Systematic Review

Beyond lockdowns: a systematic review of the impacts of COVID-19 lockdowns on dietary pattern, physical activity, body weight, and food security

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Context: *COVID-19 lockdowns may have impacted dietary patterns and nutritional outcomes in many populations.* ***Objective:*** *The aim of this review was to evaluate the impacts of COVID-19 lockdowns on nutritional patterns, investigating behaviors in the periods before, during, and after lockdowns.* ***Data Source:*** *This systematic review followed the PRISMA-P methodology. The articles included were identified by searching the key words in Web of Science, PubMed, and Scopus. The key words used in the search included: "COVID19" AND "diet*", "coronavirus" AND "diet*", "coronavirus 2" AND "diet*", "COVID19" AND "nutri*", "coronavirus" AND "nutri*", "coronavirus 2" AND "nutri*", "COVID19" AND "food".* ***Data Extraction:*** *Twenty-two original studies were included in this review. Data extraction tables were created for recording author names, year of publication, location of study, duration, lockdown phase, design, methods, aims, number of participants, age, gender, health status, education, socioeconomic status, dietary patterns, food security, physical activity, body weight change or body mass index, and associations with sociodemographic characteristics.* ***Data Analysis:*** *Impacts of lockdowns on eating patterns, physical activity, body weight or body mass index, and food security were the primary outcomes investigated. Secondary outcomes investigated were associations with sociodemographic characteristics.* ***Conclusion:*** *COVID-19 lockdowns were associated with significant changes in dietary and lifestyle behaviors of worldwide populations. Impacts were seen during and post-lockdown likely due to more time spent at home, working from home, decreased food availability and accessibility, and augmented stress associated with lockdown.*

INTRODUCTION

Evidence suggests that COVID-19 lockdowns have impacted the dietary patterns, physical activity, and nutritional outcomes of populations around the world.[1] The macronutrients and micronutrients of a balanced diet are appropriate for supporting daily human functioning, and normal human growth, development, and body metabolism.[2] A balanced diet is vital for good health and protects against various chronic diseases such as obesity, cardiovascular complications, and diabetes.[3] An imbalance in diet, on the contrary, has consistently been found to increase the risk of chronic diseases.[4] Also, an imbalanced diet, to some extent, is

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considered to be a form of food insecurity, as implied by the Food and Agriculture Organization (FAO) definition of food security.[5] Food security as defined by FAO is "when all people, at all times, have physical, social and socioeconomic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[5] It consists of 4 main pillars: availability of food, access to food, stability to ensure food being secure at all times, and utilization of the various nutrients in food for nutritional wellbeing.[5] Physical activity and exercise are critical for maintaining overall health and well-being and for the prevention of several chronic diseases, such as obesity, diabetes, and cancer.[6] Physical activity is known as any bodily movement that causes energy expenditure,[7] and a subset of it is known as exercise, which is rather planned, structured, and repetitive, and aims at improving physical fitness.[8] Reduction in physical activity level accompanied by increased energy intake results in weight gain.[9]

Dietary and physical activity behaviors are closely associated with nutritional outcomes such as body mass index (BMI) and food security.[10] Nutritional outcomes are critical in relation to overall health outcomes, such as morbidity and mortality,[11] which are likely moderate determinants of long-term socioeconomic performance of a population.[12] A clearer understanding of the influences of COVID-19 lockdowns in 2020 and 2021 on nutritional and lifestyle behaviors is considered crucial for the development and implementation of public health strategies. These strategies are vital for the health protection of various populations in cases of future pandemics, natural disasters, and other scenarios that disrupt food supply at various levels and for various durations of time.

To our knowledge, a systematic review of the influence of COVID-19 lockdowns on dietary patterns, physical activity, body weight/BMI, and food security combined has not been reported. Therefore, this systematic review examines the impacts of COVID-19 lockdowns on dietary patterns, physical activity, body weight/BMI, and food security, covering a period during and after lockdowns in various populations around the world and altogether. Comparison with behaviors reported in previous cohort and cross-sectional studies before lockdown, in some cases, has been used to compare behaviors during and after lockdowns with those before lockdowns.

METHODS

This systematic review followed the PRISMA-P procedure to ensure an easily understood, comprehensive, and clear process.[13] This review protocol was not registered. The completed PRISMA checklist is provided as a Supporting Information file (see Table S1 in the Supporting Information online). The inclusion and exclusion criteria were determined based on multiple purposes developed from the study aims. These primarily include outlining of international evidence, identifying and investigating conflicting findings, demonstrating and analyzing research gaps and key factors associated with the lifestyle changes, informing nutrition-related decision-making at the clinical and population level and future research directions, in the practical implications and the significance of future research.[14] These purposes share characteristics between a traditional systematic literature review and the recently emerged systematic scoping review. The study purposes and the features of a scoping study require the authors to examine all possible studies on the topic, inclusive of various aims, demographics, and methodology. If the authors had selected a common baseline for the aim, demographics, and methodology, then this review would not have enabled the study to achieve the desired purposes.

Search strategy and study selection

The articles included in this review were identified by searching Web of Science, PubMed and Scopus between May 14 and July 5, 2021 and updated on February 9, 2022. Only peer-reviewed journal articles published in English were included. The key words used in the search were consistent among the 3 databases, including: "COVID19" AND "diet*", "coronavirus" AND "diet*", "coronavirus 2" AND "diet*", "COVID19" AND "nutri*", "coronavirus" AND "nutri*", "coronavirus 2" AND "nutri*", and "COVID19" AND "food". The key words were used in searching abstracts and titles.

In brief, records were screened to remove duplicates. The remaining records were then screened for title and abstract according to the eligibility criteria. Records that did not meet eligibility criteria were excluded. The Academy of Nutrition and Dietetics (ADA) quality criteria checklist was used to assess the study quality for relevance and validity (full screening records are available with authors upon request).[15] Finally, the remaining studies were selected for this review. This selection process is outlined in Figure 1.

Eligibility criteria

The PICOS criteria used to define the research questions are outlined in Table 1. Inclusion and exclusion criteria for this review are outlined in Table 2.

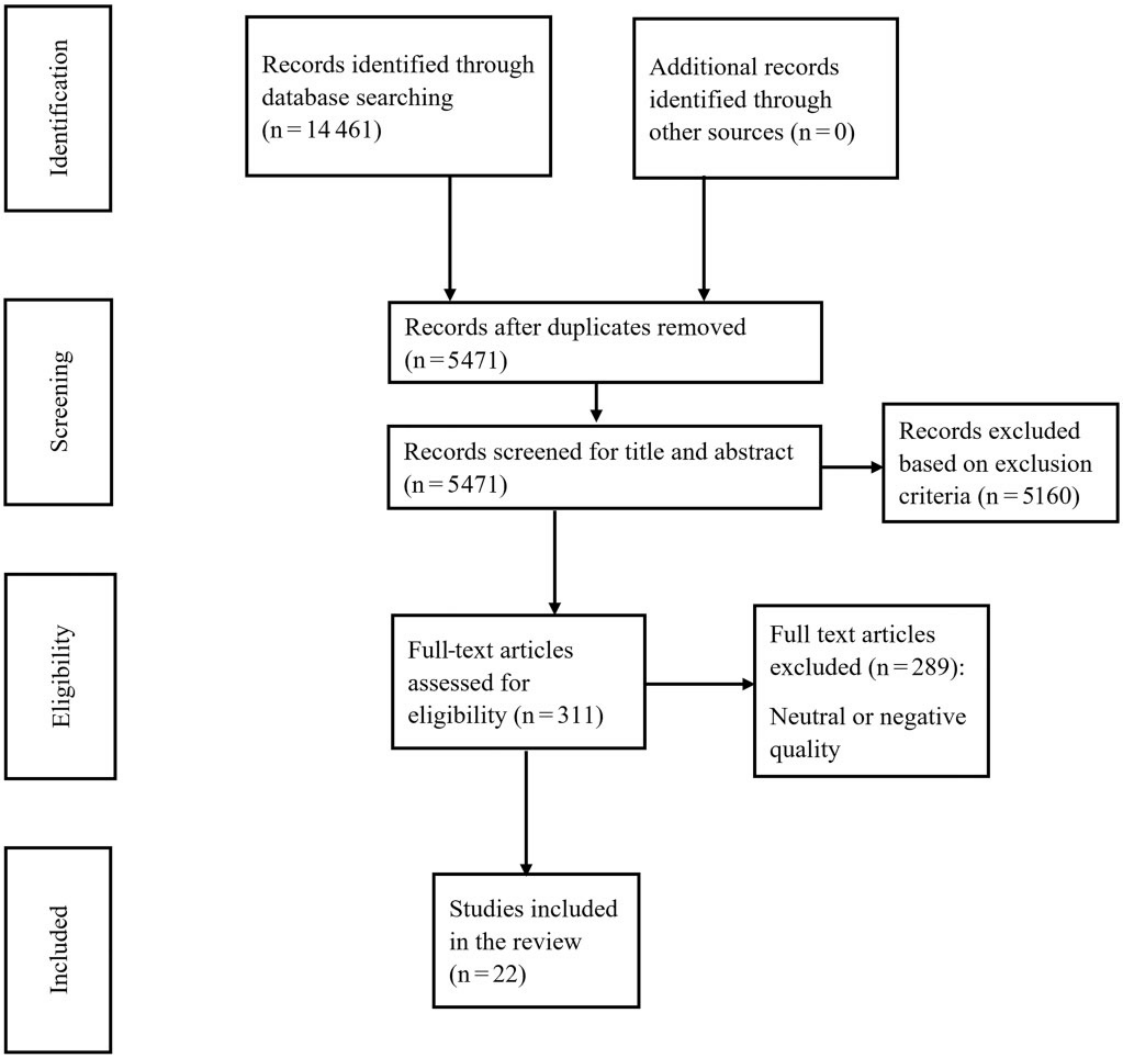

Figure 1 **Flow diagram of the literature search process**.

Table 1 **PICOS criteria used to define the research question**

Criterion	Implementation to define the research question
Population	Generally healthy population, including those apparently healthy and those with common chronic diseases but need to follow the same eating principles as the general healthy population
Intervention	COVID-19 lockdowns
Control	Same populations before lockdowns
Outcomes	Eating and lifestyle behaviors during and after COVID-19 lockdowns

Data collection process

Data extraction tables were created. Extracted data included author names, year of publication, location of study, duration, lockdown phase, design, methods, aims, number of participants, age, gender, health status, education, socioeconomic status, dietary patterns, food security, physical activity, body weight status or BMI, and associations with sociodemographic characteristics.

Risk of bias in individual studies

The validity and reliability of each study included was assessed based on the ADA quality criteria checklist.[15] This checklist was used to indicate issues of inclusion, exclusion, bias, generalizability, and data collection and analysis. This checklist categorized each study as positive, negative, or neutral, depending on overall rating within each criterion. Only studies of positive quality were included, due to the abundance of studies meeting the eligibility criteria.

Summary measures and synthesis of results

The studies were divided into 2 groups:

Table 2 **Criteria for inclusion and exclusion of studies**

Parameter	Inclusion criteria	Exclusion criteria
Location, duration of data collection, lockdown phase, methods, age, gender, education, and socioeconomic status	No restrictions	None
Design	Cross-sectional, cohort and observational studies excluding case reports or case series	Study protocols, short communication articles, case reports/series, clinical trials, reviews, and journal pre-proofs
Number of participants	Above 50 from general population	50 or fewer. (Small sample size decreases power, transferability and generalisability, and increases margin of error.)
Health status of studied populations	Healthy individuals or those with common diseases from the general population	COVID-19 cases or survivors, rare case diseases, pregnant or breastfeeding women, health-care professionals and people with eating disorders
Publication date	Between May 14, 2021 and February 9, 2022	After February 9, 2022
Language	English	Other languages
Aim	The impact of COVID-19 lockdown on dietary patterns (food groups, macronutrient and micronutrient intake, supplement intake), physical activity, food security, body mass index, or body weight. (Also, some studies that examined psychological factors if they also examined nutritional factors)	Nutritional management of COVID-19, psychological or depressive symptoms, practices to prevent COVID-19, sleeping patterns, obesity management services, knowledge or beliefs about or attitude toward COVID-19, eHealth, and use of herbal products. (Reported psychological factors and reported data on self-perceived dietary habits, snacks and meals, cooking, having breakfast or eating out)
Other	N/A	• Studies on social media influence, programs, models, datasets • Studies focusing on sociodemographic characteristics other than age, gender, education, and socioeconomic status

1. An association was found and reported between measured nutritional parameters and sociodemographic characteristics (+).
2. An association was not found and reported between measured nutritional parameters and sociodemographic characteristics (−).

RESULTS

Study selection

The initial search retrieved 14 461 articles. After removing duplicates, 5471 articles remained. A further 5160 articles were excluded during title and abstract screening according to the exclusion criteria (Figure 1). The remaining 311 articles were assessed for study quality, out of which 289 were excluded because of neutral or negative quality. This resulted in a final number of 22 articles included in the review.

Study characteristics

Location. The selected studies in this review were from Israel,[16] Japan,[17] Canada,[18] Ethiopia,[19] the USA,[20–22] Poland,[23–26] South Africa,[27] Brazil,[28,29] Turkey,[30] Australia,[31,32] Saudi Arabia,[33,34] Lebanon,[35] and Italy.[36,37] For each of Israel, Japan, Canada, Ethiopia, South Africa, Lebanon, and Turkey, one study was found. Two studies met the selection criteria for Brazil, Australia, Italy, and Saudi Arabia. For the USA, three studies were eligible, and four studies from Poland were included. These studies were spread out in all World Health Organization (WHO) regions except South East Asia. There were eight eligible studies in the European region, six in the Americas, three in the Western Pacific, three in the Eastern Mediterranean, and two in Africa.

Duration and timing of data collection. Eighteen out of 22 studies collected data over a time period of <3 months. In fact, nine out of 22 studies collected data over a period of 1–3 months, six studies from 1 week to less than 1 month, three studies <1 week, and two studies over 6 months and beyond. The time point of data collection post-lockdown was 3 months in one study[21] and around 4 weeks after the end of the lockdown in

another study.[36] All other studies collected data during lockdown.

Lockdown phase. The number of days in lockdown in each study are presented in Figure S1 in the Supporting Information online.[16–20,22–35,37] Two studies included in this systematic review were excluded from Figure S1 in the Supporting Information online, as these studies were conducted post-lockdown. The number of days in lockdown was no more than 30 days in almost all studies included (19/20). A link can be inferred between data collection duration and lockdown phase, since most studies conducted during lockdown had short-term duration of data collection.

Design. Eighteen studies included were cross-sectional[16,18–21,23–30,33–37] and four studies were cohort studies.[17,22,31,32] Most cross-sectional studies were conducted in the European region and Americas, with least cross-sectional studies being conducted in the African region and the Eastern Mediterranean. Three cross-sectional studies were conducted in the Eastern Mediterranean region.[33–35] Seven cross-sectional studies were conducted in the European region.[16,23,25,26,30,36,37] Two cross-sectional studies were conducted in the African region[19,27] and four in the Americas.[20,21,28,29] All cohort studies included in this review were conducted in the Western Pacific region. The longitudinal study[22] was conducted in the Americas. Most cross-sectional and cohort studies had a sample size of less than 500. The longitudinal study had a sample size of 636.

Data collection methods. All studies except two[17,19] adopted online data collection methods, likely due to challenges associated with face-to-face interaction during the pandemic. Data were collected using online surveys in 20 studies[16,18,20–37] and in-clinic surveys in two studies.[17,19] Baseline face-to-face home visits were combined with an online survey in one of the 20 studies that used online surveys for data collection.[32] Online surveys were mainly conducted through online platforms and distributed through social media sites.

Aims. Included studies were selected based on the presence of dietary and/or nutritional data, but the aims of these studies varied. Fourteen studies aimed to assess the impact of lockdown on dietary behaviors.[18,21–26,28,29,31,32,34,35,37] Two studies aimed to examine the impact of lockdown on lifestyle and dietary patterns of individuals with diabetes.[17,19] Two studies aimed to investigate the impact of lockdown on food security.[20,36] One study aimed to examine the impact of lockdown on physical activity.[27] Three studies aimed to examine the impact of lockdown on mental health.[16,30,33]

Number of participants. Sample sizes varied between 61 and 3797, with an average sample size of 1053 and a median sample size of 637. Eight studies engaged a sample size of <500,[17,18,20,24,28,30,32,34] six studies had a sample size of between 500 and 1000,[19,22,27,29,31,33] three of between 1000 and 1500,[23,26,37] and five of >1500.[16,21,25,35,36] Studies that used online data collection methods varied in sample size. Studies that used face-to-face data collection methods also varied in sample size, but to the lower end, having one with a sample size of <500[17] and another with a sample size of between 500 and 1000.[19]

Age of participants. At least 19 out of the 22 studies were conducted in participants aged 18 years and above.[16,17,19–25,27–29,31–37] Two studies investigated younger aged participants of between 6 years and 15 years of age.[26,30] The age of the participants was not stated in one study.[18] However, this study was conducted on university students only, thus the participants were assumed to be primarily young adults.

Gender. Female participants predominated in 18 studies (51.3%–100%)[16,18–24,26,28,29,31–37] whereas male participants were the majority in three studies.[17,27,30] One study did not specify the gender of the participants.[25] Studies in which male participants were the majority had a lower sample size of <500 or of between 500 and 1000.

Health status. The population health status of the studies in the review was healthy in 19 studies.[16,18,20–26,28–37] Two studies collected data from individuals with type 2 diabetes only,[17,19] and one study engaged healthy athletes only.[27] For individuals with diabetes, one study did not mention the proportion of the sample on insulin therapy,[19] and the second study had a higher proportion of participants not using insulin (135 out of 203 participants).[17] Most of the studies in this review were conducted on generally healthy individuals with common dietary requirements. The proportion of participants with specific dietary requirements for medical and non-medical reasons is unclear.

Education. The education level of the studied populations was mentioned in 73% of the included studies, with 68% of the populations having an education level of high school or above and 5% having an education level of below high school. Thus, the participants were mainly educated. This data is presented in Figure S2 in the Supporting Information online.

Employment and socioeconomic status. The socioeconomic status of populations in this review was retrieved by taking the predominant percentage from each socioeconomic or income group. Nine studies engaged employed participants[16,21,22,24,28,30,34,35,37] and four studies focused on unemployed participants.[20,23,33,36] Participants of high-income status were dominant in one study[19] and medium income status in four studies, as defined by highest income status percentage represented in each study.[20,22,29,32] Socioeconomic status was not stated in six studies.[17,18,25–27,31] Thus, the population in most of the studies was mainly employed with medium income status.

Reported data. Dietary patterns (food groups, macronutrient and micronutrient intake, or supplement intake) were reported in 21 studies.[16–27,29–37] Food security was reported in eight studies.[20–23,25,29,35,36] Physical activity was reported in 17 studies.[16–19,21,22,26–29,31–37] BMI or body weight was reported in 16 studies.[16,17,19–21,23,24,26,28,29,32–37] Four studies reported data on the four parameters together.[21,29,35,36]

Assessment tools. Dietary patterns were assessed using validated dietary assessment tools in the participant population, including food frequency questionnaires in nine studies,[16,18,21,24,26,29,33,35,37] ASA-24,[31] and the adolescents' food habits checklist.[25] The validity of these tools for the target populations was specified in the studies.

Food security was assessed using validated assessment tools in the participant population in four studies,[21,22,25,36] including the USDA food security module in one study,[21] the 5-item World Health Organization Well-Being Index (WHO-5) in one study,[36] the food purchase score in one study,[25] and the 2-item screen for household food insecurity in one study.[22] The validity of those tools for the target populations was specified in the studies.

Physical activity was assessed using validated assessment tools in five studies,[18,32,33,35,37] including the Godin leisure-time exercise questionnaire in one study,[18] Fitbit charge 3 activity monitoring (which was validated in one study),[32] an international physical activity short-form questionnaire in one study,[35] and the Global physical activity questionnaire in two studies.[33,37]

BMI/body weight was assessed as self-reported in 13 studies,[16,19,21,23,24,28,29,32–37] as measured by the researchers in one study[17] and by a combination of both methods in one study.[26] The validity of those tools for the target populations was specified in the studies.

Risk of bias within the studies. To assess risk of bias and quality, the ADA checklist[15] was employed, and only studies receiving an overall positive rating were included. Among the positive studies, it is likely that each study still has at least one limitation that can present a risk of bias. For instance, sampling bias was present in ten studies because of the adoption of convenience sampling.[20–24,28,30,32,36,37] In addition, risk of bias because of the cross-sectional study type was present in three studies, where cause-and-effect relationships between variables were not established.[16,19,35] Moreover, risk of bias due to data collection methods (recalls and surveys that relied on memory) or duration was present in nine studies.[17,18,25–27,29,31,33,34] Misreporting due to stress related to lockdown measures was also possible, in addition to bias associated with social desirability.[1]

Results of individual studies.

Dietary patterns. Dietary patterns were reported in 21 studies.[16–27,29–37] These can be divided into intakes of food groups, macronutrients, micronutrients, and nutritional supplements. Increases and decreases of the intakes of the main food groups were found when comparing before with during the lockdown phase, including cereal foods, vegetables and legumes, fruits, milk and yogurt, lean meats, fast foods, and tea. These are reported in Table 3.[16,18–27,29–35,37] However, butter/oil consumption increased consistently during these periods, especially in females.[19,21] Sweets and desserts consumption also increased consistently.[21,24–27]

When intakes post-lockdowns were compared with during lockdowns, increased intakes of fast foods, sweets and desserts, fruit juice, butter and oil, and tea, coffee, and other beverages were reported,[21] in addition to decreased intakes of vegetables, fruits, and milk products post-lockdowns.[21] This implies an increase in the intake of "discretionary foods" accompanied by a decrease in minimally processed foods post-lockdowns. Alcohol intakes increased during lockdowns compared with before lockdowns,[18,24,32,37] and post-lockdowns compared with during lockdowns.[21]

The intakes of macronutrients and micronutrients were reported in three studies.[18,32,33] One study reported only cross-sectional estimates, including average intakes of 127 g/day, 96 g/day, and 322 g/day for fat, protein, and carbohydrates, respectively, during lockdowns.[33] One study reported increased intakes for all macronutrients and micronutrients except vitamin C and iodine during lockdowns when compared with before lockdowns.[18] One study reported increased protein intakes during lockdowns when compared with before lockdowns by direct comparison, using linear

Table 3 **Intakes of food groups before, during, and post-lockdown in Israel, Canada, Ethiopia, USA, Poland, South Africa, Turkey, Saudi Arabia, Italy, Australia, Japan, Lebanon, and Brazil from January 2020 to November 2021**

Food groups	During lockdown	Before vs during lockdown	Post-lockdown vs during lockdown
Grain (cereal) foods	44.8% once/day (Sidor et al 2020)[23] 41% 1–4 times/week (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Bebenek et al 2020, Luszczki et al 2021)[18,24,26] ↑(Mascherini et al 2021)[37]	↓(Bin Zarah et al 2020)[21]
Vegetables and legumes	40.2% few times/week (Sidor et al 2020)[23] 33.5% once/day (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Mekonnen et al 2021, Litton et al 2021, Luszczki et al 2021)[18–20,26] ↑(Skolmowska et al 2021, Zengin et al 2021, Sultan et al 2021)[25,30,34] No change (Rogers et al 2021)[22]	↓(Bin Zarah et al 2020)[21]
Fruit	42.1% once/day (Sidor et al 2020)[23] 40.4% 1–4 times/week (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Mekonnen et al 2021, Litton et al 2021, Luszczki et al 2021, Sultan et al 2021)[18–20,26,34] ↑(Skolmowska et al 2021, Zengin et al 2021, Macherini et al 2021)[25,30,37] No change (Rogers et al 2021)[22]	↓(Bin Zarah et al 2020)[21] for whole fruits; ↑for fruit juice (Bin Zarah et al 2020)[21]
Milk and yogurt	40% 1–4 times/week (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Mascherini et al 2021)[18,37], ↑(Luszczki et al 2021)[26]	↓(Bin Zarah et al 2020)[21]
Lean meats	65.2% eats poultry/white meat more than red meat (Kaufman-Shriqui et al 2022)[16] 36.8% never (Sidor et al 2020)[23] 50.2% 1–4 times/week (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Litton et al 2021, Mascherini et al 2021)[18,20,37], ↑(Bebenek et al 2020, Luszczki et al 2021, Pillay et al 2020)[24,26,27] No change (Rogers et al 2021)[22]	↓(Bin Zarah et al 2020)[21]
Fast foods	50.8% less than once/month or 0 (Al-Musharaf et al 2020)[33] 28.3% occasionally (Sidor et al 2020)[23] 57.6% none (Al-Musharaf et al 2020)[33]	↓(Bebenek et al 2020, Skolmowska et al 2021, Luszczki et al 2021, Sultan et al 2021)[24–26,34], ↑(Zengin et al 2021)[30] No change (Rogers et al 2021)[22]	↑(Bin Zarah et al 2020)[21]
Butter/oil	65.6% uses olive oil as main fat (Kaufman-Shriqui et al 2022)[16]	↑(Mekonnen et al 2021)[19]	↑(Bin Zarah et al 2020)[21]
Tea and other beverage	Water: 49% 1000 mL/day–1500 mL/day (Al-Musharaf et al 2020)[33] Coffee: 30.1% once/day (Sidor et al 2020)[23], 31.4% once/day (Cheikh Ismail et al 2021)[35] Tea: 37.1% more than once/day (Sidor et al 2020)[23], 31.4% once/day (Cheikh Ismail et al 2021)[35]	↓(Bertrand et al 2021, Bebenek et al 2020, Luszczki et al 2021, Pillay et al 2020)[18,24,26,27] ↑(Sultan et al 2021, Cheikh Ismail et al 2021)[34,35] No change (Rogers et al 2021)[22]	↑(Bin Zarah et al 2020)[21]
Sweets and desserts	36.6% few times per week (Sidor et al 2020)[23] 46% sometimes (Al-Musharaf et al 2020)[33] 47.9% 1 to 4 times/week (Cheikh Ismail et al 2021)[35]	↑(Bebenek et al 2020, Skolmowska et al 2021, Luszczki et al 2021, Pillay et al 2020)[24–27]	↑(Bin Zarah et al 2020)[21]
Alcohol	↑(Sidor et al 2020, Pillay et al 2020)[23,27] 89.4% had no habit of drinking alcohol (Mekonnen et al 2021)[19] Intake of 3 beverages/week (Kaufman-Shriqui et al 2022)[16] ↓in 55.8% (Santana et al 2021)[29]	↑(Bertrand et al 2021, Bebenek et al 2020, Curtis et al 2021, Mascherini et al 2021)[18,24,32,37] No difference (Gallo et al 2020)[31] No change (Rogers et al 2021)[22]	↑(Bin Zarah et al 2020)[21]

↑: increase; ↓: decrease.

mixed-effects models for a statistical comparison.[32] Post-lockdown data on macronutrient and micronutrient intake was absent in this study. Deduction of macronutrient and micronutrient intakes from comparison of food groups intakes during and post-lockdown may be inferred. Hence, increased intake of fats post-lockdown when compared with during lockdown can be concluded, along with decreased intakes of vitamins, minerals, and proteins post-lockdown.

Supplement intake was investigated in five studies.[16,18,21,24,27] Mainly, the investigated supplements included vitamins A, C, D, E, B group vitamins, and multivitamins. Supplement type was not reported in one study.[15] There was no change in intakes of vitamin D, magnesium, B group vitamins, multivitamins, minerals, cod liver oil, or omega-3 fatty acids between before and during lockdowns in Polish adults.[24] During lockdown, two other studies reported an average of 33% of adult participants taking supplements.[16,27] Post-lockdown (named quarantine in this study), supplement intake was 20.7%,[21] and intakes of vitamin supplements were higher than other supplements after the lockdowns compared and during the lockdown periods.[21,27] Despite being unable to compare results directly from crosssectional studies in different populations, the studies[16,27] found indicate that a lower proportion of adults may have consumed dietary supplements post lockdown than during lockdown, however the intakes of vitamin supplements were self-reported to be higher than other supplements post lockdown and during lockdown.[21,27]

Food security. Food security was reported in 8 studies.[20–23,25,29,35,36] Reduced purchasing of fruits and vegetables was reported during lockdown in a study that examined the relationship between food security status and fruit and vegetable intake during the lockdown.[20] Several reasons were associated with the reduced purchase of fruits and vegetables, including lower quality, decreased availability, higher prices, fewer trips to stores, and worries of contamination.[20] In addition, fear of contracting the virus during shopping was reported during lockdowns.[23] This likely impacted food security by voluntarily restricting food access.[23] Food security status was found to correlate with dietary habits post-lockdown, when individuals who were food secure were less likely to alter their food and beverage consumption habits.[21] Another study indicated that total food purchases increased during lockdowns, accompanied by decreased household food waste and impulse buying as compared with before the lockdown phase, implying a positive influence of lockdowns on food security.[36] One study reported that the alteration of income did not hinder the acquisition of food in 67% of the studied populations during lockdown.[29] Reduced purchases were reported for pastries or cakes, with a rise in take-away meals purchases during lockdowns.[25] In addition, stocking up of foods was reported during lockdowns in 60.6% of participants in one study.[35] In one study, however, food insecurity risk decreased during lockdowns as compared with before it from 54% to 41% of study participants.[22]

Physical activity. Physical activity was reported in 13 studies.[16–19,21,27–29,31–33,36,37] Three of these studies reported only cross-sectional data but did not compare this with before lockdown periods,[19,33,36] with one study categorizing the data by number of days of exercise per week and the number of minutes of exercise per day in five days.[19] This study found that 52% of the population exercised less than five days per week, and 77.9% of the population exercised for 30 minutes or more per day in five days.[19] Eleven studies reported decreased physical activity during lockdowns compared with before it,[16–18,26,27,29,31,32,34,35,37] followed by an increased physical activity post-lockdown compared with during lockdowns.[21] One study reported that vigorous activity was not affected during lockdowns,[31] and two others noted it increased during lockdowns.[28,37] One study found that participants engaged in more cycling during lockdowns, with a reduction in light activity.[32] The increase in cycling was due to increased efforts during lockdowns to evade public transport; ie, public transport was replaced by bicycles.[32] The decrease in light activity was due to working from home during lockdowns, thereby reducing the active daily commutes.[32] One study reported no change in physical activity during lockdowns as compared with before it.[22] These data suggest that, overall, physical activity decreased during lockdowns and then increased post-lockdown. It is unclear whether post-lockdown physical activity level has increased to full pre-pandemic levels, from the studies included in this review.

BMI/body weight. BMI and/or body weights were reported in 15 studies.[16,17,19,21,23,24,26,28,29,32–37] Weight gain was reported during lockdowns as compared with before lockdown in 10 studies,[16,17,23,24,28,29,33–35,37] with an average of 32.4% of participants reporting weight gain. This weight gain was found to continue post-lockdown in 38% of participants.[21] Two studies reported no change in body weight during lockdowns compared with before lockdown.[26,32] BMI was reported as descriptive cross-sectional data only in seven of the studies.[19,21,23,32,33,35,36] Among those studies, 34.4 to 51.9% of participants were found to be overweight, 53.6

to 68.6% within the healthy weight range,[23,33,35,36] and 47% of the participants were found to be obese.[21] One study reported increases in BMI during lockdowns as compared with before it, but it remained in the normal range of 18.5 kg/m^2 to 24.9 kg/m^2.[37] Three studies reported increases in overweight and obese percentages during lockdowns as compared with before the lockdowns.[24,29,34] Overall, it seemed that body weights were negatively impacted by lockdowns when compared with pre-lockdown levels.

Synthesis of the results

Associations between dietary patterns, physical activity, food security, BMI, or body weight with sociodemographic characteristics were reported in 16 studies.[16,18–21,23,24,27–33,36,37] Twelve studies reported positive associations, where different sociodemographic characteristics were associated with impacts on either dietary patterns, physical activity, food security, BMI, or body weight changes.[16,19,20,23,27–29,31,33,37] These associations were seen in the data collected post-lockdown.[21,36] Three studies did not report associations between different sociodemographic characteristics and either dietary patterns, physical activity, food security, BMI, or body weight.[23,29,31] The reported associations are presented in Table 4,[16,18–21,23,27–29,31,33,36,37] showing each influenced pattern and corresponding sociodemographic characteristics. The associations of sociodemographic characteristics with dietary patterns, physical activity, food security, and BMI or body weight are further elaborated in the following section.

Associations with dietary patterns Positive associations were found between dietary patterns and a number of sociodemographic characteristics, such as age, gender, family income, and course of study of students. Older age showed a positive influence on these patterns in two studies, where older age participants reported healthier dietary patterns.[16,23] Younger age showed a positive influence on dietary patterns in two studies.[29,37] Male gender was also associated with positive influences on dietary patterns in three studies.[18,19,37] Increased family income had a positive impact on dietary patterns.[33] Interestingly, not being a health-course student also had a positive influence on dietary patterns.[29]

Negative associations were also found between dietary patterns and various sociodemographic characteristics such as age, gender, employment status, educational status, and socioeconomic status. Older age showed a negative influence on dietary patterns in four studies,[21,23,29,37] but younger age also showed a negative influence on dietary patterns in one study.[28] Contradicting findings (positive and negative influences) were also noted for associations with gender. Female gender had a negative influence on dietary patterns in eight studies,[16,18,21,23,27,29,31,37] while male gender had a negative influence in one study.[18] Unemployment was highly correlated with a negative influence on dietary patterns, as found in five studies.[16,19,20,33,36] Also, lower education negatively impacted dietary patterns in three studies,[16,19,23] and lower wealth had the same impact in five studies.[16,19,20,33,36]

Associations with physical activity Both positive and negative associations were found between physical activity and various sociodemographic characteristics. However, sociodemographic characteristics were only limited in findings to gender and age. Being a female had a positive impact on physical activity, as evident in eight studies.[16,18,21,23,27,29,31,37] As for age, contradicting findings were reported. Younger age showed both a positive[37] and negative[28] influence on physical activity.

Associations with food security Sociodemographic characteristics that had a negative impact on food security, including gender, employment, wealth, and education. Female gender had a strong negative influence on food security status in eight studies.[16,18,21,23,27,29,31,37] Both unemployment and less wealth impacted food security negatively. This was found in five studies.[16,19,20,33,36] Interestingly, having a higher education qualification imposed a negative impact on food security.[23]

Associations with BMI or body weight Limited investigation has been reported for influence of sociodemographic characteristics on BMI or body weight. The only reported sociodemographic characteristics was age, where older age had a negative influence on BMI or body weight.[21,23,29,37]

DISCUSSION

Overall, the findings from the included studies indicated negative impacts of lockdowns on dietary patterns, food security, physical activity, and body weight/BMI, in addition to significant associations with various sociodemographic characteristics of the studied populations.

Dietary patterns, food security, physical activity, and BMI/body weight

The intake of "discretionary foods" including fast foods, sweets and desserts, fruit juice, butter and oil, and tea and coffee increased post-lockdown, based on the results of the present review. However, the intake of

Table 4 **Associations between dietary patterns, physical activity, food security, body mass index or body weight, and sociodemographic characteristics**

Influence from sociodemographic characteristics	Dietary patterns	Physical activity	Food security	Body mass index or body weight
Positive influence	Older age (Kaufman-Shriqui et al 2022, Sidor et al 2020)[16,23] Male gender (Betrand et al 2021, Santana et al 2021, Mascherini et al 2021)[18,29,37] Increased family income (Al-Musharaf et al 2020)[33] Younger age (Santana et al 2021, Mascherini et al 2021)[29,37] Not being a health course student (Santana et al 2021)[29]	Female gender (Kaufman-Shriqui et al 2022, Bertrand et al 2021, Bin Zarah et al 2020, Sidor et al 2020, Mascherini et al 2021, Santana et al 2021, Gallo et al 2020)[16,18,21,23,27,29,31,37] Younger age (Mascherini et al 2021)[37]	N/A	N/A
Negative influence	Older age (Bin Zarah et al 2020, Sidor et al 2020, Santana et al 2021, Mascherini et al 2021)[21,23,29,37] Female gender (Kaufman-Shriqui et al 2022, Bertrand et al 2021, Bin Zarah et al 2020, Sidor et al 2020, Mascherini et al 2021, Santana et al 2021, Gallo et al 2020)[16,18,21,23,27,29,31,37] Unemployment (Kaufman-Shriqui et al 2022, Mekonnen et al 2021, Litton et al 2021, Al-Musharaf et al 2020, Scacchi et al 2021)[16,19,20,33,36] Lower education status (Kaufman-Shriqui et al 2022, Mekonnen et al 2021, Sidor et al 2020)[16,19,23] Male gender (Kaufman-Shriqui et al 2022)[18] Younger age (Brito et al 2021)[28] Lower wealth status (Kaufman-Shriqui et al 2022, Mekonnen et al 2021, Litton et al 2021, Al-Musharaf et al 2020, Scacchi et al 2021)[16,19,20,33,36]	Younger age (Brito et al 2021)[28]	Female gender (Kaufman-Shriqui et al 2022, Bertrand et al 2021, Bin Zarah et al 2020, Sidor et al 2020, Mascherini et al 2021, Santana et al 2021, Gallo et al 2020, Mascherini et al 2021)[16,18,21,23,27,29,31,37] Unemployment (Kaufman-Shriqui et al 2022, Mekonnen et al 2021, Litton et al 2021, Al-Musharaf et al 2020, Scacchi et al 2021)[16,19,20,33,36] Lower wealth status (Kaufman-Shriqui et al 2022, Mekonnen et al 2021, Litton et al 2021, Al-Musharaf et al 2020, Scacchi et al 2020)[16,19,20,33,36] Higher education (Sidor et al 2020)[23]	Older age (Bin Zarah et al 2020, Sidor et al 2020, Santana et al 2021, Mascherini et al 2021)[21,23,29,37]

vegetables, fruits, and milk products was shown to decrease post-lockdown compared with during lockdown. Consumption of butter and oil increased in female groups during and post-lockdown. Alcohol intake increased during and post-lockdown. These findings are similar to the those of a study showing decreased intake of fresh food, particularly fruit, but increased intake of sweets, cookies and cakes.[38] Reduced physical access to usual food outlets appeared to be a major factor in such changes. Individuals reported less-frequent grocery shopping, along with difficulties accessing their typical food stores or finding

their favored food products.[38] Other reasons for such dietary changes may have included mood alterations, and lack of motivation in lockdown, accompanied by boredom or anxiety.[39]

Decreased intakes of cereal foods, vegetables and legumes, fruits, milk products, and lean meats were sustained post-lockdown. In addition, increased intakes of fast foods, butter and oil, sweets and desserts, and alcohol were sustained post-lockdown. Increase in alcohol intake during lockdowns may have been due to spending more time at home, boredom, and increased stress, as reported by the Australian Institute of Health and Welfare.[40] Other potential causes for such increases include job loss, reduced working hours, or having a child-care role.[41,42]

Data on macronutrient and micronutrient intake post-lockdown appeared lacking. Further research to examine longer-term impacts of the lockdowns on specific macronutrient and micronutrient intakes of populations is needed. Nutrient intake data can be important for the development and monitoring of national or regional public health nutrition policies and interventions, as well as product and food service development.[43]

Supplement intake decreased during lockdowns when compared with before lockdowns. This contradicts findings from another study explaining that consumer demands for vitamin and mineral supplements increased during COVID-19 outbreak due to their perceived boost of their immune systems and overall health,[44] in addition to self-protection from contracting the virus.[44] Supplement intake decreased post-lockdown when compared with during the lockdown. Interestingly, based on the results of the macronutrient and micronutrient intake analysis of the present review, vitamin C and iodine intake did not decrease during lockdown. This potentially reflects the perceived immune-boosting benefits of vitamin C[45] and iodine[46] during lockdown, and thus the lack of alteration in intake of vitamin C and iodine as a protective measure against COVID-19.[44] The influence of online information distributed via social media and simple internet search results[44] on population consumption of dietary supplements during and post-lockdown requires further investigation.

The current review found that food security was impacted during and post-lockdown, in line with the World Bank Report[46] highlighting that populations from all over the world are being challenged with rising levels of food insecurity, even before the pandemic, due to several factors such as conflict, natural risks, and climate change.[46] The World Bank clarified that the pandemic caused drastic rises in worldwide food insecurity, specifically affecting susceptible households in different countries.[46] This impact is expected to continue into 2022.[46] Food insecurity health implications are concerning if unresolved, and they can include stress, fasting and binge eating cycles. Higher-cost, nutritious food can be replaced with lower-cost, higher-energy food, and nutrient deficiencies, weight loss, or overweight and obesity can result.[47] Food insecurity issues can be addressed through food assistance programs.[48]

The decrease in physical activity during lockdowns and the increase post-lockdowns demonstrated in this study may be attributed to various factors. The decrease could have been due to increased screen time while being at home,[49] and a shift to working from home accompanied by gym access restrictions.[50] It is plausible that post-lockdown physical activity increased due to restored gym access. In addition, post-lockdown, people have returned to their pre-pandemic lifestyles partially or fully, thus allowing them to shift back to their pre-pandemic physical activity level, at least partially. Pre- and post-lockdown physical activity levels remain to be investigated.

Body weight was shown to increase during, and post-lockdown when compared with pre-lockdown status. BMI was shown to increase during lockdowns, with a data gap post-lockdowns. The weight/BMI increase may reflect an increased intake of some discretionary foods,[51] as demonstrated in this review. Pellegrini et al associated weight gain with self-reported anxiety and depression,[52] which seemed to have increased during lockdown.[52] Other reasons may include increased stress eating, eating because of boredom in lockdowns, and increased food cravings.[53]

Summary

This systematic review confirms that COVID-19 lockdowns had short-term effects up to 3 months post-lockdown on the dietary patterns, physical activity, food security, and body weight/BMI of populations in many countries. Dietary patterns were highly impacted, and an increase in the intake of discretionary foods and alcohol was noted, along with a decrease in the intakes of fresh foods and supplements. Changes in food consumption were noted due to less food availability and accessibility or increased anxiety. Supplement intakes had a remarkable role in immunity boosting as perceived by populations, and increased stress and boredom were associated with elevated alcohol consumption. The shifts in dietary patterns also resulted in shifts in populations' body weight and BMI, where marked increases where noted. The impact on physical activity was rather short-term: it was altered negatively during the lockdown phase, but went back to normal post-lockdown. An alarming impact on food security was found, and many populations from around the world are projected to suffer from food shortage and insecurity, even post-lockdown.

The study characteristics can be summarized in terms of location, duration of data collection, lockdown

phase, design, methods, aims, characteristics of participants, reported data, and assessment tools. Studies included in this review were conducted in all WHO regions except South East Asia. In most (20/22) studies, the duration of the data collection was 1 months to 3 months or less. Most (20/22) studies were conducted during lockdown or compared data before with data during lockdown. Most (18/22) studies were of cross-sectional design. The majority of studies (20/22) used online surveys. Most studies (14/22) aimed to assess the impact of the lockdown on dietary behaviors, followed by mental well-being, then food security, then physical activity. Most studies had a sample size of below 500 (8/22), adults aged 18 years or more (19/22), females (18/22), healthy participants from the general population (19/22), educated people, employed people, and those of medium wealth status. Most studies (21/22) reported data on dietary patterns, followed by physical activity, then BMI/body weight, and then food security. Only four studies reported data on all outcomes together. Eleven studies used validated assessment tools for dietary patterns, four for food security and five for physical activity, and BMI/body weight were assessed by self-reports in 13 studies.

Gaps in the current data

Based on the data patterns of the studies in this review, the data gaps found are summarized in Table 5. It is, however, considered challenging to address multiple gaps in a single study with a reasonable sample size and characteristics representative of the general population.

Practical implications and significance of future research

The findings of future studies may be employed in several practices. To begin with, preventive and/or corrective measures can be taken by various authorities to aid people on various levels in dealing with the long-term impacts that may be imposed by the lockdowns. To deal with prospective impacts on dietary patterns and other lifestyle behaviors, medical and nutritional staff can help through guiding populations in regard to the appropriate medical nutritional therapies available to protect them from short- and long-term impacts of harmful dietary and other lifestyle behaviors on their health. Second, financial and employment training support can be applied by governmental bodies to aid people suffering from hardships, mainly socioeconomic, resulting from lockdown impacts that may continue beyond the end of lockdown. Third, prospective findings can be employed as basis of cooperation with food industries. Insights into evidence-based dietary needs derived from dietary changes resulting from lockdown can help the private sector plan for the supply, distribution and marketing of foods in local marketplaces. This can help them better sustain their businesses in a time of challenges associated with the pandemic and beyond.

Strengths and limitations

This systematic review addresses the gap in understanding of impacts of lockdown on dietary and physical activity behaviors and nutritional outcomes in the immediate months beyond lockdown. An additional strength is the inclusion of possible associations of those lifestyle and nutritional outcomes with various sociodemographic characteristics in a number of populations. A limitation of this review is that gray literature was not included. Factors other than socioeconomic and sociodemographic characteristics have not been included when reviewing impacts on lifestyle changes. In addition, the vast majority of studies included were of positive study quality according to ADA assessment. Studies excluded were of negative or neutral quality, which may have resulted in selection bias in the findings. Moreover, additional bias in our results may be present because of the limitations in the methodologies used to collect dietary data from the included studies. COVID-19 lockdowns may have added to the stress during study participation, which may have caused under-reporting of dietary intakes or dietary behaviors, leading to inconsistencies in the dietary intake data comparing the before-lockdown with the during-lockdown phases.[1] Furthermore, many of the limitations of the dietary assessment methods were part of the impacts of the lockdown measures at the time of the study and ethical considerations regarding minimizing risk of COVID-19 transmission. The complexity of adopting participant recruitment online and physically may also have shifted the preferences of recruitment strategies to the online environment. There is evidence that participants recruited for online settings posses distinct sociodemographic or socioeconomic characteristics from participants recruited in traditional face-to-face settings.[54,55] This cautions against the generalizability of the reported findings. The same impacts on risk of bias could also occur due to online-only data collection, which was adopted in 20 studies.[16,18,20–37] This is also highlighted as a data gap and is presented in Table 5. This review is a timely update of the status quo of the impacts of an unprecedented global public health challenge on dietary and nutritional outcomes.

CONCLUSION

This systematic review has accumulated evidence showing that COVID-19 lockdowns imposed a major impact on various dietary and lifestyle parameters of people

Table 5 **Data gaps and future research suggestions**

Gap	Future research	Applicable or not (possible challenge[s])
No studies in South East Asia	Studies to be conducted in this region	Applicable
Fewer long-term duration of data collection/longitudinal designs	More studies using longitudinal designs	Applicable
Fewer studies post-lockdown or comparing pre- to post-lockdown	More studies post-lockdown or comparing pre- to post-lockdown	Applicable
Fewer cohort studies	More cohort studies	Challenging depending on lockdown restrictions
Fewer interviews to collect data	More qualitative studies	Challenging depending on lockdown restrictions
Fewer studies aimed to assess the impact of lockdown on dietary patterns, physical activity, food security, and body mass index/body weight, all combined	More studies with such aims	Applicable
Fewer sample sizes above 500, including elderly, children, and adolescents, males, with common diseases, less educated, unemployed, and lower socioeconomic status	More studies with larger sample size, including elderly, children, or adolescents, males, with common diseases, and lower socioeconomic status	Challenging depending on: • People's motivation to participate in the study • Internet/online access known to be more common for adults, more educated, and may vary by wealth status
Use of validated assessment tools for assessing various parameters less common	Recommendation to use validated tools or conduct validation studies if such tools are absent	May be challenging if the baseline data to be used for comparison did not use validated assessment tools for all parameters
Use of researcher measurement to assess body mass index/body weight less common	Recommendations to collect such data either self-reported or through properly trained assessors	Challenging depending on lockdown restrictions, time, and budget

around the world. Impacts were observed during and post-lockdown on dietary patterns, food security, physical activity, and body weight/BMI. These changes may have developed for several reasons, including but not limited to less availability of food, increased home time, shift to working from home, and increased lockdown-related stress. More research is needed on the longer-term effects of the COVID-19 lockdowns, to assess how long these impacts will remain and to what extent they will affect population nutrition and well-being and socioeconomic development. Findings on those longer-term impacts may be employed in several practical implications, including preventive or corrective measures, medical nutritional therapies, governmental control measures, and food industry business plans. Most importantly, future studies can investigate whether the COVID-19 pandemic will or will not leave behind influences for people to endure, even when its associated restrictions are over. These therapeutical, organizational, policy, and industry changes may help remedy impacts of past lockdowns and reduce disruptions to food and nutrition systems due to wide-scale challenges associated with human or planetary health.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Figure S1 Number of days in lockdown represented in each study

Figure S2 Educational levels of the populations studied, showing the percentages of the populations with an education level of high school completion or above, and the percentages who have not completed high school

Table S1 Completed PRISMA checklist

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