |
| Wang et al. 2020 (35) | China | Longitudinal | 3544 | **Age:** 51.6 ± 8.9  **Sex (F):** 1226 (34.6%)  **Occupation/characteristic:** General population | Daily step counts recorded by the accelerometer sensor | Significant decrease in daily steps during COVID:reduced by 2678 (95% CI 2582-2763) |
| Xiang M et al. 2020 (51) | China | Longitudinal | 2426 | **Age:** 6-17  **Sex (F):**  1184 (48.8%)  **Occupation/characteristics:**  Children and adolescents (6–17 years) | WHO Global Physical Activity Questionnaire | Reduction in median time spent in physical activity (minutes/week) during COVID, 540 vs 105 (p<0.001)  Increase in prevalence of physically inactive students, (21.3% vs 65.6%) *P value NR*  Increase in screen time (minutes/week) by +1730 min [or approximately 30 h] per week on average (p<0.001) |
| Sassone et al. 2020 (44) | Italy | Longitudinal | 24 | **Age:** 72±10  **Sex (F):** 7 (29%)  **Occupation/characteristic:** Patients with implantable cardioverter-defibrillators | ICD-embedded accelerometric sensors | Significant reduction in physical activity during forced confinement (*p=0.0001)* |
| Tornaghi et al. 2020 (47) | Italy | Longitudinal | 1568 | **Age:** 15-18  **Sex:** not stated  **Occupation/characteristics:** High school students | IPAQ | No significant change in physical activity between during and pre-restriction or during and post-restriction COVID rules*.*  Only highly active students increased their PA during and after the lockdown measures with respect to their baseline levels |
| Zheng et al. 2020 (45) | Hong Kong | Longitudinal (n=70)  Cross sectional (n=631) | 631 | **Age:** 21.2 ± 2.9  **Sex (M:F):**  386 (61.2%)  **Occupation/characteristics:** Young adults | IPAQ | Decrease in vigorous (p < 0.05) and moderate (p < 0.01) physical activity during COVID.  Significant decrease in walking during COVID (p<0.01).  Significant increase in sedentary time during COVID (p<0.01) |
| Schmidt et al. 2020 (46) | Germany | Longitudinal | 1711 | **Age:**4-17  **Sex (F):**  852 (49.8%)  **Occupation/characteristics:** 4–17-year-olds | Questionnaire | Increase of 0.44 active days per week (*p* < 0.01) during COVID  11.1% overall increase in adherence to WHO physical activity guidelines.  Screen time guideline adherence decreased by 17.5% (p<0.01) |
| Hanke et al. 2020 (48) | Germany | Longitudinal | 248 | **Age:**  Females: 52.3 ± 13.7  Males: 56.3 ± 13.7  **Sex (F):** 89 (35.9%)  **Occupation/characteristics:** Kidney transplant patients | Questionnaire | Significant decrease in sport (hours/week) during lockdown (p= 0.008)  Significant increase in leisure activity\* (hours/week), (p<0.001)  \*includes walks, bike rides, bicycle ergometer training, dancing, and bowling.  p<0.001 |
| Yang Y, & Koenigstorfer J. 2020 (49) | USA | Longitudinal | 431 | **Age:** 39.1 ± 10.6  **Sex (F):**  221 (51.3%)  **Occupation/characteristics:**  Healthy adults aged between 18 and 65 years old | IPAQ-SF | Significant decrease in moderate PA (p<0 .01) , vigorous PA (p < 0.001) and PA in MET (metabolic equivalent of task) minutes/week (p<0.01) during lockdown.  No significant change in sedentary time, (p = 0.85) or walking (p =0 .067). |
| Huckins JF et al. 2020 (37) | USA | Longitudinal | 217 | **Age:** 18-22  **Sex (F):**147 (67.8%)  **Occupation/characteristics:**  Undergraduate students | Mobile Phone Sensor Data | Individuals were more sedentary during COVID (p<0.001) |
| Gallo LA et al. 2020 (50) | Australia | Longitudinal | **2018** n=174(for PA 158)  **2019** n=185 (for PA 177)  **2020** n=150 (for PA 149) | **Age:** [19-27]  **Sex (F):**  For physical activity:  2018:97  2019:104  2020:84  **Occupation/characteristics:**  Undergraduate students | Active Australia Survey | **Males**  Walking participation  Significant reduction in 2020 combined with years 2018/2019, (*p<0.05)*  Vigorous activity  No difference between 2020 and years 2018/2019, (*p = 0.257)*  **Females**  Walking participation  Significant reduction in 2020 combined with years 2018/2019, (*p<0.05)*  Vigorous activity  No difference between 2020 and years 2018/2019 combined (*p = 0.245)* |
| Hemphill NM et al. 2020 (36) | Canada | Longitudinal | 109, of which 56 had longitudinal 2019 and 2020 data  2019 n=83  2020 n=82 | **Age:**  2019: 13.0 ± 2.3  2020: 13.2 ± 2.3  **Sex (F):**  2019: 42%  2020: 48%  **Occupation/characteristics:**  Children With Congenital Heart Disease aged 9-16 | Step count data | Significant reduction in step count during lockdown (p<0.001)  During the early phase of the COVID-19 pandemic in Canada, children with CHD had a decline of 21%-24% of their overall daily step counts. |
| Bourdas et al. (2020) (38) | Greece | Longitudinal | 8495 | **Age:** 37.2±0.2  **Sex(F):**  5241 (61.7%)  **Occupation/characteristics:** General population | Activity questionnaire | Overall physical activity decreased during lockdown measures (*p*<0.05)  Significant reduction (p<0.05) in sporting activities |
| Munasinghe et al. (2020)(39) | Australia | Longitudinal | 582 | **Age:** 13-19  **Sex (F):** 465 (79.9%)  **Occupation/characteristics:** Adolescents | Questionnaire | Significant decrease in physical activity after physical distancing measures |
| Muriel et al. (2020) (40) | Spain | Longitudinal | 18 | **Age:** 24.9 (2.8)  **Sex (F)**:0 (0%)  **Occupation/characteristics:** Professional cyclists | Objective data collection - specialist software | Total training volume decreased by 33.9% during the lockdown (*P* < 0.01)  Large reductions in best 5-minute and best 20-minute performances (p<0.001) |
| Martinez-de-Quel et al. 2020 (31) | Spain | Longitudinal | 161 | **Age:** 35.0 ± 11.2 [19-65]  **Sex (M:F):** 60 (37%)  **Occupation/characteristics:** General population | Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ) | Total physical activity significantly decreased during lockdown (*p <0.001)*  Increase in number physically inactive during the pandemic (*p<0.001)* |
| Savage et al. (2020) (41) | UK | Longitudinal | 214 | **Age:** 20.0  **Sex(F)**: 154 (72 %)  **Occupation/characteristics:** Students | Questionnaire | Physical activity significantly decreased during the first 5weeks of lockdown (p<0.01).  Sedentary time significantly increased (p<0.0001). |
| Vetrovsky et al. (2020)(42) | Czech Republic | Longitudinal | 26 | **Age:** 58.8 (9.8)  **Sex (F):** 8 (30.7%)    **Occupation/characteristics:** Heart failure patients | Accelerometer | Significant decrease in daily step count during quarantine period (p<0.001) |
| Zenic et al. (2020)(43) | Croatia | Longitudinal | 823 | **Age:**16.5 ± 2.1  **Sex (F):** NR  **Occupation/characteristics:** Adolescents | Questionnaire | Physical activity levels significantly decreased during social distancing (p < 0.01).  This was greater in urban than rural adolescents |

**Table 3: Characteristics of included studies investigating the relationship between COVID-19 and financial status**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study ID | Country | Study Type | Sample size | Sample characteristics | Assessment Tool | Outcome |
| Evanoff et al. 2020 (52) | USA | Cross sectional | 5550 | **Age:** not specified  **Sex (F)**: 4274 (77.3%)  **Occupation/characteristics:** Benefits-eligible university faculty, staff, and postdoctoral scholars | Worse financial well-being due to COVID-19–related work or life changes n (%) | Significant increase in worse financial wellbeing for  1732 (31.4%) *p<0.001* |
| Wilson et al. 2020 (55) | USA | Cross sectional | 474 | **Age:** median 40 (19-85)  **Sex (F):** 218 (46.4%)  **Occupation/characteristic:** Currently employed adults | Questionnaire | **Job insecurity**  Not worried: 19.6%  Slightly worried: 18.8%  Somewhat worried:  23.2%  Worried:  16.6%  Very worried:  21.9%  *P-value NR*  **Financial concern over next 12 months**  Some degree of concern:  31.9%  *P-value NR* |
| Wanberg et al. 2020 (57) | USA | Longitudinal observational | 1143 | **Age:** 30-81  **Sex (F):**635 (55.6%)  **Occupation/characteristics**: RAND American Life Panel, general population | Questionnaire | Laid off due to COVID-19: 40 (3.5%)  Furloughed due to COVID-19: 32 (2.8%)  *P-value NR* |
| Donnelly et al. 2020 (58) | USA | Cross-sectional | State-specific sample size ranging from 11,279 (Wyoming) to 77,811 (California) | **Age:**  44.4±11.86 [18-65]  **Sex (F):** 61.76%  **Occupation/characteristics**: General population | National survey | Reduction in household income after March 13 2020:  45% of the analytic sample  *P-value NR* |
| McDowell et al. 2020 (59) | USA | Cross sectional | 2303 | **Age:** 18-75  **Sex (F):** 1520 (66%)  **Occupation/characteristics**: Adults in employment before Covid-19 | Working status | **Lost employment due to pandemic:** 13%  *P-value NR* |
| Almandoz JP et al. 2020 (61) | USA (Texas) | Cross sectional | 123 | **Age:** 51.2±13.0  **Sex (F):**107 **(**87%)  **Occupation/characteristics:**  Adults with Obesity | Survey/Questionnaire | **Lost job since COVID-19:**  11 (9.6%)  *P-value NR* |
| Garcia-Alvarez et al. 2020 (60) | Spain | Cross sectional | 21207 | **Age:** 39.7±14.0  **Sex (F):** 14768 (69.6%)  **Occupation/characteristics:** General population | Questionnaire | **Reduction in income due to covid-19:**  Up to 25% 2292 (10.8%)  26-50%: 1367 (6.4%)  51-100%:  1738 (8.2%)  Income increase:  133 (0.6%)  *P-value NR*  **Job loss:**  Temporary or permanent lay off:  1871 (8.9%)  Dismissal: 390 (1.9%)  Forced vacation:  954 (4.5%)  *P-value NR* |
| Gualano MR et al. 2020 (62) | Italy | Cross sectional | 1515 | **Age:** Median 42 (IQR23)  **Sex (F):** 973 (65.6%)  **Occupation/characteristics:** General population | Questionnaire | **Fear of Losing Employment:**  No: 543 (85.4%)  Yes: 93 (14.6%)  *P-value NR*  **Income Reduction:**  No: 46 (23.5%)  Yes: 150 (76.5%)  *P-value NR*  **Job situation:**  Layoff: 98 (6.5%)  Lost Job: 18 (1.2%)  *P-value NR* |
| Song L et al. 2020 (54) | China | Cross sectional | 709 | **Age:** 35.35±6.61  **Sex (F):** 526 (74.2%)  **Occupation/characteristics:**  Working adults, not infected | Questionnaire | **Income change:**  Decrease: 244 (34.4%)  No change: 436 (61.5%)  Increase: 39 (4.1%)  *P-value NR*  **Some degree of worry about unemployment caused by covid-19:**  251(35.5%) |

Table 4: Characteristics of included studies investigating the relationship between COVID-19 and diet

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study ID | Country | Study Type | Sample size | Sample characteristics | Assessment Tool | Outcome |
| Alhusseini and Alqahtani, 2020 (80) | Saudi Arabia | Longitudinal observational | 2706 | **Age:** 18+  **Sex (F):** 1466 (54.2%)  **Occupation/characteristic:**  General population | Dietary habit questionnaire | Increase in healthy food rating *(p<0.05.)*  Increased consumption of home cooked meals (*p<0.001).*  Increased quantity of food consumption (*p<0.001)* |
| Robinson et al. 2020 (81) | UK | Cross sectional | 2002 | **Age:** 34.74 ±12.3  **Sex (F)**: 1236 (62%)  **Occupation/characteristics:** General population | Short 13 item food frequency questionnaire (SFFQ) | **Diet during COVID relative to baseline**:  Better: 694 (35%)  Same: 620 (31%)  Worse: 688 (35%)  56% reported snacking more frequently  *P-value NR*  Having a higher BMI was independently associated with lower diet quality (p<0.01) |
| Buckland et al. 2020 (65) | UK | Cross sectional | 588 | **Age:** 33.4±12.6  **Sex (F):** 403 (69%)  **Occupation/characteristics**: General population | Questionnaire | Increased food consumption: 268 (48%)  Increased meal amount: 173 (31%)  *P-values NR* |
| Do et al. 2020 (82) | Vietnam | Cross sectional | 5209 | **Age:**  21-40: 4304 (82.6%)  41-60: 905 (17.4%)  **Sex (F):** 3495 (67.1%)  **Occupation/characteristic:** Health care workers | Online survey | **Dietary change compared to pre-pandemic:**  Unchanged or healthier:  5042 (96.8%)  Less healthy:  167 (3.2%)  *P-value NR* |
| Carroll et al. 2020 (84) | Canada | Cross-sectional data  (from longitudinal study) | 361 parents from 254 families | **Age:**  Mothers  39.4 (SD 5.5)  Fathers  (37.5, SD 4.8)  Children  (5.7 SD 2.0)  **Sex: (F):** 235 (65%)  **Occupation/characteristic:** Families with young children | Food questionnaire | Eating more food since confinement (mothers 57%, fathers 46%, children 42%)  More snack foods (mothers 67%; fathers, 59%; children, 55%)  *P-value NR* |
| Huber et al. 2020 (63) | Germany | Cross sectional | 1964 | **Age:** 23.3±4.0  **Sex (F)**: 1404 (71.5%)  **Occupation/characteristic:** University students | Questionnaire | **Overall food intake during lockdown**  Increased:  31.2%  Decreased: 16.8%  *P-value NR*  Increase in food intake was mainly triggered by consumption of bread (increased in 46.8%) and confectionery (increased in 64.4%).  *P-value NR* |
| Visser et al. 2020 (64) | Netherlands | Longitudinal cohort | 1119 | **Age**: 74±7  **Sex (F):** 593 (52.8%)  **Occupation/characteristics:**Dutch older adults | Questionnaire | **Change in eating habits during pandemic**  Eating less than normal: 12.1%  *p=0.003*  Eating too little or losing weight: 6.6%  *p=0.260*  Snacking more: 32.4%  *p<0.001*  Skipping warm meals: 9.1%  *p=0.003* |
| Lopez-Moreno et al. 2020 (33) | Spain | Cross sectional | 675 | **Age:** 39.1±12.9  **Sex (F):** 472 (70%)  **Characteristics:** General public | Questionnaire | **Overall worsening of diet:** 112 (16.2%)  Increased food intake: 19.6%  Increased purchase of snacks: 39%  Increased purchase of processed foods: 25%  *P-value NR*  **Overall improvement of diet:** 266 (38.4%)  Decreased food intake: 33.3%  *P-value NR* |
| Rodríguez-Pérez C et al. 2020 (77) | Spain | Cross-sectional | 7514 | **Age:**  <20: 229  21-35: 2558  36-50: 2371  51-65: 1928  >65: 428  **Sex (F):**  5305 (70.6%)  **Occupation/characteristics:** General population | Mediterranean Diet Adherence Screener (MEDAS) | Increased adherence to mediterranean diet(*p<0.001)*  Reduced alcohol intake  *(p<0.001)*  Self-reported ‘not eating more’ during confinement:  63.7% (*p<0.001)* |
| Sánchez-Sánchez E et al. 2020 (72) | Spain | Cross-sectional | 1065 | **Age:** 38.7 ± 12.4  **Sex (F):** 775 (72.8%)  **Occupation/characteristics:** General population | Mediterranean Diet PREDIMED Questionnaire | Increased adherence to meditarraenan diet (*p=0.004)*  Significant increase in daily portions of vegetables, olive oil, fruit, red meat, sugary/carbonated beverages (*p<0.05)*  Significant increase in proportion drinking wine ≥7x/week (*p<0.001)* |
| Ruiz-Roso MB et al. 2020 (69) | Spain (Madrid) | Cross-sectional | 72 | **Age:** 41.12 ± 13.05  **Sex (F):** 46 (64.1%)  **Occupation/characteristics:** Cohort of adults with T2DM  (1) between the age of 40 and 80 (2) BMI ≥25 and <40 kg/m2. | Phone Interview | **Snacking**  Increased sugary food servings ≥=5 times/week (2.9% vs 5.7%)  Increased snacking ≥ 4 times/week ( 5.7% vs 12.9%)  Significant increase in vegetable consumption (*p<0.0001)* |
| Di Renzo L et al. 2020 (66) | Italy | Cross-sectional | 3533 | **Age:** 40.03 ± 13.53  [12-86]  **Sex (F):**848 ( 24%)  **Occupation/characteristics:** General population | Mediterranean Diet Adherence Screener (MEDAS) | Healthier diet:(fruit, vegetables, nuts and legumes) 37.4%  Unhealthier diet: 35.8%  *P-value NR*  Significant decrease in junk food consumption (*p = 0.002)* |
| Pietrobelli A et al. 2020 (67) | Italy | Longitudinal | 41 | **Age:** 13.0±3.1  **Sex (F):** 19 (46%)  **Occupation/characteristics:**  Children and adolescents with obesity | Interview & Questionnaire | Increased number of daily meals  *(p<0.001).* Increased fruit intake (*p=0.055).* No change in vegetable intake.  Increase in potato chips, red meat, and sugary drink intake (*p=0.005)* |
| Almandoz JP et al. 2020 (61) | USA (Texas) | Cross-sectional | 123 | **Age:** 51.2±13.0  **Sex (F):** 107 **(**87%)  **Occupation/characteristics:** Adults with Obesity | Survey/Questionnaire | **Dietary changes during pandemic:**  Stress eating: 61.2%  Cooking more often: 63.8%  **Food behaviours:**  Reported healthy eating to be more challenging during pandemic: 61.2%  Skipping meals when not food insecure: 12.1%  *P-value NR* |
| Knell G et al. 2020 (73) | USA | Cross-sectional | 1809 | **Age:** 18+  **Sex (F):** 1220 (67.4%)  **Occupation/characteristics:** General population | Alcohol Questionnaire | Significant increase in alcohol consumption (*p<0.01)* |
| Błaszczyk-Bębenek E et al. 2020 (26) | Poland | Cross-sectional | 312 | **Age:** 41.12 ± 13.05  **Sex (F):** 200 (64.1%)  **Occupation/characteristics:** General population | Dietary Habits and Nutrition Beliefs Questionnaire | Significant increase in number of meals consumed and snacking  *(p<0.0001).* Significant increase in alcohol  *(p=0.0031).*  Significant decrease in takeaways and fast food (*p<0.0001).*  Significant decrease in energy drink consumption  *(p=0.015).* |
| Sidor A, & Rzymski P. 2020 (23) | Poland | Cross-sectional | 1097 | **Age:** 27.7 ± 9.0  [18-71]  **Sex (F):**1043 (95.1%)  **Occupation/characteristics:** General population | Questionnaire | **Dietary changes during pandemic:**  Eating more:  43.5%  More frequent snacking: 51.8%  Cooking more often: 62.3%  *P-value NR*  **Alcohol intake changes:**  Increase: 14.6%  No change: 77%  Unsure: 8.3%  *P-value NR* |
| Górnicka M et al. 2020 (68) | Poland | Cross-sectional | 2381 | **Age:**  <30y: 700  30-39: 1067  40-49: 306  50-59: 160  **Sex (F):** 2138 (89%)  **Occupation/characteristics:** Over 18yo not pregnant or lactating/breastfeeding | Questionnaire | Increase in unhealthy eating  *(p<0.001).* Increase in Confectionary and alcohol (*p<0.001)*  **Positive dietary changes during pandemic:**  Increased water intake (*p<0.001).*  Decreased fast food intake (*p<0.001).* Increased consumption of homemade meals (*p<0.001).* |
| Yan AF et al. 2020 (78) | China | Cross-sectional | 9,016 | **Age:**18-80  **Sex (F):**  5,177 (57.4%)  **Occupation/characteristics**  General population | Alcohol Question | Significant increase in alcohol consumption  *(p<0.001).*  54% diabetic and 10.2% non-diabetic participants reported significant increases in drinking |
| Wang X et al. 2020 (70) | China | Cross-sectional | 2289 | **Age:** 17.8±12  **Sex (F):** 1113 (49%)  **Occupation/characteristics:** Healthy Chinese Adults  Aged >18yo | Questionnaire adapted from online nutritional survey of Guangdong Nutrition Society and Sun Yat-sen University | **Daily eating frequency:**  Reduced: 23.1%  No change: 60%  Increased: 17.3%  **Food behaviour changes:**  Appetite unchanged: 71.4%  Healthier diet: 23%  More vegetables, fruits and milk: >30%  Increased snacking: ~30%  *P-value NR* |
| Elran-Barak R, & Mozeikov M. 2020 (71) | Israel | Cross-sectional | 315 | **Age:** 18+  **Sex (F):**  178 (59.5%)  **Occupation/characteristics:** Israelis with a variety of chronic conditions | Questionnaire | **Overall food consumption:**  Much more than before: 19.7%  A little more than before: 30.5%  Same as before: 40.0 %  A little less than before: 7.0%  Much less than before: 2.9%  *P-value NR*  No significant change in fruit consumption (*p-value= 0.060*). Decrease in vegetable consumption (*p=0.008)* |
| Gallo LA et al. 2020 (50) | Australia | Cross sectional | 2018 n=174 (for diet 166)  2019 n=185 (for diet 159)  2020 n=150 (for diet 146) | **Age:** [19-27]  **Sex (F):**  2018: 101  2019: 96  2020: 82  **Occupation/characteristics:** Third-year biomedical practical students from University of Queensland in 2018, 2019, 2020 | Automated Self-Administered Dietary Assessment Tool | **Total energy intake over 24h (females):**  No significant change between 2019/20 (*p=0.067).* Significant increase between 2018/20 (*p-value<0.05)*  **Total energy intake over 24h (males):**  No significant difference |
| Husain W, & Ashkanani F. 2020 (74) | Kuwait | Cross-sectional | 415 | **Age:** 38.47 ± 12.73  **Sex (F):** 285 (68.7%)  **Occupation/characteristics:** General population | Questionnaire | Significantly increased snacking (p = 0.006), more late-night snacks (p < 0.001).  Main meal was significantly more likely to be freshly made (p = 0.001), with reductions in fast food consumption (p < 0.001).  Decreased frequency of seafood consumption. No change to beverage consumption |
| Steele EM et al. 2020 (75) | Brazil | Longitudinal | 10,116 | **Age:**  18–39: 5,174 (51.1%)  40–59: 4,034 (39.9%)  >60: 908 (9.0%)  **Sex (F):** 7,895 (78.0%)  **Occupation/characteristics:** Adults >18yo, NutriNet Brasil Cohort | Adaptation of an instrument developed by the authors for the Ministry of Health Surveillance of Risk and Protective Factors for Chronic Diseases by Telephone Survey | **Dietary behaviour changes during pandemic:**  Increased consumption of vegetables and fruits  *(p<0.05).*  Increased consumption of beans/legumes (*p-value<0.05)* |
| Malta DC et al. 2020 (76) | Brazil | Cross-sectional | 45,161 | **Age:** 18+  **Sex (F):** 24,206  (53.6%)  **Occupation/characteristics:** General population | "ConVid Behavior Survey" | **Alcohol consumption:**  Increased: 17.6%  *P-value NR*  **Healthy food consumption:**  Decreased regular consumption of vegetables (37.3% vs 33%)  **Unhealthy food consumption 2 or more days/week:**  Increase in frozen food intake (10.0% vs 14.6%).  Increase in savoury snacks:(9.5% vs 13.2%).  Increased consumption of chocolate/desserts (41.3% vs 47.1%)  *P-value NR* |
| Ruiz-Roso et al. 2020 (79) | Italy, Spain, Chile, Colombia and Brazil | Cross-sectional | 820 | **Age:**15 (10-19)  **Sex (F):** 501(61.1%)  **Occupation/characteristics:** Adolescents between 10-19 | Online questionnaire | Legumes, vegetables, and fruit intakes were significantly increased (*p* < 0.05). Reduced fast food consumption (*p* < 0.0001)  Increased intake of fried foods and sweet foods (*p* < 0.001) |
| Ammar et al. 2020 (83) | Asia (36%), Africa (40%), Europe (21%) and other (3%) | Cross-sectional survey | 1047 | **Age:** 18+  **Sex (F):** 563 (53.8%)  **Occupation/characteristic:** general population | Short diet behaviour questionnaire for lockdowns - SDBQ-L | Increase in self-reported unhealthy eating (*p<0.001).*  Increased uncontrolled eating *(p <0.001).*  Increased snacking (*p<0.05).* |

Table 5: Characteristics of included studies investigating the relationship between COVID-19 and depression

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Study ID | Country | Study Type | Sample size | Sample characteristics | Assessment Tool | Outcome |
| Chen et al. 2020 (85) | Hong Kong | Longitudinal | 543 (completed both baseline and follow up) | **Age:** 10.88 ± 0.72  **Sex (F):** 273 (51%)  **Occupation/characteristic:** School children | DASS-21 | Significant increase in DASS-21 during COVID (*p<0.001)* |
| Ettman CK et al. 2020 (93) | USA | Cross-sectional w/ Comparison to NHANES (National Health and Nutrition Examination survey) data 2017-18 | 1441 during pandemic, 5065 pre-pandemic | **Age:** 18+  **Sex (F):**  Baseline: 2588(51.4%)  Post-pandemic:718(51.9%)  **Occupation/characteristic:** General population | PHQ-9 | More than 3 fold increase in depression symptoms during COVID  *P-value NR*  **Prevalence of depressive symptoms baseline vs during pandemic:**  Mild depressive symptoms: 1.5 fold higher  Moderate depressive symptoms: 2.6 fold higher  Moderately severe depressive symptoms: 3.7 fold higher  Severe depressive symptoms: 7.5 fold higher  *P-value NR* |
| Kannampallil et al. 2020 (94) | USA | Cross sectional | 393 | **Age**: Not included  **Sex (F):**  218 (55.5%)  **Occupation/characteristic:** Physician trainees | DASS-21 | No significant difference in DASS-21 score between those exposed to COVID and those not  *p=0.70* |
| Coughenour et al. 2020 (86) | USA | Longitudinal | 194 | **Age:** 25.11 SD 7.84  **Sex (F):** 140 (72.2%)  **Occupation/characteristic**: College students | PHQ9 | Significant increase in PHQ9 depression score after stay at home order*, p<0.01* |
| Flentje A et al. 2020 (92) | USA | Longitudinal | 2288 | **Age:** 36.9±14.7  **Sex (F):** 1428 (63.0%)  **Occupation/characteristic:** LGBT population | PHQ-9 | Significant increase in PHQ9 depression score in the total population during COVID-19, (p <0 .001).  Significant decrease in PHQ9 depression score in those with a positive baseline screen, (p < 0.001).  Significant increase in PHQ9 depression score in those with a negative baseline screen, (p <0 .001) . |
| Wanberg et al. 2020 (57) | USA | Longitudinal | 1143 | **Age:** 30-81  **Sex (F):** 635 (55.6%)  **Occupation/characteristics:** RAND American Life Panel, general population | PHQ8 | Significant increase in depressive symptoms during the pandemic (*p=0.01)* |
| Xiang et al. 2020 (95) | China (Shanghai) | Longitudinal | 2427 | **Age:** 6-17  **Sex (F):**1185 (49%)  **Occupation/characteristic:** School-age children | Children's Depression Inventory – Short Form (CDI‐S) | Significant decrease in CDI-S score, 4.19 baseline vs 3.90 during school closure (*p < 0.01)*  Therefore no evidence of increased depressive symptoms among students after a 2‐month school closure. |
| Liu et al. 2020 (96) | China | Cross sectional | 2126 | **Age:** 16+  **Sex (F):** 2077 (97.7%)  **Occupation/characteristic:**: Obstetrician: 770, Midwife: 1356 | PHQ9 | Significant increase in PHQ9 score during COVID (*p<0.001).*  Those with direct contact with COVID more likely to have severe depression *p<0.05* |
| Cai et al. 2020 (98) | China | Longitudinal study | 1330  709 (53.3%) from the outbreak period and 621 (46.7%) from the stable period | **Age:**18+  **Sex (F):**  Peak:684(96.5%)  Stable: 605 (97.4%)  **Occupation/characteristic**: Nurses | PHQ9 | Significant increase in mean PHQ-9 score during the pandemic (4.67 vs 5.59, *p<0.001).*  During the outbreak, nurses had significantly higher proportions of depressive symptoms *(p<0.001).*  Depression significantly higher in those on the frontline *(p<0.05).* |
| Li et al. 2020 (100) | China | Longitudinal | During Outbreak (T1) (n=164,101)  During remission (T2) (n=148,343) | **Age**:not specified.  **Sex (F):**  During outbreak: 103,645 (63.2%)  During remission: 92,859 (62.6%)  **Occupation/characteristic**: College students | PHQ9 | Increase in PHQ9 depression score during remission (3.66 vs 3.95)  *P-value NR*  Significant increase in prevalence of depression (PHQ-9 score >9) during remission, *p<0.001*  Depression more likely in seniors and those who consumed alcohol *(p<0.001)* |
| Li W et al. 2020 (91) | China | Longitudinal | 385 | **Age:** median 25 (IQR 23-28 )  **Sex (F):** 247 (64%)  **Occupation/characteristic:** Physicians from 12 Shanghai hospitals who enrolled in the prospective Intern Health Study in August 2019 | PHQ-9 | Significant increase in depressive symptoms from T1(pre-pandemic) to T2 (during pandemic)  *95% CI, 0.08 to 1.14*  *p =0 .02* |
| Quittkat et al. 2020 (97) | Germany | Cross sectional | 586 | **Age:** 34.06±13.45  **Sex (F)** : 470 (80%)  **Occupation/Characteristic**: Pre-existing depression | DASS-D | **Depression compared to pre-pandemic:**  Considerable improvement:48 (8.19%)  Slight improvement:113 (19.28%)  No change: 88 (15.02%)  Slight worsening: 218 (37.2%)  Considerable worsening: 119 (20.3%)  *P-value NR* |
| Thombs et al. 2020 (99) | Canada, France, UK, US | Longitudinal study | 388 | **Age**: 56.9 SD 12.6  **Sex (F)**: 343(88.5%)  **Occupation/characteristic**: Systemic sclerosis patients | PHQ8 | Changes in depressive symptoms were minimal (reduction of 0.3 points, 95% CI -0.7 to 0.2) during pandemic  *P-value NR* |
| Elmer T et al. 2020 (87) | Switzerland | Longitudinal | N=212 (who experienced the crisis)  N=54 (earlier cohort who didn't) | **Age:** Unspecified  **Sex (F)**  Current year, Major I (n=70) 33.7%  Current year, Major II (n=142) 15.3%  Previous year, Major I (n-54) 38.9%  **Occupation/characteristic:** Undergraduate students | CES-D | Students become significantly more depressed during the pandemic (*M*diff = 4.44, *p* <0 .001).  No significant difference between Majors. |
| Pieh et al. 2020 (88) | Austria | Cross-sectional (Compared to Austrian Health Interview Survey 2014) | 1005 | **Age**:18+  **Sex (F):**530 (52.7%)  **Occupation/characteristic:** General population | PHQ-8 | Significant increase in PHQ8 depression score during pandemic (2.5 vs 5.9, *p<0.001)* |
| Munk AJL et al. 2020 (89) | Germany | Cross-sectional | 949 | **Age**: 28.9± 10.8    **Sex (F):** 754 (79.5%)  **Occupation/characteristic**: Recruited via Justus-Liebig University email, and social media | BDI | **Clinically depressive symptoms**  Baseline:  7.7% depression rate from study (Jacobi et al.2014)  During pandemic:  35.3% (BDI-Score >13)  *P-value NR* |
| Schmitz et al. 2020 (90) | Canada | Cross-sectional | 1607 (Quebec Sample)  52,996 (CCHS sample\*)  *\*Baseline data from the 2015/2016 Canadian Community Health Survey (CCHS)* | **Age:** 18+  **Sex (F)**  CCHC: 51.2%  Quebec: 51.3%  **Occupation/characteristic:** General Population | PHQ-8 (compared to PHQ-9 in CCHS) | Increase in score >10 in PHQ8 during pandemic (6.8% vs 19.2%)  **Reported depressive symptoms**  Baseline:  Males: 5%  Females: 9%  During pandemic:  Males: 17%  Females: 22%  *P-value NR* |

**Figure 1: PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Review and Meta-Analysis.**