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Eating behavior and mental health during the COVID-19 pandemic

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Eating behavior and mental health during the COVID-19 pandemic

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Editorial: Eating behavior and mental health during the COVID-19 pandemic

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Editorial on the Research Topic
Eating behavior and mental health during the COVID-19 pandemic

Eating behavior is a complex set of actions encompassing what, where, how and with whom we eat. It involves phylogenetic and ontogenetic factors, as well as the ability to control food intake through physiological mechanisms such as neurotransmitters, hormones, sensory receptors, and metabolism (1). External stimuli (such as the organoleptic properties of food), psychological pressure, and the social environment also affect food choices (2–4). Thus, eating behavior emerges from the interaction of the individual's biological characteristics with economic, social, and cultural contexts.

Beyond nourishing the body, food occupies a privileged place in human life in creating and maintaining social ties. During the COVID-19 pandemic, changes in social life due to city-wide movement restrictions and social distancing recommendations have altered food acquisition (Besoro-Moreno et al.) and eating patterns (Paz-Graniel et al.) and commensality (Di Nucci et al.). This is the scope of this Research Topic: the understanding of different aspects of food, nutrition, and eating behaviors associated with psychological factors linked to the pandemic (Wu et al.), brain metabolism (Juby et al.) and COVID-19, eating disorders (Yang et al.) as well as the changes imposed by the pandemic on lifestyle and consumption habits (Galvão et al.).

Preparing to manage a pandemic involves considerable time and planning. Based on the knowledge acquired from facing other severe epi or pandemics, four methods have been frequently used to manage and control the viral spread: (1) risk communication to raise public awareness, (2) vaccines and antiviral therapies, (3) adherence to preventive behaviors, and (4) restrictive measures on movement (5).

The effects of a long and uncertain pandemic have two major facets. On the one hand, it is known that the consequences of COVID-19, especially the damage caused directly by the virus infection, have led to various complications, or even neurological diseases resulting from neuroinflammation of the Central Nervous System (CNS) (Juby et al.). In addition to these, a multitude of cognitive and emotional dysfunctions, sensory ones such as the loss of smell and taste, and even problems regarding motor mobility and strokes. On the other hand, the stress associated with work, lockdowns, physical, and social isolation, as well as the long social distancing and quarantine, which are responses imposed by health and government authorities commonly used to contain the spread of the coronavirus (in this case, its SARS-CoV-2 version), also substantially affect human mental health. The combination of social isolation, information overload, interruptions to daily life, exacerbation of unemployment rates, and economic difficulties have caused growing feelings of anticipatory grief, worry, and anxiety around the world (5, 6).

All of this means that the pandemic, whatever its scope and definition, is always dual. In fact, we can even go as far as to say that the psychological effects (psychological footprint) of the COVID-19 pandemic will, as in most pandemics, be much higher, more pronounced, more widespread, and longer-lasting than the somatic effects of the infection (medical footprint) (6, 7). The COVID-19 pandemic, as a global experiment, without prior consent nor the approval of any ethics committee, has seriously affected us, continues to affect us, and will affect us throughout the journey of life. No forgiveness for the virus.

The continuous and immense scientific literature on the subject, revealed the direct and indirect, short and long term, effects of COVID-19 on the Central Nervous System (CNS), leading to the decline in people's mental health. In all of these cases, some of the social determinants of mental health, and their impact on disadvantaged populations in times of crisis, can help policymakers establish action plans to mitigate the mental health turmoil of the COVID-19 pandemic, both during this period and in what is to come.

The studies included in this special volume, dedicated to the effects of the COVID-19 pandemic on eating behavior and mental health constitute just a small sample of issues related to food and nutrition. Gathered together, they immediately reveal that the global mental health crisis, especially in relation to lifestyles and eating behaviors (Cachero et al.; Ge et al.; Paz-Graniel et al.), caused by COVID-19 has lasted longer than we all expected. With its high uncertainty and limited control, the COVID-19 pandemic has affected all populations. Of course, the studies summarized here show much more than that, but they also reveal that individual differences exist and are caused not only by personality factors, but also by psychological and social factors, such as economic, educational, health, and social differences, which plague a large proportion of nations around the world.

Considering that eating behavior involves mechanisms that respond to social pressures, the papers in this Topic seek to elucidate how mental health problems during the pandemic, including depression and anxiety, relate to eating behaviors and body image (Wu et al.; Yang et al.). Many among them have examined the correlation between mental health and eating behavior, eating habits, and consumption patterns during the COVID-19 pandemic (Besoro-Moreno et al.; Cachero et al.; Galvão et al.; Ge et al.; Yang et al.).

We are grateful to our countless colleagues and friends for the support and encouragement they have collectively given us. Moreover, we mainly recognize the authors and reviewers for the manuscripts that comprise this special issue with attention and precision. We will be immensely rewarded if this volume helps to advance psychological knowledge about the effects of the COVID-19 pandemic on the behaviors and eating habits of the global population, in the hope that it will assist us in coping adaptively, or resiliently, with future infectious diseases.

Author contributions

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References

1. Shin S, You IJ, Jeong M, Bae Y, Wang XY, Cawley ML, et al. Early adversity promotes binge-like eating habits by remodeling a leptin-responsive lateral hypothalamus–brainstem pathway. *Nat Neurosci.* (2023) 26:79–91. doi: 10.1038/s41593-022-01208-0

2. Cohen DA, Farley TA. Eating as an automatic behavior. *Prev Chronic Dis.* (2008) 5:1–7.

3. Bruch H. *La Gabbia D'Oro L'Enigma Dell'Anoressia Mentale. 3rd ed.* Milano, Italy: Feltrinelli (2008).

4. Tan EJ, Raut T, Le LK, Hay P, Ananthapavan J, Lee YY, et al. The association between eating disorders and mental health: an umbrella review. *J Eat Disor.* (2023) 11:1–4. doi: 10.1186/s40337-022-00725-4

5. Giordani RCF, Giolo SR, Zanoni Da Silva M, Muhl C. Risk perception of COVID-19: Susceptibility and severity perceived by the Brazilian population. *J Health Psychol.* (2022) 27:1365–78. doi: 10.1177/13591053211044536

6. Norton R. *The Covid-19 Catastrophe: What's Gone Wrong and How to Stop it Happening Again*. Polity Press: Medford, MA, USA. (2020).

7. Taylor S. *The Psychology of Pandemics: Preparing for the Next Global Outbreak of Infectious Disease*. Lady Stephenson Library, Newcastle upon Tyne, UK: Cambridge Scholars Publishing. (2019).

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The impact of COVID-19 pandemic on food habits and neophobia in children in the framework of the family context and parents' behaviors: A study in an Italian central region

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Objective: This paper aims to evaluate whether changes in lifestyle and eating habits resulting from the Covid-19 emergency have influenced the post-pandemic level of food neophobia and in children living in an Italian central region.

Methods: A sample of 99 children took part in a retrospective assessment carried out with a self-administrated questionnaire. Pre and post-pandemic evaluation of eating habits, physical activity, and lifestyle indicators was carried out. Food neophobia was evaluated following the Child Food Neophobia Scale (CFNS). Descriptive statistics were produced. A contingency analysis was performed to check associations between variables.

Results: For a large part of the sample (97%) the selective food refusal did not change during the pandemic period. About 70% of participants did not change their eating habits, with some subgroups reporting an increase in the consumption of fruits (22.2%), vegetables (19.2%), and legumes (21.2%). Relevantly the impact of the pandemic on the sedentary attitude passed from 25.3 to 70.7%. Neophobia was not associated with ponderal status (p-value 0.5). However, in normal-weight children, a high prevalence of intermediate-level neophobia (78.4%) was found. 39.4% of the studied children were involved in meal preparation during social isolation, with an increase in the proportion of children that shared all meals with their family (32.3% vs. 78.8%). Non-coercive parent behaviors in reaction to food refusal were associated with low levels of neophobia (p-value < 0.05).

Discussion: In this sample, for the effect of parents' attitudes, the pandemic positively affected children's food habits and, consequently, the level of

neophobia after the social restrictions. The main implication of the study is the importance of capitalizing on the period of restrictions in order to involve children in meal sharing and food preparation.

KEYWORDS

neophobia, eating habits, COVID-19 restrictions, children, Italy

Introduction

In children of the Mediterranean region, there has been a trend of abandoning the Mediterranean Diet (MD) with a shift toward a Westernized dietary pattern (1). In Italy, data collected in 2019 (2) highlighted that the consumption of fruit, vegetables, and legumes, typical MD foods, was inadequate for many children.

One of the causes of low fruit and vegetable consumption in children could be food neophobia which is defined as the reluctance to eat new or unknown foods. It is a very common behavior among children with a well-defined onset and evolution. Normally neophobia appears during the complementary feeding period, at 4–6 months of age when food is gradually introduced into the child's diet, it increases sharply as the child becomes more mobile and independent, reaching a peak between 2 and 6 years of age and then gradually decreases into adulthood (3).

As reported by Cooke et al. (4), food neophobia is primarily a hereditary trait, in which the genetic determinants accounted for 78%. However, the development of eating behavior is determined by the dynamic interplay of genetics (5), environmental factors (e.g., interaction with caregiver) (6) and food-related experiences (7). Among environmental factors, the so-called social facilitation mechanism (8) should be mentioned, which is characterized by an improvement in the performance of a task in the presence of others, e.g., family components, compared to behavior when staying alone. Translating this concept to food habits, the more the people around a child consume new and unusual food, the more willing the child will be to try it (3). It has been observed that how food is offered to the child has a significant impact on the development of food neophobia. Parental pressure for children to eat foods they do not like results in greater resistance to consumption. In addition, the absence of affectionate behavior during meals results in children associating eating with negative emotions such as anxiety and tension. These emotions reinforce the rejection of unfamiliar foods when offered and exacerbate neophobic behaviors (9).

From an evolutionary point of view, food neophobia could be considered a protective mechanism that reduces the risk of eating potentially harmful foods. Reinforcing the habit of choosing familiar and safe foods, instead of new, unfamiliar, and potentially dangerous food (10). For these reasons, the neophobic attitude is mainly manifested in the consumption of foods with bitter or acidic tastes such as fruits and vegetables, in which it is more likely to find unsafe substances (11–14). As well as manifesting in the case of animal foods which are primary sources of bacteria responsible for food toxicoinfections (15).

It was also demonstrated that food neophobia limits the adherence to the MD in the sense that a higher level of food neophobia is associated with lower adherence to the MD (16).

Food neophobia does not limit the amount of ingested food but impacts the variety and nutritional quality of the diet (17). The neophobic people's diets are often characterized by a high intake of saturated fats and sugars (17, 18), foods not targeted by neophobia considering the innate preference for sweet and savory flavors (13, 19). This dietary pattern limits the intake of several nutrients such as vitamin E, folate, calcium, zinc, and fibers that are essential, especially in childhood, for physical and intellectual development and to prevent future occurrence of chronic non-communicable diseases (9).

For these reasons, it was hypothesized that food neophobia could be a predictor of childhood obesity as parents compensate for children's reluctance to eat healthy foods by providing foods that are more accepted such as sweet and calorie-dense foods (18, 20). However, limited studies are available on the relationship between food neophobia and child weight status, and the findings are not univocal. Absence of association between food neophobia and weight status was frequently reported (19, 21–23), however, an increase of overweight related to neophobia was also observed (24). According to Rioux (25), to date there are insufficient studies demonstrating a robust association between food neophobia and child weight status.

The covid-19 pandemic changed people's daily behaviors including lifestyle and eating habits. Due to the rapid spread of the virus in China and other countries around the world, on the 30th January 2020, the World Health Organization (WHO) Emergency Committee declared the Covid-19 disease a global health emergency (26), and then, on 11 March 2020, a pandemic disease (27). Consequently, to contain the spread of the virus, the Italian government approved a series of rigorous containment measures which consisted of an intense social isolation (28). As an effect of these containment measures children could not attend school, see their friends, or play sports activities, and this negatively impacted their psychological and physical health status (29). Several Italian studies on children's lifestyles and eating habits during the first lockdown showed a

drastic reduction of time spent in physical activity and more time dedicated to sedentary activities such as watching TV and playing video games (30–32). This could explain the weight gain observed during the COVID-19 pandemic, especially in children already suffering from overweight (33). In addition to that, studies carried out during the severe phases of the pandemic reported a worsening of eating habits characterized by increased consumption of calorie-dense and comfort foods such as chocolate, sweet snacks, and desserts but also bread, pizza, and bakery products (28, 30, 34). The increased consumption of these foods could be related to anxiety (35) attributable to the disruption of the daily routine, limitation of physical activities and opportunities for socialization (36) but also to fight against boredom resulting from the long time spent at home during social isolation (37, 38).

However, the lockdown also had positive effects, creating opportunities to involve children in the preparation of meals (31, 32) and to consume foods with the rest of the family (32), contributing positively to the conviviality and familiarization with foods they do not like (32, 39).

In consideration of the present scenario, we decided to assess the impact of social restrictions related to the Covid-19 pandemic on eating habits and the occurrence of neophobia in children living in Lazio, an Italian central region. The hypothesis underlying this study was that several conditions related to the social restrictions of the pandemic influenced the children's neophobic behavior. Stress, worries, and bad mood caused by the COVID-19 pandemic may have affected parents' attitudes toward foods, for example forcing the child to eat, showing disapproval, or using food as a reward, all conditions that promote the neophobic attitude. In consideration of this hypothesis, the main purpose of this study was to evaluate whether changes in lifestyle and eating habits resulting from the Covid-19 emergency have influenced the post—pandemic food neophobia level in a sample of children. Specific objectives of the experimental work were the identification of the factors promoting or attenuating the neophobic attitude as well as the analysis of the strategies able to counteract neophobic behavior and promote healthy eating habits in children.

This study would contribute to addressing the following research questions: (i) to what extent and in which sense did the social restrictions related to the Covid-19 pandemic influence the neophobic attitude? (ii) could there be unexpected positive effects of the Covid-19 lockdown on children's neophobia? (iii) what were the lessons learned from this extraordinary experience that could be capitalized on in other contexts?

Materials and methods

Study design

The present assessment is a retrospective study carried out on a sample of children aged 2–11 years and living in the Italian central region of Lazio. Pre and post—pandemic evaluation of eating habits, physical activity, and lifestyle indicators was carried out and the reported changes were considered in the light of the level of neophobia of studied children measured at the time of the assessment. The class of age and the geographical provenience were the eligibility criteria of the study that consisted of an online administration of a questionnaire distributed through instant messaging apps (e.g., WhatsApp), and by mailing personal contacts. Google Form® was used for online data collection for a self-reported compilation. This simple non-probabilistic approach to recruiting respondents online, by inviting them to follow a link to a survey sent by email, or other similar means, is defined as "river" sampling by Lehdonvirta et al. (40). A sample of 106 children was reached at the end of the survey period. The data collection was performed between July 26 and October 1, 2021, and the answers referred to the conditions related to the second lockdown that started in Italy on November 6, 2020 (41).

Data collection procedure

Following the European Commission General Data Protection Regulation (679/2016) those willing to participate signed a privacy policy and consent form concerning the collection and processing of socio-demographic data in advance. Before starting the data collection, participants were informed about the objective of the research, the consequent statistical analysis, and the intention to publish the results of the assessment in a scientific journal. Participation in the study was fully voluntary and anonymous and subjects could withdraw from the study at any time for any reason. This study was conducted according to the guidelines of the Declaration of Helsinki (42). The present research is not considered either as medical experimentation, or a direct intervention on human subjects with diet changes or formulated food administration and did not involve any invasive procedures. In addition to that the Council for the Research Economics and Agriculture (CREA) is part of the National Statistical System (SISTAN) and guarantees individual data protection (43). Hence an additional ethical committee review of the study protocol was considered unnecessary once informed consent was obtained.

The questionnaire

The questionnaire was specifically developed for the scope of the survey and the respondent was an adult that acted as a caregiver. A total number of 57 questions were provided in four sections: (1) socio-demographic data of parents and children (9 questions on age, gender, caregiver's education, number of family members, presence of children under 11 in the family, weight, and height of the child); (2) Eating habits and lifestyle

of the child in the pre-pandemic period (20 questions on eating habits, school catering, the conviviality of the meals, time spent in physical activities, and the use of electronic devices); (3) Eating habits and lifestyle of the child during the second lockdown (18 questions on eating habits, the conviviality of the meals, impact of the covid-19 pandemic on eating habits and eating behavior, caregiver's feeding practices, time spent in physical activities, and the use of electronic devices); (4) Evaluation of food neophobia.

The questions on eating habits, physical activity, and lifestyle were taken from the National Statistics Multi-purpose Survey on Families: Aspects of Daily Life (44) and from the surveillance system on overweight and obesity and related risk factors carried out every 2 years in children of primary schools (45). These questions were used in other studies carried out in Italy (46–48). Food Neophobia was quantified with the Child Food Neophobia Scale (CFNS) developed by Pliner (49) and validated in Italy by Laureati et al. (50). The CFNS consists of 10 items (five referring to neophiliac and five to neophobic attitude) evaluated with a 7-point scale ranging from 1 = "I strongly disagree" to 7 = "I strongly agree." The full questionnaire is reported in **Supplementary Table 1**.

Eating habits data were compared with the current Italian recommendations as reported in the Italian Dietary Guidelines—IDGs (51). Physical activity level was compared with the WHO guidelines that recommend at least an average of 60 min per day of moderate-to-vigorous intensity, mostly aerobic, physical activity, across the week (52). The inactivity level was evaluated in consideration of advice from the Italian Society of Pediatrics that recommend no more than 1 h per day of sedentary activities in children aged 2–5 years and no more than 2 h per day in children aged 5–8 years (53).

The individual CFNS scores were computed according to Predieri et al. (16) as the sum of the scores of the 10 items, reversing the neophiliac items to have a univocal sense of all the responses. Therefore, the scores theoretically ranged from 10 to 70 with higher scores reflecting higher Food Neophobia (FN) levels. The frequency distribution of CFNS scores was calculated and respondents were divided into three groups according to their FN level: low, medium, and high. A standardized way to develop cut-offs of FN scores for classifying individuals as neophobic or neophiliac does not exist because this tool examines the neophobia-neophilia continuum in humans (54) and some authors have used the mean value of FN scores as the cut-off point to differentiate between neophobic and neophiliac consumers (55, 56). However, in this study we used the method most commonly applied for neophobic classification that differentiated 3 consumer segments corresponding to neutrals (score in the interval mean ± 1 SD), neophobic (score > mean + 1 SD), and neophiliac (score < mean – 1 SD) (18, 57).

The child's weight and height were reported by the respondents. Since Body Mass Index (BMI—kg/m^2) was calculated and then compared with growth charts of the WHO to evaluate weight status based on the cut-offs for evolutive age proposed by WHO (58, 59).

Statistical analysis

Descriptive statistics of the data collected were produced. Single continuous and categorical variables were summarized as mean ± standard deviation and percentage (%). A contingency analysis was performed to check associations between variables. Specifically, double-entry tables were processed, and the Chi-square test of independence was applied, along with *post-hoc* tests to check pairwise comparisons, with Bonferroni corrections of the *p*-values. The test of independence on the mean was applied to compare continuous variables with categorical variables. Results were considered significant for p-value < 0.05. Statistical analysis was performed using Microsoft® Excel software.

Results

Socio-demographic characteristics of the sample

The survey was completed by 106 children. After data cleaning, 7 questionnaires were excluded from the analysis for the following reasons: 3 did not meet the inclusion criteria

TABLE 1 General characteristics of children and parents/caregivers.

	Overall = 99 ***n*** **(%)**
Children	
Gender	
Male	47 (47.5)
Female	52 (52.5)
Age ranges	
2–5 years	29 (29.3)
6–11 years	70 (70.7)
Caregivers	
Type	
Mother	88 (88.8)
Father	9 (9.1)
Others	2 (2.1)
Age ranges	
18–29 years	1 (1.0)
30–49 years	96 (97.0)
50–69 years	2 (2.0)
Education	
Lower secondary school	5 (5.0)
Upper secondary school	48 (48.5)
Bachelor's degree/master's degree/Ph.D	46 (46.5)

because were out of the classes of age for the study as defined in the inclusion criteria and for the remaining 4 there was an inconsistency between socio-demographic and anthropometric data (parents declared a child's stature unrealistically with respect to the age). Then the results were based on a sample of 99 children (52.5% males and 47.5% females). With this sample size the precision level of the study was 9%, according to the formula of Pourhoseingholi et al. (60) based on the expected prevalence of Neophobia in Italy; 26% (16). The value for Cronbach's Alpha for the study was $\alpha = 0.60$ corresponding to moderate internal consistency and moderate reliability of the scale measured (61) since the assessment consisted of 27 questions out of 46 having short scales (less than 5 items). In addition to that the overall questionnaire resulted from the combination of subsections having different value for Cronbach's Alpha. In particular the set of questions related to the neophobia scale had $\alpha = 0.80$, the lifestyle questions had $\alpha = 0.60$, and food habits had $\alpha = 0.30$. The general characteristics of both children participating in the study and the respondent caregivers are described in **Table 1**. The average age of the sample was 6.98 years (SD = 2.2) with the majority (70.7%) of the children aged 6–11 years. The questionnaire was completed primarily by mothers (88.8%) thus most of the respondents were aged 30–49 years (97%). The caregivers' educational level qualification was balanced between upper secondary school (48.5%) and bachelor's degree/master's degree/Ph.D. (46.5%).

The average family size was 3.8 ± 0.66 individuals with more than half (62.6%) of the families consisting of four people, one-fourth of the families (25.3%) consisting of three individuals. Larger families were less common (11.1% five components and 1% seven people) (data not shown).

Eating habits and lifestyle in the pre-pandemic period

Eating habits

Table 2 reports the eating habits in the pre-pandemic period of the assessed children. The dietary habits in line with the IDGs are those related to the consumption of whole grains (3–5 times a week for 58.6% of the sample), the prevalent use of olive oil as seasoning fat (95.9%) with limited use of butter or margarine (no serving for 83.9% of the sample). Behaviors that deviate far from the recommendations were the inadequate consumption of fruit (71.7%) and vegetables (58.6%), excessive consumption of red meat (>2 portions per week in 54.6% of the sample), inadequate consumption of fish (0–1 portion per week in 62.6% of the sample) and legumes (0–1 portion per week in 42.4% of the sample) and excessive consumption of sugary beverages with 19.2% of the sample that declare to consume them > 3 portions per week.

Lifestyle habits

Table 3 shows the lifestyle habits of the sample in the pre-pandemic situation. Catering service was present in 59.6% of the schools attended by the assessed children. However, not all the parents used the service, since the percentage of children who attended the school meal service was limited to 44.4%. Moreover, the survey showed that in the pre-pandemic period only 32.3% of the sample consumed all meals with the family. In the pre-pandemic period, physical activity levels, and the correspondent sedentary activities of the sample were very far from the recommendations, with 25.3% that declared not practicing physical activities and the rest of the sample that had a frequency of physical activity largely lower than the recommendations (55.5% 1–2 times/week and 16.2% 3–4 times/week). Among sedentary activities, it was found that a large part of the sample spent more time than recommended (1 h/day) in front of a screen (41.4% of the sample 2 h/day, 19.2% 3–4 h/day, and 3% more than 4 h per day). It is relevant to note that 40.4% of the sample used electronic devices during meals.

Food neophobia in children

The child's level of neophobia was measured using the CFNS. An average score of 37.8 (DS = 11.4) was obtained. No correlation was observed between the child's age and neophobia (dependency ratio on average 0.03). As far as neophobia levels, the large majority of the sample (73.7%) showed an intermediate level of neophobia, 12.1% of the assessed children had a high level of neophobia, and 14.2% of the sample resulted in a low level of neophobia. **Table 4** reports the association of neophobia levels with socio-demographic data and pre-pandemic food consumption of selected food groups. Based on the results, child gender (p-value 0.3) and parental education (p-value 0.7) are not associated with neophobia levels.

Neophobia-related food consumption was assessed in terms of the association between their pre-pandemic consumption and neophobia levels. The low consumption of fish was associated with neophobia (p-value < 0.05) in the sense that a high level of neophobia was observed in respondents that consumed limited quantities of fish. However, no statistically significant differences were observed between the level of neophobia and the consumption of vegetables (p-value 0.6), fruit (p-value 0.7), legumes (p-value 0.7), and whole-grain cereals (p-value 0.3). On the other hand, the highest consumption levels of sugary beverages were associated with higher levels of neophobia (p-value < 0.05).

Table 4 reports the children's ponderal status, resulting in almost half (51%) of the respondents with normal weight, 22% with overweight, 20% with obesity, and 6% with underweight. Neophobia is not associated with ponderal status (p-value 0.5), however, in normal-weight children a particularly high

TABLE 2 Eating habits in the pre-pandemic period.

Food categories	Consumption frequencies *n* (%)			
Vegetables/day *1 serving = 200 g*	***1*** 58 (58.6)	***2*** 25 (25.3)	***>2*** 2 (2.0)	***None*** 14 (14.1)
Fruit/day *1 serving = 150 g*	***1–2*** 71 (71.7)	***3*** 3 (3.1)	***>3*** 2 (2.0)	***None*** 23 (23.2)
White bread/day *1 serving = 50 g*	***1*** 54 (54.5)	***2*** 27 (27.3)	***>2*** 9 (9.1)	***None*** 9 (9.1)
Whole-grain cereals (bread, pasta, rice. . .)/week	***1–2*** 21 (21.2)	***3–4*** 22 (22.2)	***>5*** 36 (36.4)	***None*** 20 (20.2)
Red meat, hamburgers, or meat products (ham, sausage, etc.)/week *1 serving of meat = 100 g* *1 serving of meat products = 50 g*	***1*** 8 (8.1)	***2*** 34 (34.3)	***>2*** 54 (54.6)	***None*** 3 (3.0)
What types of meat do you prefer to eat?	***None***	***Mainly chicken and/or turkey and/or rabbit***	***All types of meat including beef, hamburger, pork, and lamb***	
	1 (1.0)	36 (36.4)	62 (62.6)	
Fish/week *1 serving = 150 g*	***1*** 47 (47.5)	***2*** 30 (30.3)	***>3*** 7 (7.1)	***None*** 15 (15.1)
Legumes/week *1 serving of fresh legumes = 150 g* *1 serving of soaked legumes = 50 g*	***1*** 31 (31.3)	***2*** 41 (41.4)	***>3*** 16 (16.2)	***None*** 11 (11.1)
Were the dishes consumed by the child seasoned exclusively with extra virgin olive oil?		***Yes*** 95 (95.9)		***No*** 4 (4.1)
Butter and/or margarine/week *1 serving = 10 g*	***1*** 13 (13.1)	***2*** 0 (0.0)	***>3*** 3 (3.0)	***None*** 83 (83.9)
Sugary beverages (orangeade, cola) including fruit juice/week	***1*** 26 (26.3)	***2*** 23 (23.2)	***>3*** 19 (19.2)	***None*** 31 (31.3)
Commercial sweets or pastries (not homemade) (cakes, cookies, sponge cake, or custard)/week	***1*** 17 (17.2)	***2*** 25 (25.2)	***>3*** 52 (52.5)	***None*** 5 (5.1)
Water/day	**<1 L** 28 (28.3)	**1 L** 46 (46.5)	**1.5 L** 17 (17.1)	**>1.5 L** 8 (8.1)

n and percentage values.

prevalence of intermediate level of neophobia (78.4%) was found.

Weight status was compared with the child's physical activity and parental education. In this sample, the risk of being overweight/obese is not related to the parents' educational level (p-value 0.6) and to the physical activity of the child (p-value 0.9) (**Supplementary Table 2**).

Eating habits and the family context during the second lockdown

As reported in **Supplementary Table 3**, worries caused by covid-19 pandemic did not influence the family's eating habits for almost half of the sample (41.4%), however, a third of the respondents (34.3%) reported an influence of the concerns related to the pandemic on family eating habits. The lockdown largely impacted the habit of sharing meals which was reported by 32% of respondents (**Table 3**) before the pandemic and became 79% when affected by social restrictions (**Table 5**). Considering the long time spent at home, it was asked whether the child's diet changed: in 43.4% of the cases no changes were reported; in 39.4% of the sample, the lockdown was an occasion to involve the children in the preparation of meals and, finally, in a minority of children (17.2%) the social isolation was characterized by moments of boredom compensated by excessive eating or with sedentary activities (**Table 5**). A significant correlation (p-value < 0.05) was found between the emotional consequences (stress, worries) of the pandemic and the changes in children's eating habits. In particular, the majority (64.7%) of the children that experienced boredom, and consequently compensated with greater food intake, reported a family context that included worries about the COVID-19 pandemic (**Table 5**).

Table 5 shows the results of questions related to the changing consumption of food groups normally associated

TABLE 3 Eating and lifestyles habits in the pre-pandemic period.

	Frequencies *n* (%)				
	Present			**Absent**	
School catering	59 (59.6)			40 (40.4)	
	Used by parents			**Not used by parents**	
	44 (44.4)			55 (55.6)	
Family meals consumption	**One meal**	**Two meals**	**Three meals**	**All meals**	
	4 (4.1)	25 (25.2)	38 (38.4)	32 (32.3)	
Screen time	**1 h**	**2 h**	**3–4 h**	**>4 h**	
	36 (36.4)	41 (41.4)	19 (19.2)	3 (3.0)	
Use of an electronic device during meals	**Yes**		**No**		
	40 (40.4)		59 (59.6)		
Physical activity	**Less frequently**	**1–2 times per week**	**3–4 times per week**	**>5 times per week**	**Does not practice physical activity**
	1 (1.0)	55 (55.5)	16 (16.2)	2 (2.0)	25 (25.3)

Frequencies, *n*, and percentage values.

with neophobia; the changing was qualitatively evaluated asking if the selected food consumption remained the same, increased or reduced. A large part of the sample reported no changes in the consumption of these foods. However, almost one-fifth of respondents reported an increase in the consumption of vegetables (19.2%), fruit (22.2%), legumes (21.2%), and whole-grain cereals (12.1%). The family context in terms of food habits during the second lockdown was found to be significantly associated with the changes in the consumption of fruit, vegetables and legumes (p-value < 0.05) in children's diets. For more than half of the children that increased the consumption of fruit (68.2%), vegetables (68.4%), and legumes (61.9%) it was reported that lockdown was an opportunity to engage them in cooking activities as shown in Table 5. Involvement in kitchen was significantly associated with increased consumption of fruit and vegetables while the association did not reach the statistical significance for legume consumption. On the other hands reduced legume consumption was significantly associated with the behavior of using food to compensate for boredom. Family meal consumption (e.g., conviviality) was found to be significantly associated with vegetable and legume consumption during the second lockdown (p-value < 0.05). Combining the frequencies of the responses of sharing three or all meals with the family, as reported in the last two columns of Table 5, it is possible to see that the conviviality is particularly common in children who increased vegetable (94.7% the sum of 42.1 and 52.7%) and legume (90.4% the sum of 33.3 and 57.1%) consumption. On the other hand, fruit (p-value 0.7) and whole-grain cereal (p-value 0.6) consumption changes were not associated with family meal frequency during the second lockdown.

Figure 1 shows that lockdown largely impacted the level of physical activity. Compared with the pre-pandemic period, the percentage of children who do not practice physical activity increased to 70.7%, while among the remainder only a frequency of physical activity of 1–2 times a week was reported (17.2%); the highest frequencies of physical activity were uncommonly reported.

The sedentary attitude was characterized by a large screen-time behavior during the pandemic period in which the proportion of the sample spending 3–4 h in front of an electronic device passed from 19.2 to 36.4%, and the proportion of the children spending more than 4 h in front of a screen passed from 3 to 14.1%. Finally, compared to the pre-pandemic period, an increase in the use of screens during mealtime was observed (40.4% vs. 51.5%) (Figure 1).

For almost the totality of children (96.9%) there was no worsening of food refusal during the second lockdown reported. Consistently, the parent in a large majority of cases (70.7%) did not experience difficulty in managing the refusals, which was claimed as a problem by 8.1% of the respondents. Figure 2 shows the results regarding the strategies adopted by parents when the child refused food. Most of them did not force the child to eat the meal (64.6%) (disagree/fully disagree), did not show disapproval (58.6%) (disagree/fully disagree), nor used the food as a reward (75.8%) (disagree/fully disagree). The most practiced feeding practices consisted of dialogue with the child (61.7%) (agree/fully agree) or increasing the palatability of the foods (71.7%) (agree/fully agree). No significant association was found between these items and the change in vegetable, fruit, whole-grain cereals, and legumes consumption in the second lockdown (p-value > 0.05) (Supplementary Tables 4–8).

Table 6 reports the association of neophobia levels with pandemic eating habits, lifestyles, and feeding practices. Parents showing disapproval toward food refusal is the only item that was found to be associated with neophobia (p-value < 0.05). Also, changes in the consumption of foods connected with neophobia during the pandemic period and the neophobia levels were not associated (p-value > 0.05). However, among children that increased the consumption of fruit, vegetables, legumes, and whole-grain cereals a higher percentage (93.1% vs. 84.3%) of children with intermediate/high level of neophobia was observed with respect to children that did not change their eating habits.

As shown in Table 7, parents that did not experience difficulties in managing food refusal (disagree/fully disagree) tend to adopt conciliatory strategies to cope with this refusal, with 60.9% of cases that agreed and 73.3% fully agreed to have a dialogue with the child, 78.8 and 90.3% of cases that, respectively, disagreed and fully disagreed in forcing the child

TABLE 4 The relationship between the level of neophobia and socio-demographic data, pre-pandemic food group consumption, *n* and percentage values.

		Level of neophobia *n* (%)		
		Low 14 (14.2)	**Medium 73 (73.7)**	**High 12 (12.1)**
Socio-demographic data				
Gender	Male	10 (19.2)	37 (71.2)	5 (9.6)
	Female	4 (8.5)	36 (76.6)	7 (14.9)
Parental education	Lower secondary school	0 (0)	5 (100.0)	0 (0.0)
	Upper secondary school	9 (18.8)	34 (70.8)	5 (10.4)
	Bachelor's degree/master's degree/Ph.D	5 (10.9)	34 (73.9)	7 (15.2)
Weight status	Underweight	0 (0.0)	6 (100.0)	0 (0.0)
	Normal weight	5 (9.8)	40 (78.4)	6 (11.8)
	Overweight	6 (27.3)	13 (59.1)	3 (13.6)
	Obese	3 (15.0)	14 (70.0)	3 (15.0)
Pre-pandemic food groups consumption				
Fruit consumption	No serving	2 (8.7)	17 (73.9)	4 (17.4)
	1–2	10 (14.1)	53 (74.6)	8 (11.3)
	3	1 (33.3)	2 (66.7)	0 (0.0)
	>3	1 (50.0)	1 (50.0)	0 (0.0)
Vegetable consumption	No serving	0 (0.0)	10 (71.4)	4 (28.6)
	1	9 (15.5)	41 (70.7)	8 (13.8)
	2	5 (20.0)	20 (80.0)	0 (0.0)
	>2	0 (0.0)	2 (100.0)	0 (0.0)
Legumes consumption	No serving	0 (0.0)	8 (72.7)	3 (27.3)
	1	4 (12.9)	24 (77.4)	3 (9.7)
	2	6 (14.6)	29 (70.7)	6 (14.6)
	>3	4 (25.0)	12 (75.0)	0 (0.0)
Whole grain cereals consumption	No serving	2 (10.0)	13 (65.0)	5 (25.0)
	1	5 (23.8)	16 (76.2)	0 (0.0)
	2	4 (18.2)	17 (77.3)	1 (4.5)
	≥5	3 (8.3)	27 (75.0)	6 (16.7)
Fish consumption	No serving	0 (0.0)	13 (86.7)	2 (13.3)
	1	4 (8.5)	35 (74.5)	8 (17.0)
	2	6 (20.0)	22 (73.3)	2 (6.7)
	>3	4 (57.1)*	3 (42.9)	0 (0.0)
Sugar beverages consumption	No serving	3 (9.7)	27 (87.1)	1 (3.2)
	1	2 (7.7)	22 (84.6)	2 (7.7)
	2	7 (30.4)*	11 (47.8)	5 (21.7)
	≥3	2 (10.5)	13 (68.4)	4 (21.1)

*$p < 0.05$. Calculated performing the Chi-square test with Bonferroni correction.

to eat the meal, in 69.7 and 96% of cases that, respectively, disagreed and fully disagreed in showing disapproval, and in 65.7% of cases that disagreed and 75% fully disagreed in using food as a reward (p-value < 0.05). On the other hand, the preparation of foods to increase palatability was not associated with parents' difficulties in managing food refusal.

Discussion

The objective of this experimental work was to evaluate the behavioral changes that occurred during the COVID-19 pandemic period and the relation between eating habits and parental attitude toward neophobia in a sample of children living in Lazio, an Italian central region. Food neophobia is a very common behavior among children, without distinction of gender, especially in the period from 2 to 6 years. In this developmental period children acquire more autonomy, becoming more neophobic; the neophobic attitude tends to progressively reduce during adulthood (3). The results of the present study confirm the extent of the problem, since more than half of the sample (73.7%) has an intermediate level of neophobia and 12.1% a high level, still without distinction between males and females. Food neophobia in children has

TABLE 5 Comparison between food groups' consumption and changes in eating habits, conviviality during COVID-19 pandemic, *n* and percentage values.

			Changing eating habits			Sharing meals during the COVID-19 pandemic			
Food groups	**Food consumption**	**Total**	**No changing 43 (43.4)**	**Children have been involved in cooking 39 (39.4)**	**Using food as a reward 17 (17.2)**	**One meal 2 (2)**	**Two meals 4 (4)**	**Three meals 15 (15.2)**	**All meals 78 (78.8)**
Pandemic vegetable consumption	Less	9 (9.1)	2 (22.2)	4 (44.4)	3 (33.3)	0 (0.0)	1 (11.1)	0 (0.0)	8 (88.9)
	Not changed	71 (71.7)	36 (50.7)	22 (31.0)	13 (18.3)	2 (2.8)	2 (2.8)	7 (9.9)	60 (84.5)
	More	19 (19.2)	5 (26.3)	13 (68.4)*	1 (5.3)	0 (0.0)	1 (5.3)	8 (42.1)*	10 (52.6)
Pandemic fruit consumption	Less	12 (12.1)	3 (25.0)	6 (50.0)	3 (25.0)	0 (0.0)	1 (8.3)	1 (8.3)	10 (83.4)
	Not changed	65 (65.6)	36 (55.4)	18 (27.7)	11 (16.9)	2 (3.1)	3 (4.6)	8 (12.3)	52 (80.0)
	More	22 (22.2)	4 (18.2)	15 (68.2)*	3 (13.6)	0 (0.0)	0 (0.0)	6 (27.3)	16 (72.7)
Pandemic legumes consumption	Less	4 (4.1)	0 (0.0)	0 (0.0)	4 (100.0)*	0 (0.0)	1 (25.0)*	0 (0.0)	3 (75.0)
	Not changed	74 (74.7)	37 (50.0)	26 (35.1)	11 (14.9)	1 (1.4)	2 (2.7)	8 (10.8)	63 (85.1)
	More	21 (21.2)	6 (28.6)	13 (61.9)	2 (9.5)	1 (4.8)	1 (4.8)	7 (33.3)*	12 (57.1)
Whole grain cereals consumption	Less	16 (16.2)	5 (31.2)	7 (43.8)	4 (25.0)	0 (0.0)	0 (0.0)	4 (25.0)	12 (75.0)
	Not changed	71 (71.7)	34 (47.9)	27 (38.0)	10 (14.1)	1 (1.4)	3 (4.2)	9 (12.7)	58 (81.7)
	More	12 (12.1)	4 (33.3)	5 (41.7)	3 (25.0)	1 (8.3)	1 (8.3)	2 (16.7)	8 (66.7)

Effects of worries caused by	**Degree of agreement**	**Total**	**No changing**	**Children have been involved**	**Using food to compensate**	–
Worries caused by pandemic changed eating habits	Completely disagree	20 (20.2)	16 (80.0)	2 (10.0)	2 (10.0)	–
	Disagree	21 (21.2)	9 (42.6)	9 (42.6)	3 (14.3)	
	Neither agree nor disagree	24 (24.2)	10 (41.6)	13 (54.2)	1 (4.2)	
	Agree	27 (27.3)	5 (18.5)	12 (44.5)	10 (37.0)	
	Completely agree	7 (7.1)	3 (42.8)	3 (42.8)	1 (14.3)	

*$p < 0.05$. Calculated performing the Chi-square test with Bonferroni correction.

also been assessed in other Italian studies (23, 62). Although different prevalence emerged [26.5% low, 44.3% medium, and 29.2% high level of neophobia (23); 24% low, 53.8% medium, and 22.1% high level of neophobia (62)], it should be pointed out that in the other studies the intermediate level of neophobia was consistent with the results of the present study. However, considering that the different Authors used different neophobia scales, comparisons must be made with caution.

Childhood obesity in Italy, as in other industrialized European countries, represents a priority public health problem. A surveillance system on overweight and obesity and related risk factors has been activated in Italian primary schools (45) which began in 2008. The latest survey (63) reports that in the Lazio region the prevalence of ponderal excess accounted for 30.8%, this means that our sample showed a particularly high prevalence of overweight and obesity (42%) in comparison with the rest of the region. This finding is probably related to the fact that our sample from the south of the Lazio region bordering the Italian region with the highest prevalence of children overweight (Campania region, 44.2%) (64). It has been hypothesized that food neophobia may contribute to childhood obesity, because to compensate for the child's rejection of food, parents offer them a more palatable and acceptable alternative, such as high-calorie foods rather than healthy foods such as fruits and vegetables, consequently increasing of the risk of excess weight. Our study confirms the absence of association between neophobia and ponderal status which was also reported in several other papers (19, 21, 23). Deserving comment, however, is the observation that a high prevalence of children with an intermediate level of neophobia (78.4%) are among those with normal weight. These results are consistent with the literature that defines food neophobia as a natural stage of child development that does not impair growth rate (65). We could speculate that the ambivalence of the results of the studies comparing weight status and food neophobia depends on the parental feeding style. In the case of parents that counteract neophobia with dialogue and a non-constrictive approach, the child would probably maintain a normal weight; otherwise, if neophobia is addressed

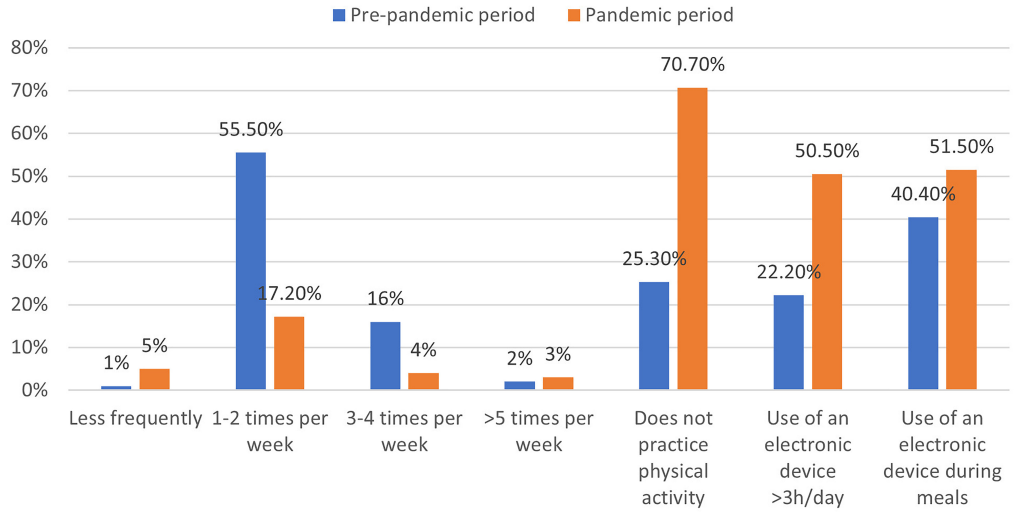

FIGURE 1
Comparisons of lifestyles between pre-pandemic and pandemic periods.

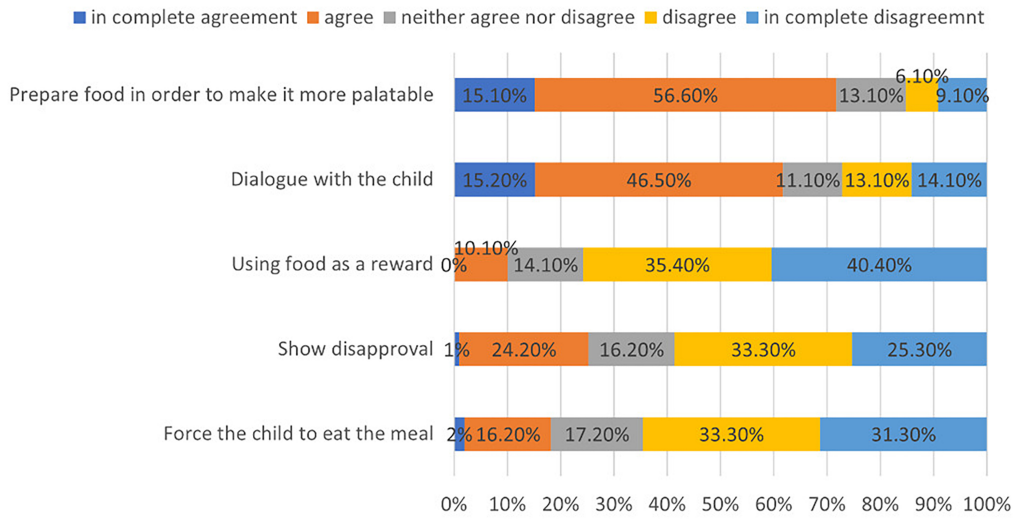

FIGURE 2
Educational strategies adopted in case of food refusal.

by offering palatable and calory-dense foods to compensate for the non-acceptance of healthy foods, the child might develop overweight or obesity.

The consumption of foods most commonly associated with food neophobia was evaluated in the studied sample. The results showed low consumption of foods typical of the Mediterranean model (66) such as fruit, vegetables, and legumes, and, on the contrary, high consumption of foods typical of a Western dietary model (67), such as sweets, sugary beverages, and red meat. Therefore, the results of this study support the literature that reports a trend toward the abandonment of the MD with a shift toward a more Westernized dietary patterns in children living in industrialized countries (1). Several behavioral factors may be the cause of this phenomenon including the habits of purchasing ready meals or foods that are easy to prepare as a consequence of limited time to prepare fresh foods (1). However, neophobia could also be one among many factors contributing to the mentioned shift in food consumption patterns. Neophobia typically occurs with highly recommended foods such as fruits, vegetables, and legumes, which have a bitter or acidic taste, it also typically occurs with animal source food, such as fish (68). The results of the present study showed that the consumption of these foods, although not in line with the recommendations for a large part of the

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TABLE 6 The relationship between pandemic food groups' consumption, use of the electronic device during meals, and educational strategies.

		Level of neophobia *n* (%)		
		Low 14 (14.2)	**Medium 73 (73.7)**	**High 12 (12.1)**
Use of electronic device				
Electronic devices during meals in pandemic period	Yes	8 (15.7)	34 (66.7)	9 (17.6)
	No	6 (12.5)	39 (81.2)	3 (6.3)
Educational strategies				
Pressure to eat	Completely disagree	8 (25.8)	19 (61.3)	4 (12.9)
	Disagree	5 (15.2)	24 (72.7)	4 (12.1)
	Neither agree nor disagree	0 (0)	15 (88.2)	2 (11.8)
	Agree	1 (6.2)	14 (87.5)	1 (6.2)
	Completely agree	0 (0.0)	1 (50.0)	1 (50.0)
Show disapproval	Completely disagree	8 (32.0)	11 (44.0)	6 (24.0)*
	Disagree	3 (9.1)	27 (81.8)	3 (9.1)
	Neither agree nor disagree	3 (18.8)	13 (81.2)	0 (0.0)
	Agree	0 (0.0)	22 (91.7)	2 (8.3)
	Completely agree	0 (0.0)	0 (0.0)	1 (100.0)
Using food as a reward	Completely disagree	10 (25.0)	27 (67.5)	3 (7.5)
	Disagree	2 (5.7)	27 (77.1)	6 (17.1)
	Neither agree nor disagree	1 (7.1)	11 (78.6)	2 (14.3)
	Agree	1 (10.0)	8 (80.0)	1 (10.0)
	Completely agree	0 (0.0)	0 (0.0)	0 (0.0)
Dialogue with the child	Completely disagree	2 (14.3)	10 (71.4)	2 (14.3)
	Disagree	1 (7.7)	11 (84.6)	1 (7.7)
	Neither agree nor disagree	2 (18.2)	6 (54.5)	3 (27.3)
	Agree	7 (15.2)	35 (76.1)	4 (8.7)
	Completely agree	2 (13.3)	11 (73.3)	2 (13.3)
Prepare food in order to make it more palatable	Completely disagree	2 (22.2)	5 (55.6)	2 (22.2)
	Disagree	0 (0.0)	6 (100.0)	0 (0.0)
	Neither agree nor disagree	2 (15.4)	8 (61.5)	3 (23.1)
	Agree	8 (14.3)	42 (75.0)	6 (10.7)
	Completely agree	2 (13.3)	12 (80.0)	1 (6.7)
Pandemic food groups consumption				
Pandemic fruit consumption	Greater	1 (4.5)	19 (86.4)	2 (9.1)
	Less	2 (16.7)	6 (50.0)	4 (33.3)
	Equal	11 (16.9)	48 (73.8)	6 (9.2)
Pandemic vegetables consumption	Greater	1 (5.3)	16 (84.2)	2 (10.5)
	Less	1 (11.1)	5 (55.6)	3 (33.3)
	Equal	12 (16.9)	52 (73.2)	7 (9.8)
Pandemic whole-grain cereals consumption	Greater	1 (8.3)	11 (91.7)	0 (0.0)
	Less	4 (25.0)	10 (62.5)	2 (12.5)
	Equal	9 (12.7)	52 (73.2)	10 (14.1)
Pandemic legumes consumption	Greater	2 (9.5)	18 (85.7)	1 (4.8)
	Less	0 (0.0)	3 (75.0)	1 (25.0)
	Equal	12 (16.2)	52 (70.3)	10 (13.5)

*$p < 0.05$. Calculated performing the Chi-square test with Bonferroni correction. *n* and percentage values.

sample, was not associated with the level of neophobia, except for the consumption of fish, which was less consumed by neophobic children. Other studies in the literature document poor adherence to nutritional recommendations in children with neophobia (17); actually in the present assessment we could confirm that food neophobia limits dietary variety and quality.

The pandemic impacted eating habits as shown in different studies conducted in Italy during lockdown, showing that the consumption of fruits, vegetables, and legumes did not change (28) or in some cases improved (32, 34). However, other studies showed an increase in the consumption of sweet or salty snacks with high energy density, sugar beverages, and red meat (30, 34). In this study, for the majority of the sample, eating habits did not change and, notably, an increased consumption of fruits, vegetables, and legumes was observed in approximately 20% of children. The fact that the pandemic period also impacted some eating habits positively was confirmed in other studies (47, 69).

A relevant aspect that emerges from this study concerns the identification of factors that could be responsible for the variation of children's eating habits during the lockdown. Van der Horst (39) reported that the involvement of children in the preparation of meals contributes to improving the quality of the diet and their consumption of vegetables (39), as it represents a strategy to help children become familiar with the non-accepted foods. Consistently, in the present study, for more than half of the children that increased the consumption of fruit, vegetables, and even with not significant association, of legumes it was reported that lockdown was an opportunity to engage them in cooking activities. These data confirm that involving children in meal preparation is an effective strategy for increasing vegetable consumption and reducing food neophobia (70).

TABLE 7 The relationship between difficulty to manage the children's food refusal and educational strategies.

Educational strategies		Difficulty to manage the refusal of food *n* (%)				
		Completely disagree 36 (36.4)	**Disagree 34 (34.3)**	**Neither agree nor disagree 21 (21.2)**	**Agree 7 (7.1)**	**Completely agree 1 (1)**
Pressure to eat	Completely disagree	24 (77.4)	4 (12.9)	2 (6.5)	1 (3.2)	0 (0.0)
	Disagree	7 (21.2)	19 (57.6)	7 (21.2)	0 (0.0)	0 (0.0)
	Neither agree nor disagree	2 (11.8)	7 (41.2)	6 (35.3)	2 (11.8)	0 (0.0)
	Agree	3 (18.7)	3 (18.7)	6 (37.5)	4 (25.0)	0 (0.0)
	Completely agree	0 (0.0)	1 (50.0)	0 (0.0)	1 (0.0)	1 (50.0)*
Show disapproval	Completely disagree	18 (72.0)*	6 (24.0)	0 (0.0)	1 (4.0)	0 (0.0)
	Disagree	9 (27.3)	14 (42.4)	9 (27.3)	1 (3.0)	0 (0.0)
	Neither agree nor disagree	3 (18.7)	8 (50.0)	4 (25.0)	0 (0.0)	1 (6.2)
	Agree	6 (25.0)	6 (25.0)	7 (29.2)	5 (20.8)	0 (0.0)
	Completely agree	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)
Using food as a reward	Completely disagree	24 (60.0)*	6 (15.0)	8 (20.0)	1 (2.5)	1 (2.5)
	Disagree	4 (11.4)	19 (54.3)	7 (20.0)	5 (14.3)	0 (0.0)
	Neither agree nor disagree	4 (28.6)	6 (42.8)	4 (28.6)	0 (0.0)	0 (0.0)
	Agree	4 (40.0)	3 (30.0)	2 (20.0)	1 (10.0)	0 (0.0)
	Completely agree	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dialogue with the child	Completely disagree	10 (71.4)	2 (14.3)	2 (14.3)	0 (0.0)	0 (0.0)
	Disagree	5 (38.4)	4 (30.8)	3 (23.1)	1 (7.7)	0 (0.0)
	Neither agree nor disagree	8 (72.7)	2 (18.2)	1 (9.1)	0 (0.0)	0 (0.0)
	Agree	8 (17.4)	20 (43.5)	13 (28.3)	5 (10.8)	0 (0.0)
	Completely agree	5 (33.3)	6 (40.0)	2 (13.3)	1 (6.7)	1 (6.7)*
Prepare food in order to make it more palatable	Completely disagree	6 (66.7)	2 (22.2)	1 (11.1)	0 (0.0)	0 (0.0)
	Disagree	2 (33.3)	3 (50.0)	1 (16.7)	0 (0.0)	0 (0.0)
	Neither agree nor disagree	5 (38.5)	4 (30.7)	4 (30.7)	0 (0.0)	0 (0.0)
	Agree	18 (32.1)	21 (37.5)	12 (21.4)	5 (8.9)	(0.0)
	Completely agree	5 (33.3)	4 (26.7)	3 (20.0)	2 (13.3)	1 (6.7)

*$p < 0.05$. Calculated performing the Chi-square test with Bonferroni correction. *n* and percentage values.

During the pandemic period, due to social isolation, it was reported an increase in the number of meals consumed in the family (32) and this is confirmed by the results of this study showing that the percentage of children who consumed all meals in the presence of their parents increased from 32.3 to 78.8%. In addition, family meal consumption was found to be significantly associated with the consumption of vegetables and legumes during the lockdown: almost all children in whom there was increased consumption of vegetables (94.7%) and legumes (90.4%) had shared three or all meals with the family. We could interpret these data considering the findings of Lumeng et al. (71) which reported that the eating habits adopted in the family influenced children's food choices because, through a process of observation and imitation called modeling (72), the child learns to accept new foods. In this study, the healthy eating habits of parents and increased family mealtimes contributed to influencing the eating habits of the children as described by Litterbach and co-workers (73).

The use of electronic devices during mealtime is associated with increased energy intake and risk of childhood obesity, but also with the risk of worsening the level of food neophobia as the presence of distractors during mealtime (e.g., TV) has been shown to lead children to refuse more food (74). In this study, screen time was observed to be significantly increased during the lockdown, especially the use of these devices during the meal (51.5% vs. 40.4%) as shown in **Figure 1**, however, there was not a significant association found between screen time and the child's level of food neophobia (**Table 6**).

The feeding practice most adopted by the parents in the studied sample were dialogue and the preparation of the not preferred foods in a more palatable way. The only strategy associated with the level of neophobia is the parents' disapproval. The feeding practices adopted by parents at mealtime may also influence the child's eating habits and level of neophobia. Forcing the child to consume the proposed food, showing disapproval (75–78), or using food as a reward (79) are considered strategies with limited impact, perhaps even worsening the children's attitude. Actually in the studied sample it was observed a reduction in legume consumption in children with parents that used foods to compensate for boredom probably because the typology of foods used as a reward is more likely to be products nearest to the children requests, such as salty or sweet items. In contrast, an open attitude based on dialogue with convincing themes (80) or preparing the food to make it more palatable (81) are considered most efficient.

Data on neophobia during the pandemic period were scarce; in a study conducted on Brazilian children during the pandemic period, it was hypothesized that children's eating habits and behaviors were affected by the pandemic with a consequent increase in the level of neophobia (82). This hypothesis is not confirmed by our data which demonstrated that the family context influences the eating habits and the eating behavior of the child. In the present study, the families particularly worried about the pandemic adopted food consumption behaviors aimed to counteract the increased boredom, embracing eating as a compensatory strategy. However, no greater rejection of selected food by the child was observed and therefore no worsening of the level of neophobia.

The majority of parents (70.7%) did not experience difficulties in managing the children's refusal of food. In particular, the correlations between the parent's ability to manage this refusal and the feeding practices adopted showed that in the absence of difficulties, in most cases the parent preferred dialogue. Parents also demonstrated disagreement with the adoption of forcing strategies such as pressuring the child to eat, disapproval or using food as a reward.

Outside the family context and parents' behaviors, different socioenvironmental factors may contribute to the development of food neophobia. In a study carried out in school age children in Saudi Arabia a significant positive association between peer modeling and cognitive factors and the occurrence of food neophobia was found (78). Early taste experience, prenatal food exposure and breastfeeding and complementary feeding habits, are associated with food choices later in life (83). These periods are largely influenced by parents' attitude, however, according to Ventura and Worobey (84) social influences become increasingly important for the development of food preferences throughout infancy, and may either support or contrast the preferences learned during the prenatal period. Moreover, the early postnatal periods and the factors that influence the food habit changes that occur become more complex through the years. Particularly relevant is the analysis of the relationship between food neophobia occurrence in the vulnerable population groups. Low-income Brazilian preschoolers with a high level of food neophobia showed a lower adherence to traditional dietary patterns and distinct food preferences than their peers with low-middle food neophobia. Therefore, neophobic Brazilian children were more likely to eat ultra-processed foods, such as chips, cookies, and sweets (85). The retrospective cross-sectional design that we applied as well as our sample size did not permit the differentiation between the influence of other variables such as income and educational level as confounding factors on the occurrence of food neophobia. However, in our sample, the neophobic children showed a low consumption of foods typical of the Mediterranean model such as fruit, vegetables, and legumes confirming the parallelism between neophobia and low adherence to traditional dietary pattern as reported in the study of Anjos et al. (85).

This study has strengths and limitations. The main strength is the fact that the study provided a picture of a very particular moment in which the daily life of people and in particular of children were largely affected either in a positive or negative sense and any data and findings that contributed to explaining these moments are important to be described and shared. In terms of limitations, first, the study design involved the administration of an online self-completed questionnaire, with

limited possibility to verify if the response corresponds to a real attitude and behaviors or was a reaction to a question influenced by accepted social norms. The evaluation of the bias of a self-administrated questionnaire compared to an evaluation mediated by an interviewer is complex and not univocal, in the sense that the presence of an interviewer is not always an advantage in terms of control of the quality of response. Large numbers of studies, especially during pandemic period, rely on self-reported information and the validity of self-reported data is an aspect to be discussed. Self-reported data are accurate when individuals understand the questions and when there is a strong sense of anonymity and little fear of reprisal, all aspects that increase the validity of the results (86). However, no survey is perfect, and there is always a certain margin of error. The issue of the anonymity is further mentioned by Althubaiti (87) stating that self-reporting data can be affected by an external bias caused by social desirability or approval, especially in cases where anonymity cannot be guaranteed at the time of data collection. Actually with the online system and the confidentiality that we established, which necessary in consideration of the Italian and European normative framework, these aspects were largely assured. A further limitation of the study was the fact that the questionnaire was constructed to carry out a retrospective survey, therefore, the reliability of the answers depends on the memory of the respondents. However, the recall period was relatively short and we asked for routine and usual habits that are reported as elements to minimize the recall bias (87). An important limitation was the small sample size; in this study the sample size was small because the pandemic limited the possibility to reach a large number of participants. In consideration of the target (children) it would have been useful to establish a direct contact with the respondent families that was not possible for effect of the social constraints of the lockdown. With the present sample size, our study has a precision level of 9%. There is not an accepted guideline for choosing an appropriate precision level, some authors recommended selecting a precision level of 5% if the prevalence of the main outcome is going to be between 10 and 90% (60). In this study we used the prevalence of 26% of food neophobia (16) hence our precision level could be considered low. However according to Button et al. (88) the median statistical power of studies in the neurosciences, in which neophobia is included, is approximately between 8 and 31%, hence in our case the precision level is in line with other similar studies. The cross-sectional retrospective design with the same subjects that were assessed in pre and post pandemic conditions minimized the effect of confounding factors. However this self-controlled design has a major limitation the applicability that is circumscribed to a narrow set of situations (89). For all these reasons, as prudential attitude, we avoided too much conclusive considerations and generalization of the outcomes of this study, limiting the observations in the poll of people living in the very defined territory (south province of an Italian central region). Nonetheless it would be advisable to extend the study to a larger number of individuals, more evenly distributed throughout the country, to give greater solidity to the conclusions drawn.

Conclusion

In conclusion, in the sample of children analyzed in the present work, the level of neophobia was not affected by the pandemic period and globally, the assessed children did not experience an increase in selected food refusal. Consistently, parents did not perceive difficulties in managing their child's refusal of food, and therefore feeding practices were not coercive, but based on dialogue or using the expedient of preparation of the most palatable foods.

For most of the assessed children, eating habits did not change compared with the pre-pandemic period with a subset of them that improved their eating habits based on the effect of a larger involvement in food preparation and greater frequency of family meals. This study, even with the limited sample size, confirms the effectiveness of these strategies as tools to increase vegetable consumption and mitigate food neophobia. It also suggests that the pandemic, and especially social isolation, in this group of children could positively affect food neophobia if it was an opportunity to share more family meals or if the long time spent at home was capitalized on to involve children in food preparation, helping them to become familiar with new foods.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

ADN and US carried out the research questions, conceptualization, and design of the study. LR and FG revised the methodology. ADN and FG carried out the database compilation and data analysis. ADN carried out the manuscript writing and original draft preparation. LR, FG, and US did the writing, review, and editing. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.1070388/full#supplementary-material

References

1. Cabrera S, Fernández N, Rodríguez C, Nissensohn M, Román-Viñas B, Serra-Majem L. Kidmed test; prevalence of low adherence to the mediterranean diet in children and young; a systematic review. *Nutr Hosp.* (2015) 2015:2390–9. doi: 10.3305/nh.2015.32.6.9828

2. EpiCentro. *Indagine nazionale 2019: i dati nazionali*. (2020). Available online at: https://www.epicentro.iss.it/okkioallasalute/indagine-2019-dati (accessed July 29, 2022).

3. Dovey T, Staples P, Gibson E, Halford J. Food neophobia and 'picky/fussy' eating in children: a review. *Appetite.* (2008) 50:181–93. doi: 10.1016/j.appet.2007.09.009

4. Cooke L, Haworth C, Wardle J. Genetic and environmental influences on children's food neophobia. *Am J Clin Nutr.* (2007) 86:428–33. doi: 10.1093/ajcn/86.2.428

5. Kral T, Faith M. Influences on child eating and weight development from a behavioral genetics perspective. *J Pediatr Psychol.* (2009) 34:596–605. doi: 10.1093/jpepsy/jsn037

6. Hampson S, Tonstad S, Irgens L, Meltzer H, Vollrath M. Mothers' negative affectivity during pregnancy and food choices for their infants. *Int J Obes.* (2010) 34:327–31. doi: 10.1038/ijo.2009.230

7. Mennella J, Beauchamp G. Experience with a flavor in mother's milk modifies the infant's acceptance of flavored cereal. *Dev Psychobiol.* (1999) 35:197–203. doi: 10.1002/(SICI)1098-2302(199911)35:33.0.CO;2-J

8. Clayton D. Socially facilitated behavior. *Quilt Rev Biol.* (1978) 53:373–92. doi: 10.1086/410789

9. Torres T, Gomes D, Mattos M. Factors associated with food neophobia in children: systematic review. *Rev paul pediatr.* (2021) 39:e2020089. doi: 10.1590/1984-0462/2021/39/2020089

10. Mustonen S, Rantanen R, Tuorila H. Effect of sensory education on school children's food perception: a 2-year follow-up study. *Food Qual Pref.* (2009) 20:230–40. doi: 10.1016/j.foodqual.2008.10.003

11. Galloway A, Lee Y, Birch L. Predictors and consequences of food neophobia and pickiness in young girls. *J Am Diet Ass.* (2003) 103:692–8. doi: 10.1053/jada.2003.50134

12. Nicklaus S, Boggio V, Chabanet C, Issanchou S. A prospective study of food variety seeking in childhood, adolescence and early adult life. *Appetite.* (2005) 44:289–97. doi: 10.1016/j.appet.2005.01.006

13. Cooke L, Carnell S, Wardle J. Food neophobia and mealtime food consumption in 4–5 year old children. *Int J Behav Nutr Phys Act.* (2006) 3:14. doi: 10.1186/1479-5868-3-14

14. Rubio B, Rigal N, Boireau-Ducept N, Mallet P, Meyer T. Measuring willingness to try new foods: a self-report questionnaire for French-speaking children. *Appetite.* (2008) 50:408–14. doi: 10.1016/j.appet.2007.09.012

15. Moberg L. Food poisoning and food hygiene (6th edn). *Trends Food Sc Tech.* (1994) 5:236–7. doi: 10.1016/0924-224490257-7

16. Predieri S, Sinesio F, Monteleone E, Spinelli S, Cianciabella M, Daniele G, et al. Gender, age, geographical area, food neophobia and their relationships with the adherence to the mediterranean diet: new insights from a large population cross-sectional study. *Nutrients.* (2020) 12:1778. doi: 10.3390/nu12061778

17. Russell C, Worsley A. A population-based study of preschoolers' food neophobia and its associations with food preferences. *J Nutr Ed Behav.* (2008) 40:11–9. doi: 10.1016/j.jneb.2007.03.007

18. Falciglia G, Couch S, Gribble L, Pabst S, Frank R. Food neophobia in childhood affects dietary variety. *J Am Diet Assoc.* (2000) 100:1474–81. doi: 10.1016/S0002-822300412-0

19. Perry R, Mallan K, Koo J, Mauch C, Daniels L, Magarey A. Food neophobia and its association with diet quality and weight in children aged 24 months: a cross sectional study. *Int J Behav Nutr Phys Act.* (2015) 12:13. doi: 10.1186/s12966-015-0184-6

20. Rigal N, Frelut M, Monneuse M, Hladik C, Simmen B, Pasquet P. Food neophobia in the context of a varied diet induced by a weight reduction program in massively obese adolescents. *Appetite.* (2006) 46:207–14. doi: 10.1016/j.appet.2006.01.001

21. Brown C, Vander Schaaf E, Cohen G, Irby M, Skelton J. Association of picky eating and food neophobia with weight: a systematic review. *Child Obes.* (2016) 12:247–62. doi: 10.1089/chi.2015.0189

22. Gibson E, Cooke L. Understanding food fussiness and its implications for food choice, health, weight and interventions in young children: the impact of professor Jane Wardle. *Curr Obes Rep.* (2017) 6:46–56. doi: 10.1007/s13679-017-0248-9

23. Laureati M, Bertoli S, Bergamaschi V, Leone A, Lewandowski L, Giussani B, et al. Food neophobia and liking for fruits and vegetables are not related to Italian children's overweight. *Food Qual Pref.* (2015) 40:125–31. doi: 10.1016/j.foodqual.2014.09.008

24. Finistrella V, Manco M, Ferrara A, Rustico C, Presaghi F, Morino G. Cross-sectional exploration of maternal reports of food neophobia and pickiness in preschooler-mother dyads. *J Am Coll Nutr.* (2012) 31:152–9. doi: 10.1080/07315724.2012.10720022

25. Rioux C. Food neophobia in childhood. In: Meiselman H editor. *Handbook of eating and drinking*. Cham: Springer International Publishing (2019). p. 1–20. doi: 10.1007/978-3-319-75388-1_159-1

26. Velavan T, Meyer C. The COVID−19 epidemic. *Trop Med Int Health.* (2020) 25:278–80. doi: 10.1111/tmi.13383

27. World Health organization [WHO]. *WHO director-general's opening remarks at the media briefing on COVID-19 – 11 march 2020*. (2020). Available online at: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 (Accessed July 29, 2022).

28. Di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. *J Transl Med.* (2020) 18:229. doi: 10.1186/s12967-020-02399-5

29. Brooks S, Webster R, Smith L, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *Lancet.* (2020) 395:912–20. doi: 10.1016/S0140-673630460-8

30. Pietrobelli A, Pecoraro L, Ferruzzi A, Heo M, Faith M, Zoller T, et al. Effects of COVID−19 lockdown on lifestyle behaviors in children with obesity living in verona, Italy: a longitudinal study. *Obesity.* (2020) 28:1382–5. doi: 10.1002/oby.22861

31. Nicodemo M, Spreghini M, Manco M, Wietrzykowska Sforza R, Morino G. Childhood obesity and COVID-19 lockdown: remarks on eating habits of patients enrolled in a food-education program. *Nutrients.* (2021) 13:383. doi: 10.3390/nu13020383

32. Censi L, Ruggeri S, Galfo M, Buonocore P, Roccaldo R. Eating behaviour, physical activity and lifestyle of Italian children during lockdown for COVID-19. *Int J Food Sci Nutr.* (2022) 73:93–105. doi: 10.1080/09637486.2021.1921127

33. Cena H, Fiechtner L, Vincenti A, Magenes V, De Giuseppe R, Manuelli M, et al. COVID-19 pandemic as risk factors for excessive weight gain in pediatrics: the role of changes in nutrition behavior. A narrative review. *Nutrients.* (2021) 13:4255. doi: 10.3390/nu13124255

34. Pujia R, Ferro Y, Maurotti S, Khoory J, Gazzaruso C, Pujia A, et al. The EFFECTS of COVID-19 on the eating habits of children and adolescents in Italy: a pilot survey study. *Nutrients.* (2021) 13:2641. doi: 10.3390/nu13082641

35. Cherikh F, Frey S, Bel C, Attanasi G, Alifano M, Iannelli A. Behavioral food addiction during lockdown: time for awareness, time to prepare the aftermath. *Obes Surg.* (2020) 30:3585–7. doi: 10.1007/s11695-020-04649-3

36. Singh S, Roy D, Sinha K, Parveen S, Sharma G, Joshi G. Impact of COVID-19 and lockdown on mental health of children and adolescents: a narrative review with recommendations. *Psychiatry Res.* (2020) 293:113429. doi: 10.1016/j.psychres.2020.113429

37. Havermans R, Vancleef L, Kalamatianos A, Nederkoorn C. Eating and inflicting pain out of boredom. *Appetite.* (2015) 85:52–7. doi: 10.1016/j.appet.2014.11.007

38. Crockett A, Myhre S, Rokke P. Boredom proneness and emotion regulation predict emotional eating. *J Health Psychol.* (2015) 20:670–80. doi: 10.1177/1359105315573439

39. van der Horst K. Overcoming picky eating. Eating enjoyment as a central aspect of children's eating behaviors. *Appetite.* (2012) 58:567–74. doi: 10.1016/j.appet.2011.12.019

40. Lehdonvirta V, Oksanen A, Räsänen P, Blank G. Social media, web, and panel surveys: using non−probability samples in social and policy research. *Policy Int.* (2021) 13:134–55. doi: 10.1002/poi3.238

41. Gazzetta Ufficiale. (2020). Available online at: https://www.gazzettaufficiale.it/eli/id/2020/11/04/20A06109/sg (accessed July 29, 2022).

42. World Medical Association [WMA]. *The world medical association-declaration of helsinki*. (2022). Available online at: https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/ (accessed July 29, 2022).

43. Sette S, Le Donne C, Piccinelli R, Arcella D, Turrini A, Leclercq C. The third Italian national food consumption survey, INRAN-SCAI 2005–06 – part 1: nutrient intakes in Italy. *Nutr Metab Cardiovasc Dis.* (2011) 21:922–32. doi: 10.1016/j.numecd.2010.03.001

44. Istituto Nazionale di Statistica. *Indagine multiscopo sulle famiglie: aspetti della vita quotidiana – parte generale*. (2022). Available online at: https://www.istat.it/it/archivio/91926 (Accessed August 19, 2022).

45. EpiCentro. *Cos'è il sistema di sorveglianza OKkio alla SALUTE?*. (2007). Available online at: https://www.epicentro.iss.it/okkioallasalute/la-sorveglianza (accessed July 29, 2022).

46. Scalvedi M, Gennaro L, Saba A, Rossi L. Relationship between nutrition knowledge and dietary intake: an assessment among a sample of Italian adults. *Front Nutr.* (2021) 8:714493. doi: 10.3389/fnut.2021.714493

47. Grant F, Scalvedi M, Scognamiglio U, Turrini A, Rossi L. Eating habits during the COVID-19 lockdown in Italy: the nutritional and lifestyle side effects of the pandemic. *Nutrients.* (2021) 13:2279. doi: 10.3390/nu13072279

48. Aureli V, Rossi L. Nutrition knowledge as a driver of adherence to the mediterranean diet in Italy. *Front Nutr.* (2022) 9:804865. doi: 10.3389/fnut.2022.804865

49. Pliner P. Development of measures of food neophobia in children. *Appetite.* (1994) 23:147–63. doi: 10.1006/appe.1994.1043

50. Laureati M, Spinelli S, Monteleone E, Dinnella C, Prescott J, Cattaneo C, et al. Associations between food neophobia and responsiveness to "warning" chemosensory sensations in food products in a large population sample. *Food Qual Pref.* (2018) 68:113–24. doi: 10.1016/j.foodqual.2018.02.007

51. Rossi L, Berni Canani S, Censi L, Gennaro L, Leclercq C, Scognamiglio U, et al. The 2018 revision of Italian dietary guidelines: development process, novelties, main recommendations, and policy implications. *Front Nutr.* (2022) 9:861526. doi: 10.3389/fnut.2022.861526

52. Bull F, Al-Ansari S, Biddle S, Borodulin K, Buman M, Cardon G, et al. World health organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med.* (2020) 54:1451–62. doi: 10.1136/bjsports-2020-102955

53. Bozzola E, Spina G, Ruggiero M, Memo L, Agostiniani R, Bozzola M, et al. Media devices in pre-school children: the recommendations of the Italian pediatric society. *Ital J Pediatr.* (2018) 44:69. doi: 10.1186/s13052-018-0508-7

54. Rabadán A, Bernabéu R. A systematic review of studies using the food neophobia scale: conclusions from thirty years of studies. *Food Qual Pref.* (2021) 93:104241. doi: 10.1016/j.foodqual.2021.104241

55. Rabadán A, Álvarez-Ortí M, Martínez E, Pardo-Giménez A, Zied D, Pardo J. Effect of replacing traditional ingredients for oils and flours from nuts and seeds on the characteristics and consumer preferences of lamb meat burgers. *LWT.* (2021) 136:110307. doi: 10.1016/j.lwt.2020.110307

56. Schnettler B, Grunert K, Miranda-Zapata E, Orellana L, Sepúlveda J, Lobos G, et al. Testing the abbreviated food technology neophobia scale and its relation to satisfaction with food-related life in university students. *Food Res Int.* (2017) 96:198–205. doi: 10.1016/j.foodres.2017.04.003

57. Kozioł-Kozakowska A, Piórecka B, Schlegel-Zawadzka M. Prevalence of food neophobia in pre-school children from southern poland and its association with eating habits, dietary intake and anthropometric parameters: a cross-sectional study. *Public Health Nutr.* (2018) 21:1106–14. doi: 10.1017/S1368980017003615

58. Who MG, Onis M. WHO child growth standards based on length/height, weight and age: WHO child growth standards. *Acta Paediat.* (2007) 95:76–85. doi: 10.1111/j.1651-2227.2006.tb02378.x

59. de Onis M. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ.* (2007) 85:660–7. doi: 10.2471/BLT.07.043497

60. Pourhoseingholi M, Vahedi M, Rahimzadeh M. Sample size calculation in medical studies. *Gastroenterol Hepatol Bed Bench.* (2013) 6:14–7.

61. Hinton P, McMurray I, Brownlow C. *SPSS Explained*. London: Routledge (2004). 400 p. doi: 10.4324/9780203642597

62. Laureati M, Cattaneo C, Bergamaschi V, Proserpio C, Pagliarini E. School children preferences for fish formulations: the impact of child and parental food neophobia. *J Sens Stud.* (2016) 31:408–15. doi: 10.1111/joss.12224

63. EpiCentro. *OKkio alla SALUTE: i risultati dell'indagine 2019 in Lombardia*. (2021). Available online at: https://www.epicentro.iss.it/okkioallasalute/indagine-2019-report-lazio (accessed July 29, 2022).

64. EpiCentro. *OKkio alla SALUTE: i risultati dell'indagine 2019 in Campania*. (2019). Available online at: https://www.epicentro.iss.it/okkioallasalute/indagine-2019-report-campania (accessed July 29, 2022).

65. Białek-Dratwa A, Szczepańska E, Szymańska D, Grajek M, Krupa-Kotara K, Kowalski O. Neophobia—a natural developmental stage or feeding difficulties for children? *Nutrients.* (2022) 14:1521. doi: 10.3390/nu14071521

66. Davis C, Bryan J, Hodgson J, Murphy K. Definition of the mediterranean diet; a literature review. *Nutrients.* (2015) 7:9139–53. doi: 10.3390/nu7115459

67. Azzam A. Is the world converging to a 'western diet'? *Public Health Nutr.* (2021) 24:309–17. doi: 10.1017/S136898002000350X

68. Cooke L, Wardle J, Gibson E. Relationship between parental report of food neophobia and everyday food consumption in 2–6-year-old children. *Appetite.* (2003) 41:205–6. doi: 10.1016/S0195-666300048-5

69. Catucci A, Scognamiglio U, Rossi L. Lifestyle changes related to eating habits, physical activity, and weight status during COVID-19 quarantine in Italy and some European countries. *Front Nutr.* (2021) 8:718877. doi: 10.3389/fnut.2021.718877

70. Allirot X, da Quinta N, Chokupermal K, Urdaneta E. Involving children in cooking activities: a potential strategy for directing food choices toward novel foods containing vegetables. *Appetite.* (2016) 103:275–85. doi: 10.1016/j.appet.2016.04.031

71. Lumeng J, Cardinal T, Jankowski M, Kaciroti N, Gelman S. Children's use of adult testimony to guide food selection. *Appetite.* (2008) 51:302–10. doi: 10.1016/j.appet.2008.03.010

72. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev.* (1977) 84:191–215. doi: 10.1037/0033-295X.84.2.191

73. Litterbach E, Campbell K, Spence A. Family meals with young children: an online study of family mealtime characteristics, among Australian families with children aged six months to six years. *BMC Public Health.* (2017) 17:111. doi: 10.1186/s12889-016-3960-6

74. Powell F, Farrow C, Meyer C, Haycraft E. The importance of mealtime structure for reducing child food fussiness: mealtime structure and child food fussiness. *Matern Child Nutr.* (2017) 13:e12296. doi: 10.1111/mcn.12296

75. Kaar J, Shapiro A, Fell D, Johnson S. Parental feeding practices, food neophobia, and child food preferences: what combination of factors results in children eating a variety of foods? *Food Qual Pref.* (2016) 50:57–64. doi: 10.1016/j.foodqual.2016.01.006

76. Cassells E, Magarey A, Daniels L, Mallan K. The influence of maternal infant feeding practices and beliefs on the expression of food neophobia in toddlers. *Appetite*. (2014) 82:36–42. doi: 10.1016/j.appet.2014.07.001

77. Moding K, Stifter C. Temperamental approach/withdrawal and food neophobia in early childhood: concurrent and longitudinal associations. *Appetite*. (2016) 107:654–62. doi: 10.1016/j.appet.2016.09.013

78. Kutbi H, Alhatmi A, Alsulami M, Alghamdi S, Albagar S, Mumena W, et al. Food neophobia and pickiness among children and associations with socioenvironmental and cognitive factors. *Appetite*. (2019) 142:104373. doi: 10.1016/j.appet.2019.104373

79. Cooke L, Chambers L, Añez E, Wardle J. Facilitating or undermining? The effect of reward on food acceptance. A narrative review. *Appetite*. (2011) 57:493–7. doi: 10.1016/j.appet.2011.06.016

80. Vereecken C, Legtest E, De Bourdeaudhuij I, Maes L. Associations between general parenting styles and specific food-related parenting practices and children's food consumption. *Am J Health Promot*. (2009) 23:233–40. doi: 10.4278/ajhp.07061355

81. Appleton K, Hemingway A, Saulais L, Dinnella C, Monteleone E, Depezay L, et al. Increasing vegetable intakes: rationale and systematic review of published interventions. *Eur J Nutr*. (2016) 55:869–96. doi: 10.1007/s00394-015-1130-8

82. de Almeida P, Vasconcelos I, Zandonadi R, Nakano E, Raposo A, Han H, et al. Food neophobia among Brazilian children: prevalence and questionnaire score development. *Sustainability*. (2022) 14:975. doi: 10.3390/su14020975

83. De Cosmi V, Scaglioni S, Agostoni C. Early taste experiences and later food choices. *Nutrients*. (2017) 9:107. doi: 10.3390/nu9020107

84. Ventura A, Worobey J. Early influences on the development of food preferences. *Curr Biol*. (2013) 23:R401–8. doi: 10.1016/j.cub.2013.02.037

85. Anjos L, Vieira D, Siqueira B, Voci S, Botelho A, Silva D. Low adherence to traditional dietary pattern and food preferences of low-income preschool children with food neophobia. *Public Health Nutr*. (2021) 24:2859–66. doi: 10.1017/S1368980020003912

86. Brener N, Billy J, Grady W. Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: evidence from the scientific literature. *J Adolesc Health*. (2003) 33:436–57. doi: 10.1016/S1054-139X00052-1

87. Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. *JMDH*. (2016) 211:104807. doi: 10.2147/JMDH.S104807

88. Button K, Ioannidis J, Mokrysz C, Nosek B, Flint J, Robinson E, et al. Power failure: why small sample size undermines the reliability of neuroscience. *Nat Rev Neurosci*. (2013) 14:365–76. doi: 10.1038/nrn3475

89. Nørgaard M, Ehrenstein V, Vandenbroucke J. Confounding in observational studies based on large health care databases: problems and potential solutions-a primer for the clinician. *Clep*. (2017) 9:185–93. doi: 10.2147/CLEP.S129879

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Impact of COVID-19 pandemic on the PREDIMED-Plus randomized clinical trial: Effects on the interventions, participants follow-up, and adiposity

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Background: The COVID-19 pandemic has affected the implementation of most ongoing clinical trials worldwide including the PREDIMED-Plus study. The PREDIMED-Plus is an ongoing, multicenter, controlled intervention trial, aimed at weight-loss and cardiovascular disease prevention, in which participants were randomized (1:1 ratio) to an intervention group (energy-reduced Mediterranean diet, promotion of physical activity, and behavioral support) or to a control group (Mediterranean diet with usual care advice). When the pandemic began, the trial was in the midst of the planned intervention. The objective of this report was to examine the effects of the pandemic on the delivery of the intervention and to describe the strategies established to mitigate the possible adverse effects of the pandemic lockdown on data collection and adiposity.

Methods: We assessed the integrity of the PREDIMED-Plus trial during 5 identified periods of the COVID-19 pandemic determined according to restrictions dictated by the Spanish government authorities. A standardized questionnaire was delivered to each of the 23 PREDIMED-Plus recruiting centers to collected data regarding the trial integrity. The effect of the restrictions on intervention components (diet, physical activity) was evaluated with data obtained in the three identified lockdown phases: pre lockdown, lockdown proper, and post lockdown.

Results: During the lockdown (March/2020-June/2021), 4,612 participants (48% women, mean age 65y) attended pre-specified yearly follow-up visits to receive lifestyle recommendations and obtain adiposity measures. The overall mean (SD) of the proportions reported by each center showed that 40.4% (25.4) participants had in-person visits, 39.8% (18.2) participants were contacted by telephone and 35% (26.3) by electronic means. Participants' follow-up and data collection rates increased across lockdown periods (from

≈10% at onset to ≈80% at the end). Compared to pre-lockdown, waist circumference increased during (0.75 cm [95% CI: 0.60–0.91]) and after (0.72 cm [95% CI: 0.56–0.89]) lockdown. Body weight did not change during lockdown (0.01 kg [95% CI: −0.10 to 0.13) and decreased after lockdown (-0.17 kg [95% CI: −0.30 to −0.04]).

Conclusion: Mitigating strategies to enforce the intervention and patient's follow-up during lockdown have been successful in preserving the integrity of the trial and ensuring its continuation, with minor effects on adiposity.

Clinical trial registration: https://doi.org/10.1186/ISRCTN89898870, identifier ISRCTN89898870.

KEYWORDS

COVID-19, PREDIMED-Plus, lockdown, clinical trial, weight-loss, Mediterraean diet

1. Introduction

In 2020, in an attempt to control Coronavirus disease 2019 (COVID-19) outbreaks, governments worldwide issued and enforced orders for social restrictions and lockdowns that had the potential to substantially affect the integrity of ongoing clinical trials. Since then, an important number of trials have been withdrawn or suspended and, in those in which it was decided to continue the trial, the pandemic particularly affected participant enrollment, the originally planned interventions, follow-up and data collection, and in some cases even outcome assessment (1). To mitigate potential consequences to participant safety and keep pace with the regulatory requirements established by authorities, clinical trial procedures often required amendments (2–4). In this regard, concerns regarding remote research and clinical trial integrity during and after the COVID-19 pandemic, especially regarding behavioral interventions, were reported early in 2020 (5). It was suggested that protocol modifications of ongoing clinical trials can potentially introduce biases, casting doubt on the trials' validity and final conclusions, and therefore potential remote adaptations should be considered only after thorough reflection of the impact (5). In some cases, new statistical approaches may be necessary for the correct interpretation of trial results. Guidelines for reporting trial protocols and completed trials modified due to the COVID-19 pandemic and other extenuating circumstances have been established by the CONSERVE 2021 Statement Group and the WHO, which aim to provide guidance to improve the reporting of trials in which protocols had to be modified (1, 6). The PREDIMED-Plus is an ongoing large multicenter clinical trial conducted in Spain aiming to assess the effect of a lifestyle intervention on the primary prevention of cardiovascular disease (CVD) and mortality. At the time the COVID-19 pandemic began (March 2020 in Spain), recruitment was completed but the intervention was ongoing for most participants, thus several strategies had to be established to continue with the intervention and data collection remotely.

In this report, we aimed to describe how the COVID-19 pandemic affected the intervention delivery and the follow-up of participants enrolled in the PREDIMED-Plus trial. Mitigation strategies to minimize the effect of the lockdown in the different study sites are also delineated. Finally, we report the effect of the lockdown on the study outcomes of body weight and waist circumference.

2. Materials and methods

2.1. Study design and participants

The PREDIMED-Plus study is an ongoing 8-year (6 years of active intervention plus 2 years of follow-up without intervention), multicenter, parallel-group, clinical trial conducted in 23 Spanish centers aiming to evaluate the effect of a lifestyle intervention focused on weight loss via an energy-restricted Mediterranean Diet (erMedDiet), promotion of physical activity (PA), and behavioral support (intervention group) on CVD events and mortality compared to usual care advice promoting an *ad libitum* MedDiet (control group) in individuals with overweight/obesity and metabolic syndrome (MetS). PREDIMED-Plus participants (n = 6,874; aged 55–75 years) are men and women with overweight/obesity at baseline, free of CVD, and satisfying at least three criteria for the MetS (7), who at baseline were randomized in a 1:1 ratio to one of two intervention arms. To maintain the integrity of the trial the intervention and control groups will remain blinded and will be referred to as "Group A" and "Group B" without unblinding their true designation. The trial design and inclusion and exclusion criteria are detailed elsewhere (8). The study protocol can be accessed at www.predimedplus.com, and

was registered on the ISRCTN registry (ISRCTN89898870). Both the protocol and procedures were implemented following the ethical standards of the Declaration of Helsinki and approved by the institutional ethics review boards of each study center. All participants provided written informed consent. At the time of writing this report, the intended recruitment (n = 6,874 participants) has been completed, participants had achieved the maximum weight-loss mean (achieved during the first intervention year) and were in the midst (a median [IQR] of 48.5 [43.8–58)] months of follow-up)of the planned intervention (receiving recommendations for both weight-loss and its long-term maintenance). The results of the pilot study concerning the effect of changes in body weight on CVD risk factors were published previously (9).

2.2. Lifestyle intervention and follow-up

Briefly, according to the PREDIMED-Plus study protocol, every 3 months, participants allocated to the active intervention group were to attend face-to-face visits with trained staff to receive intensive education to follow an erMedDiet, together with PA promotion and behavioral support aimed at achieving and maintaining weight loss. Additionally, participants were invited to participate in monthly group sessions providing dietary and PA counseling (12 sessions per year). Participants in the control group were to attend yearly face-to-face individual visits to receive recommendations on an *ad libitum* MedDiet, along with general lifestyle counseling, without specific advice related to PA or weight loss. In addition, every 6 months participants in the control group were to attend nutritional educational group sessions (2 sessions per year). The usual contact frequency (albeit not necessarily via face-to-face visits) between study personnel (dietitians and nurses) and participants was maintained during the lockdown phase. All participants received free extra-virgin olive oil (1 L/month) to reinforce their adherence to the MedDiet.

2.3. Anthropometric and lifestyle assessment

At baseline and yearly, all participants provided information on sociodemographic characteristics, lifestyle, PA, MedDiet adherence, among others. Anthropometric variables (height, weight, and waist circumference) were measured according to the study protocol. Body mass index (BMI) was calculated by dividing the weight (kg) by the height squared (m^2). Adherence to an erMedDiet was assessed using a validated 17-item questionnaire in which the score ranged from 0 to 17, with 0 meaning current null adherence and 17 meaning maximum adherence (10). Leisure-time PA performed during a conventional month was assessed using the validated REGICOR questionnaire (11), which collected information about the type of activity, frequency (number of days) and duration (min/day). Sedentary time was evaluated on weekdays and weekends using the validated Nurse's Health Study questionnaire for sedentary behaviors (12), which contained questions about the average daily time spent watching TV, using the computer, or sitting (at work, leisure time, or while traveling) during the last year. Possible responses included 12 categories ranging from 0 to ≥9 h/day of sitting time for the corresponding activity.

2.4. Sanitary restrictions in Spain due to the COVID-19 pandemic and changes established in the delivery of interventions during the lockdown

To slow disease transmission, a shelter-in-place order was enforced in the country by the Spanish government from March 14th to June 21st, 2020 (13). Following this, a transition plan was established to shift from severe lockdown to less restrictive conditions (14, 15). The National Health System in Spain is based on the coordination and integration between the state administration and 17 autonomous communities health services (16). As a consequence, during the post-lockdown phase (once the shelter-in-place order was raised), the severity of restrictions concerning mobility and social interactions varied in different Spanish regions according to both local COVID-19 prevalence/incidence and pressures on the health system.

As the PREDIMED-Plus trial intervention and data collection originally relied on in-person visits and group sessions, restrictions directly affected the day-to-day fieldwork of the trial. In March 2020, the trial was in the midst of the planned intervention, and to prematurely stop was not a sensible option given the study's scientific value and allocated resources. Therefore, strategies were developed to continue the individual intervention and data collection. These strategies aimed to provide alternative means of study conduct, whether regulatory requirements prohibited or discouraged in-person visits or for when participants were reluctant to *attend study visits* in medical facilities for fear of COVID-19 contagion. All strategies established to continue the interventions and participant follow-up were approved by the PREDIMED-Plus Steering Committee.

During the lockdown, in response to the initial COVID-19 surge, the intervention was done remotely, with all necessary resources in order to do this remote conduct of the trial (including mobile phones and laptops) were provided to PREDIMED-Plus personnel. Study participants were contacted by telephone to receive nutritional and PA advice, and also to collect as much information as possible on lifestyle, dietary intake, and health status by using the same validated tools and procedure as in pre-lockdown conditions. In addition, digital material (e.g., MedDiet recommendations, recipes, at home PA promoting videos, etc.) were designed and sent by electronic

means (text messaging, email, social networks) or uploaded to the participant accessible PREDIMED-Plus website to promote adherence to the interventions. For willing participants who had access to electronic devices with internet service, group sessions to continue nutrition intervention and PA promotion counseling were performed remotely by video calls.

Concerning anthropometric data, body weight was preferably measured in face-to-face interviews, but when in-person visits could not be performed this variable was self-reported or collected from clinical records (usual check-up visit with a medical doctor). Waist-circumference was measured by trained study staff at in-person study visits. During the initial complete lockdown, we did not collect biological samples, accelerometer data, or assess body composition (percentage of body fat, percentage of muscle mass, visceral adipose tissue measured by DXA).

After the initial lockdown period, when restrictions allowed, in-person visits were resumed. At the time this article was written (2021 last trimester), in-person visits were permitted across Spain. To ensure the safety and well-being of study participants and staff, standard operating procedures for site disinfection were developed and are enforced. Since the resumption of in-person visits, additional precautions have been taken (such as recommendations not to attend the study site if symptoms suspicious of COVID-19 infection are present and to report to the investigators any positive COVID-19 test results before coming to their study visit). Most group sessions continue to be conducted remotely by video calls due to local regulations.

2.5. Assessment of PREDIMED-Plus study integrity during the COVID-19 pandemic

Given the PREDIMED-Plus is a multicenter study, it was prone to be affected by region-specific health regulations. Therefore, between June and July 2021, a questionnaire designed to assess the general impact of the social and mobility restrictions enforced to slow the COVID-19 transmission on the PREDIMED-Plus intervention and data collection was sent to the principal investigators of each of the 23 recruitment centers.

The questionnaire was divided into five study periods (03-05/2020, 06-08/2020, 09-12/2020, 01-03/2021 and 04-06/2021) identified according to the timing of sanitary restrictions in Spain (**Figure 1**, represented by red colored bars). Furthermore, the questionnaire consisted of two parts. Part A included 8 questions related to the percentage of lockdown time and severity of restrictions applied. Responses could range from 0% "*There was no lockdown in that period*" to 100% "*There was total restriction throughout the period.*" Part B included 7 questions related to the proportions of the different methods of participant contact, data collection and intervention strategies used. Responses could range from 0% "*This method was not used*" to 100% "*This was the only method used.*" Responders (investigators involved in the day-to-day follow-up of participants) were asked to use only the percentages 25, 50 and 75% for intermediate situations (**Supplementary material 1**). The questionnaire was completed by the investigators of all PREDIMED-Plus centers ($n = 23$).

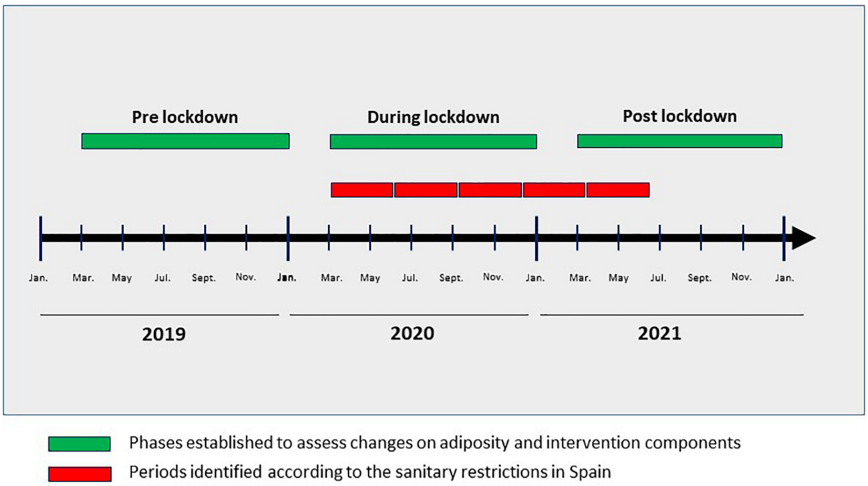

FIGURE 1
Lockdown periods assessed, and periods in which anthropometric measures, and components of the PREDIMED-Plus intervention were evaluated. Green colored boxes represent the three established lockdown phases to assess changes in adiposity and intervention components. Red colored boxes represent the five identified periods used to construct the questionnaire to assess the PREDIMED-Plus study integrity according to the prevalent sanitary restrictions in Spain.

2.6. Effect of the pandemic lockdown on body weight and each intervention component

The present analysis was performed with data from participants who underwent the follow-up visits encompassed in the three identified phases concerning the COVID-19 pandemic situation in Spain (**Figure 1**, represented by green colored bars): pre-lockdown (March–December 2019), during lockdown (March–December 2020), and post-lockdown (March–December 2021). Participants without scheduled follow-up visits in any of the aforementioned phases or those for whom it was not possible to perform in-person visits due to the pandemic were excluded from the analyses concerning adiposity measurements, or changes in the individual components of the intervention (PA promotion, sedentary behavior, or erMedDiet adherence). The number of participants who should have had a face-to-face visit but did not have it during the lockdown phases was estimated.

2.7. Statistical analyses

For the present study, we used the PREDIMED-Plus database updated until December 2021. The proportion of participants receiving the intervention and data collection method during the COVID-19 pandemic are presented as mean (SD). Repeated-measures ANCOVA adjusted by sex and age was used to compare differences among the different lockdown phases in Spain on the main intervention variables. Paired Student *t*-tests were used for group comparisons (pre vs. during, pre vs. post, lockdown phases in Spain). Sensitivity analyses excluding participants with self-reported data were conducted for adiposity measurements. Stratified analyses by intervention group were also performed to assess changes in main intervention variables across lockdown periods. The proportion of participants who showed clinically meaningful changes [at least a 5% change in body weight, BMI, and waist circumference (17, 18)] during and post-lockdown phases was estimated. The data were analyzed using the Stata 14 software (StataCorp, College Station TX, USA), and statistical significance was set at a two-tailed p-value < 0.05.

3. Results

3.1. PREDIMED-Plus study integrity during the pandemic

The investigators from all 23 PREDIMED-Plus recruitment centers responded to the questionnaire assessing the impact of the COVID-19 pandemic on the integrity of the trial. **Table 1** summarizes the mean lockdown rate in Spain from March 2020 to June 2021 and the reported percentages of participants receiving the intervention during the COVID-19 pandemic. The most severe lockdown rate (almost 100%) was reported from March to May 2020. During this period, individual nutritional and PA counseling, group sessions, and data collection through face-to-face interviews were scarcely used and participants were mainly contacted by telephone. Electronic means were also used to reinforce the intervention by developing and sharing digital materials with the participants. By the end of this assessment period (April-June 2021), face-to-face interviews had increased up to 60%; conversely, remote contacts by telephone or electronic means were reduced to 25%. Throughout the COVID-19-related study period, group sessions were mostly conducted by video calls rather than face-to-face (48.3 vs 9.8%). **Figure 2** shows the individual intervention methods used during the lockdown periods in Spain throughout the pandemic. Compliance rates with PREDIMED-Plus study interventions by recruitment center and the mode of intervention delivery and data collection during the pandemic are displayed in **Supplementary Table 1**.

During the first and most severe lockdown period, in-person measurement of anthropometric variables and collection of biological samples was performed in <10% of participants (**Table 1**). Performance rates increased in subsequent COVID-19 restriction periods. The same pattern, but with lower proportions, occurred for accelerometer data collection. The percentage of participants with face-to-face anthropometric and accelerometer data measurements and biological sample collection by recruitment center during the lockdown are displayed in **Supplementary Table 1**.

3.2. Effect of the lockdown on body weight and each intervention component

During the lockdown phase (March to December 2020), according to the study protocol 5,704 participants should have attended a yearly follow-up visit. Of them, 65.6% had in-person visits, 32.9% were contacted by telephone or data were collected from clinical records, and 1.5% could not be reached. As not all participants completed all follow-up questionnaires, there were slightly different sample sizes for measurements of adiposity, 17-point erMedDiet score, leisure-time PA, and sedentary time (**Figure 3**).

The mean values of body weight, BMI, waist circumference, 17-point erMedDiet score, leisure-time PA, and sedentary time variables before, during, and after the COVID-19 pandemic are shown in **Table 2**. In the total cohort, no differences in BMI were observed; however, significant, albeit not clinically relevant, differences among lockdown periods were observed

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TABLE 1 PREDIMED-Plus study integrity during the coronavirus pandemic.

	COVID-19 (Mar-2020/Jun-2021)	Mar–May/20	Jun–Aug/20	Sep–Dec/20	Jan–Mar/21	Apr–Jun/21
Lockdown rate (%)		98.9 ± 5.2	32.6 ± 38.0	57.6 ± 32.4	37.4 ± 38.8	33.7 ± 35.0
Performance by pandemic period, mean ± SD						
Individual nutritional and physical activity recommendations						
In-person visit[I]	40.4 ± 25.4	10.9 ± 22.4	31.5 ± 38.6	51.1 ± 36.5	47.8 ± 37.6	60.9 ± 38.3
Telephone contact[I]	39.8 ± 18.2	67.4 ± 30.6	45.6 ± 35.1	29.3 ± 24.6	32.6 ± 30.6	23.9 ± 28.7
Contact via electronic means[I]	35.0 ± 26.3	59.8 ± 35.1	31.5 ± 32.2	28.3 ± 33.1	30.4 ± 32.8	25.0 ± 33.7
Group sessions						
– Face-to-face	9.8 ± 17.9	2.2 ± 7.2	6.5 ± 21.6	8.7 ± 25.7	13.0 ± 28.1	18.5 ± 33.9
– By videocall	48.3 ± 42.2	39.1 ± 47.0	42.4 ± 48.5	51.1 ± 49.1	55.4 ± 44.6	53.3 ± 46.7
Delivery of olive oil	69.3 ± 26.0	35.9 ± 46.4	70.7 ± 35.1	79.3 ± 27.8	80.4 ± 31.0	80.4 ± 31.0
Anthropometric measurements						
– Direct by study personnel	61.3 ± 20.3	11.9 ± 23.7	56.5 ± 36.3	77.2 ± 28.1	75.0 ± 32.0	85.9 ± 25.9
– Self-reported[¥]	34.2 ± 18.0	75.2 ± 33.2	39.1 ± 36.8	20.6 ± 26.8	22.8 ± 40.0	13.0 ± 23.7
Blood sample collection	61.1 ± 22.1	8.7 ± 23.4	65.2 ± 39.0	68.5 ± 36.3	78.3 ± 30.4	84.8 ± 23.5
Fecal and urine sample collection	60.2 ± 23.7	9.8 ± 25.8	64.1 ± 40.5	67.4 ± 35.7	77.2 ± 31.9	82.6 ± 26.6
Accelerometer data collection*	47.8 ± 30.9	11.3 ± 27.5	46.3 ± 40.0	52.5 ± 38.8	57.5 ± 45.2	71.3 ± 37.4

Data represent self-reported data from the 23 centers expressed as mean ± SD rates (%).
[I]Contact means could be used simultaneously.
[¥]Only used to collect data on body weight. *Accelerometer data collected in 20 of the 23 Predimed-Plus centers.

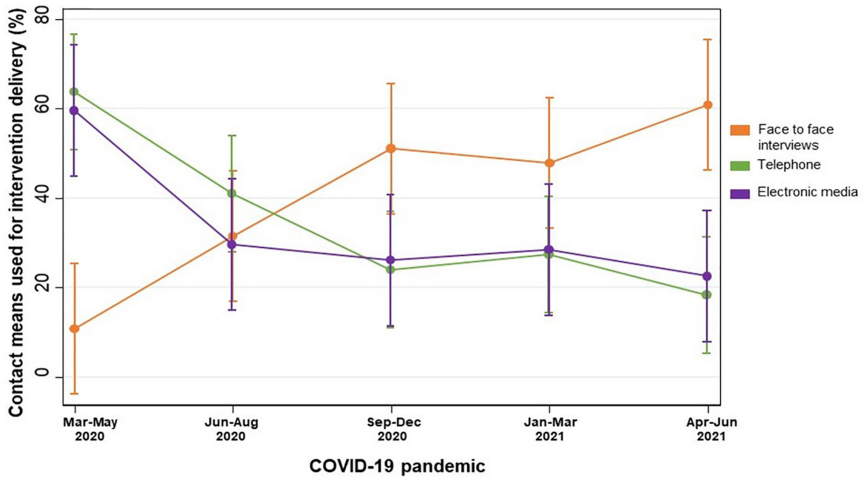

FIGURE 2
Individual intervention delivery methods applied in the PREDIMED-Plus trial during the COVID-19 pandemic in Spain. Means (SD) of the proportions of participants receiving the intervention during the COVID-19 pandemic.

for body weight, waist circumference, the 17-point erMedDiet score, leisure-time PA, and sedentary time. After the exclusion of participants with self-reported data on body weight (23.5% of participants), similar differences were observed among the study periods (Table 2). A total of 13.0% of the participants exhibited a reduction ≥5% in body weight; while 13.7% of the individuals showed an increase>5% in waist circumference (Supplementary Table 2).

In the total cohort, waist circumference and sedentary time increased during lockdown (0.75 cm [0.60; 0.91]) and (0.08 h/day [0.02; 0.13]), respectively). After lockdown, body weight, the 17-point erMedDiet score, and PA significantly

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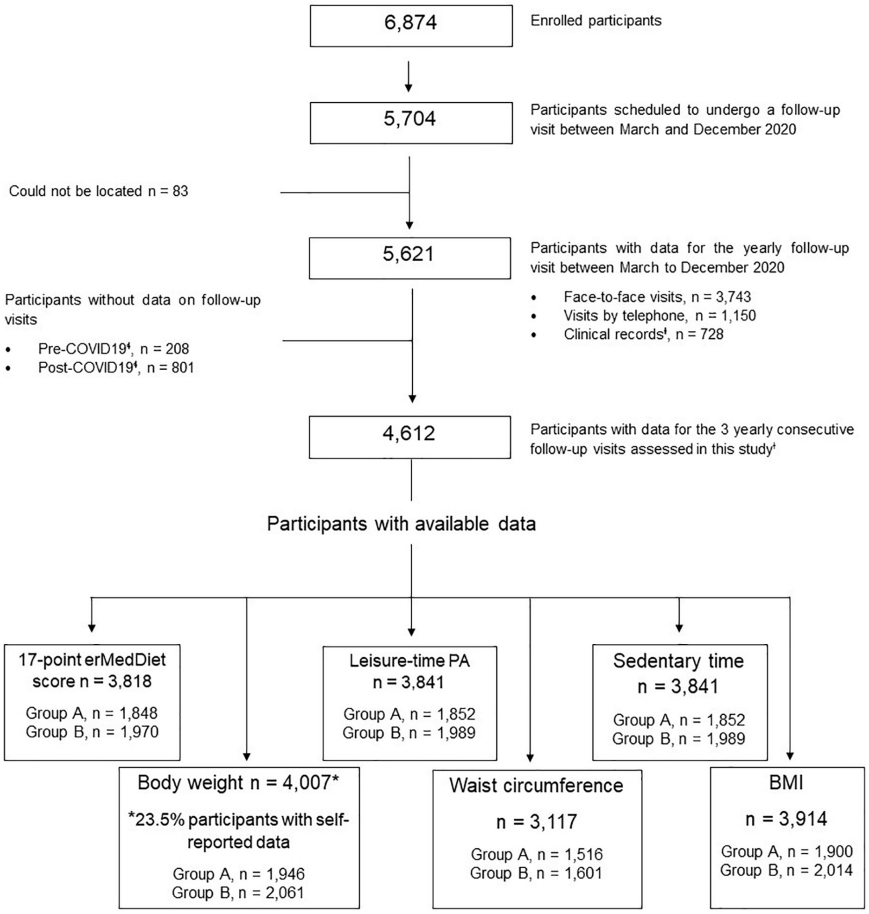

FIGURE 3
Flow diagram for study participants. P-Plus, PREDIMED-Plus study; BMI, body mass index; erMedDiet, energy-restricted Mediterranean diet; PA, physical activity; COVID-19, Coronavirus disease 2019. [1]Pre lockdown (from March to October 2019), during lockdown (from March to October 2020) and post-lockdown (from March to October 2021). [1]To collect data on body weight.

decreased in comparison with the pre-lockdown and lockdown phases (−0.17 kg [−0.30; −0.04], −0.18 points [−0.26; −0.10], and −27.9 METs.min/day [−38.8; −17.1], respectively). Waist circumference remained increased during the post-lockdown phase.

The effect of the COVID-19 pandemic on the main intervention variables of the trial by intervention group are displayed in Table 3. In both intervention groups, differences were observed for waist circumference, 17-point erMedDiet score, and leisure-time PA among assessment phases. In Group A, body weight decreased after lockdown. In Group B, increases in sedentary time were recorded during and post lockdown.

4. Discussion

The present work describes the effect of the COVID-19 pandemic lockdown and related social restrictions on the delivery of the PREDIMED-Plus interventions and participants' follow-up. We also report the strategies applied to mitigate the influence of social and mobility restrictions on the conduct of the trial, and the effect of the lockdown on the main components of the trial. Despite the strict shelter-in-place orders enforced in Spain, the intervention was not interrupted at any point of the pandemic. This was possible thanks to the early implementation of remote contact strategies (telephone, social networks, videocall platforms), and likely due to the motivated nature and possibly feelings of empowerment expressed by the participants who had been enrolled in the trial for a median [IQR] of 48.5 [43.8–58)] months when the pandemic began. During pre-lockdown, lockdown proper, and post-lockdown phases we also observed significant, albeit clinically irrelevant, differences in body weight, waist circumference, leisure-time PA, sedentary time, and adherence to the erMedDiet, while no changes were reported for BMI.

TABLE 2 Effect of the coronavirus pandemic (mean [95%CI] on intervention components and main outcome variables in the PREDIMED-Plus study (completers, *n* = 4,612).

	Pre lockdown (Mar–Dec/2019)	During lockdown (Mar–Dec/2020)	Post lockdown (Mar–Dec/2021)	*P-value*	During vs. Pre	Post vs. Pre
17-point erMedDiet score	11.8 (11.7–11.8)	11.8 (11.8–11.9)	11.6 (11.5–11.6)	<0.01	0.02 (−0.05 to 0.09)	−0.18 (−0.26 to −0.10)**
Leisure-time physical activity, METs.min/day	441.6 (434.0–449.2)	439.0 (431.4–446.7)	413.7 (406.1–421.3)	<0.01	−2.60 (−13.2 to 8.00)	−27.9 (−38.8 to −17.1)**
–Light	134.8 (131.1–138.5)	135.5 (131.8–139.2)	139.4 (135.7–143.1)	0.17	0.67 (−4.4 to 5.7)	4.6 (−0.9 to 10.1)
–Moderate	165.0 (159.7–170.3)	177.1 (171.9–182.4)	161.6 (156.7–166.9)	<0.01	12.1 (5.0–19.3)**	−3.7 (−10.9 to 4.2)
–Intense	141.8 (136.6–147.1)	126.4 (121.2–131.7)	112.7 (107.5–117.9)	<0.01	−15.4 (−22.8 to −8.1)**	−29.2 (36.6 to −21.8)**
Sedentary time, h/day	5.6 (5.5–5.6)	5.7 (5.6–5.7)	5.7 (5.6–5.7)	0.01	0.08 (0.02–0.13)**	0.07 (0.01–0.13)*
Body weight, kg[a]	83.9 (83.9–84.0)	84.0 (83.9–84.0)	83.8 (83.7–83.9)	<0.01	0.01 (−0.10 to 0.13)	−0.17 (−0.30 to −0.04)*
Measured body weight, kg[b]	83.9 (83.8, 84.0)	84.1 (84.0, 84.2)	83.8 (83.7, 83.9)	<0.01	0.19 (0.05, 0.32)**	−0.15 (−0.29, −0.00)*
BMI, kg/m^2[c]	31.7 (31.6–31.7)	31.7 (31.7–31.8)	31.7 (31.6–31.7)	0.23	0.04 (−0.01 to 0.08)	−0.00 (−0.06 to 0.05)
Waist circumference, cm[d]	105.3 (105.2–105.4)	106.0 (105.9–106.1)	105.9 (105.9–106.1)	<0.01	0.75 (0.60–0.91)**	0.72 (0.56–0.89)**

BMI, body mass index; COVID-19, Coronavirus disease 2019; erMedDiet, energy-restricted MedDiet; MET, metabolic equivaluent of task. Data is expressed as % (*n*), mean ± SD, or as mean (95% CI). Group comparisons (pre-COVID-19, during COVID-19 and post-COVID-19 lockdown phases in Spain) were performed using repeated-measures ANCOVA adjusted for sex and age ($P < 0.05$).

Group comparisons (pre vs. during and pre vs. post phases in Spain) by paired *t*-test (*$P < 0.05$; **$P < 0.01$).

[a]Includes measured and self-reported weight, $n = 4{,}007$.

[b]After exclusion of 943 participants with self-reported weight, $n = 3{,}064$.

[c]Includes measured and self-reported weight $n = 3{,}914$.

[d]Includes only measured waist circumference, $n = 3{,}117$.

4.1. COVID-19 pandemic lockdown and changes in delivery of the PREDIMED-Plus trial intervention

Since March 2020, uninterrupted measures against COVID-19 have been enforced in Spain. However, the degree of sanitary restrictions, lockdown, and curfews have varied over time across the Spanish territory. Differences in the severity of restrictions and in human and economic resources determined the methods and tools used at each center during the lockdown. These conditions have impacted PREDIMED-Plus fieldwork so that intervention delivery methods had to be modified, but the prompt response of study investigators enabled the trial to continue. Even though face-to-face fieldwork was substantially affected, individual nutritional and PA counseling was conducted in all recruitment centers through alternative approaches, and importantly the trial was not stopped at any point.

The use of technology for the remote delivery of individual counseling of nutrition and PA recommendations allowed study personnel to reach a large proportion of participants. In addition, the materials and tools designed to provide recommendations on diet and PA were focused on the home lockdown (avoiding unhealthy eating behaviors and snacking between meals, providing healthy recipes, PA video routines, etc.). The methods applied in the trial were in accordance with the advice subsequently delivered by the WHO and other research organizations suggesting the use of existing communication platforms (e.g., text messaging, email, and social media applications) to stay in touch with study participants during the pandemic (1, 6, 19). The use of electronic means, has been previously reported to be a suitable alternative for nutritional and PA promotion and data collection (1, 6, 19), in Spanish adult people (20), and the preferred strategy by older participants (2).

Biological samples and accelerometer variables were not collected during the initial lockdown period due to the restrictions and difficulties associated with participants being able to attend face-to-face visits, and the little information available regarding safety protocols for the collection, management, and storage of biological samples. Nevertheless, once the restrictions were eased and recapture protocols were established and approved in each center, the percentages of data collection showed a linear increase.

Educational group sessions were the most affected intervention component. First, due to the social and mobility restrictions that did not permit meetings, and second because older individuals tend to have little knowledge of how to use existing communication platforms. Up to July 2021, only a few centers had resumed in-place meetings, while most centers

TABLE 3 COVID-19 pandemic effect (mean [95% CI]) over the main intervention variables in the PREDIMED-Plus trial by intervention group.

	Group A				Group B			
	Pre lockdown (Mar–Dec/2019)	During lockdown (Mar–Dec/2020	Post lockdown (Mar–Dec/2021)	*P-value*	Pre lockdown (Mar–Dec/2019)	During lockdown (Mar–Dec/2020	Post lockdown (Mar–Dec/2021)	*P-value*
17-point erMedDiet score	*n* = 1,848				*n* = 1,970			
	12.9 (12.8–13.0)	12.8 (12.7–12.8)	12.6 (12.5–12.6)	<0.01	10.7 (10.7–10.8)	10.9 (10.8–11.0)	10.7 (10.6–10.8)	< 0.01
Leisure-time PA, METs/min/day	*n* = 1,852				*n* = 1,989			
	499.1 (488.0–510.1)	484.9 (473.9–496.0)	459.9 (459.9–471.0)	<0.01	388.2 (377.7–398.6)	396.3 (385.8–406.8)	370.6 (360.2–381.1)	<0.01
Sedentary time, h/day	*n* = 1,852				*n* = 1,989			
	5.5 (5.4–5.5)	5.5 (5.5–5.6)	5.5 (5.5–5.6)	0.83	5.7 (5.6–5.7)	5.8 (5.7–5.8)	5.8 (5.7–5.9)	0.01
Body weight, kg	*n* = 1,946				*n* = 2,061			
	82.7 (82.6–82.8)	82.7 (82.6–82.8)	82.5 (82.4–82.6)	0.02	85.1 (85.0–85.3)	85.2 (85.0–85.3)	85.0 (84.8–85.1)	0.09
BMI, kg/m^2	*n* = 1,900				*n* = 2,014			
	31.1 (31.1–31.2)	31.2 (31.1–31.2)	31.1 (31.1–31.2)	0.39	32.2 (32.2–32.3)	32.3 (32.2–32.3)	32.2 (32.2–32.3)	0.50
Waist circumference, cm	*n* = 1,516				*n* = 1,601			
	103.5 (103.3–103.6)	104.1 (104.0–104.3)	104.2 (104.1–104.7)	<0.01	107.0 (106.8–107.1)	107.8 (107.6–108.0)	107.7 (107.5–107.8)	< 0.01

BMI, body mass index; COVID-19, Coronavirus disease 2019; erMedDiet, energy-restricted MedDiet; MET, metabolic equivalent of task; PA, physical activity. Data is presented as mean (95% CI). Group comparisons (pre-COVID-19, during COVID-19 and post-COVID-19 lockdown periods in Spain) were performed using repeated-measures ANCOVA adjust for sex and age ($P < 0.05$).

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conducted group sessions via video calls, and only 4 centers reported not conducting any group sessions.

4.2. Effect of the COVID-19 pandemic on body weight and main components of the intervention

It is important to underline that PREDIMED-Plus is a trial in individuals with overweight/obesity in which the principal aim is weight loss and its long-term maintenance. When the confinement began, participants were in the phase of weight loss maintenance. In the present analysis, conducted with data from 67% of the total recruited participants, we observed no differences among lockdown phases regarding mean BMI. Yet, body weight, waist circumference, erMedDiet adherence, leisure-time PA, and sedentary time showed variations among lockdown periods. However, the slight increases in adiposity measurements observed during confinement were clinically irrelevant. Moreover, after lockdown, both anthropometric indicators decreased. Similar results were observed when participants with self-reported data on body weight were excluded from the analyses.

Results from previous surveys have reported increased body weight during COVID-19 lockdowns (21–23). Discrepancies regarding the degree of weight gain between our study and other reports might be due to the PREDIMED-Plus objective and design, which might have played an important role in the prevention of weight gain. Moreover, data from most of the aforementioned studies were self-reported and not measured by trained staff, as some participants were reluctant to attend in-person visits with study personnel, due to their high risk of COVID-19 complications and mortality because of potential underlying health conditions (24).

It has been reported that the pandemic and confinement affected eating behaviors (20). Interestingly, dietary changes during the pandemic were beneficial in our participants, as an increase in adherence to the intended intervention with erMedDiet was observed. This can be explained by: (a) the continuous advice received by the participants concerning healthy dietary behaviors, (b) the messages provided to them about the potential protective effect of a healthy diet and weight loss against COVID-19 complications, and, (c) the temporary closure of cafeterias, bars, and restaurants and prohibition of social encounters. These results are in line with those reported in a recent systematic review in which a worldwide moderate improvement in dietary habits was observed during lockdown (20); and with other surveys conducted in Mediterranean populations, which reported higher adherence to the MedDiet during COVID-19 confinement (25, 26). However, an increase in the consumption of certain "unhealthy" food groups (27) or alcohol (28), and an increase in the prevalence of eating behaviors such as snacking or overconsumption of ultra-processed foods, have also been reported (20, 29, 30).

Leisure-time PA showed a minimum decrease during the lockdown. This observation might be partly explained by a collateral effect of severe confinement in Spain. While during the first severe confinement trimester, outdoors sports were forbidden, during the transition phase, just after the initial lockdown, an increased number of people, more than usual, were observed on the streets performing PA. This observation is in line with previous results reporting an increase in PA during the confinement in two Italian cohorts (25). In addition, it should be noted that half of the PREDIMED-Plus participants are receiving a PA promotion program and received advice for increased at-home training. This might partially explain the differences observed with other studies that reported decreased PA and increased sedentary behaviors during the confinement (21, 31, 32). This potential explanation is supported by the results of sedentary time observed for the intervention "Group B," whose participants showed a significantly higher sedentary time during and post-lockdown compared to the pre-lockdown phase. Even so, it should also be noted that after lockdown, we observed a decrease in leisure-time PA intensity. This might be partly explained by the reluctance of participants to perform group PA indoors or outdoors. As PA promotion is one of the trial's main intervention components, PREDIMED-Plus staff acknowledge the need to further emphasize this lifestyle factor for future compliance.

The main strength of our study is its prospective design. The pre-lockdown data availability allowed for comparison of events during lockdown and post-lockdown periods, which provided the opportunity to assess the potential impact of confinement and the strategies applied to mitigate its consequences on our main intervention variables. Also, validated tools were used to assess the main components of the lifestyle intervention: adherence to erMedDiet, PA, and sedentary behaviors (10–12). Our study also has limitations. First, responses to the questionnaire used to assess the integrity of the PREDIMED-Plus trial during and after the COVID-19 pandemic were self-reported and the mean lockdown rate per period was estimated from reports of PREDIMED-Plus centers and does not represent real data from the communities or Spanish restrictions. Second, not all PREDIMED-Plus participants were included in this analysis. Data from participants who attended a follow-up visit in 2020 before confinement began were excluded (for better representativeness of the effect of the restrictions on the trial components), and this might have induced selection bias. Third, results from changes in sedentary time should be interpreted with caution as the validated Nurse's Health Study questionnaire for sedentary behaviors reflects data from the last year, and might not reflect the acute lockdown effect. Finally, contact frequency between study staff and the intervention groups differs throughout the trial, and this could have promoted different magnitudes of effect in adiposity and intervention

adherence between the two groups during the lockdown. As, in this analysis, we kept the intervention blinded to the researchers, conclusions by intervention arms should be done with caution.

Remote visits and intervention, have limitations, but when applied in the PREDIMED-Plus study proved to be feasible and largely effective to retain research participants and keep the trial ongoing in an unpredictable environment. At the time this manuscript was written, the majority of the primary outcome assessments related to weight loss and weight-loss maintenance (i.e., body weight, waist circumference, dietary adherence, and other lifestyle variables) have been successfully collected.

5. Conclusion

In the ongoing PREDIMED-Plus trial, the COVID-19 pandemic lockdown affected the delivery of interventions, the follow-up of participants, and data collection, without significantly affecting the study design or resulting in major changes to the protocol (except for group sessions). Due to the strategies implemented to address restrictions related to the pandemic lockdown, the trial was not stopped at any moment during the COVID-19 pandemic. The strategies established resulted in small effects on the different intervention components. Compared to the pre-lockdown period, participant waist circumference and measured total body weight slightly increased during the lockdown in both intervention groups.

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Data availability statement

The original contributions presented in the study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by the protocol and procedures were implemented following the ethical standards of the Declaration of Helsinki and approved by the Institutional Ethics Review Boards of each study center. The patients/participants provided their written informed consent to participate in this study.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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References

1. Singh J, Bandewar S, Bukusi E. The impact of the COVID-19 pandemic response on other health research. *Bull World Health Organ.* (2020) 98:625–31. doi: 10.2471/BLT.20.257485

2. Fitzgibbon M, Blumstein L, Schiffer L, Antonic M, McLeod A, Dakers R, et al. Adapting to the COVID-19 pandemic on building research in diet and cognition (BRIDGE) trial. *Trials.* (2021) 22:459. doi: 10.1186/s13063-021-05383-6

3. Park K, Etnier J. An innovative protocol for the artificial speech-directed, contactless administration of laboratory-based comprehensive cognitive assessments: PAAD-2 trial management during the COVID-19 pandemic. *Contemp Clin Trials.* (2021) 107:106500. doi: 10.1016/j.cct.2021.106500

4. Pisu M, Omairi I, Hoenemeyer T, Halilova K, Schoenberger Y, Rogers L, et al. Developing a virtual assessment protocol for the AMPLIFI randomized controlled trial due to COVID-19: from assessing participants' preference to preparing the team. *Contemp Clin Trials.* (2021) 111:106604. doi: 10.1016/j.cct.2021.106604

5. McDermott M, Newman A. Remote research and clinical trial integrity during and after the coronavirus pandemic. *JAMA.* (2021) 325:1935. doi: 10.1001/jama.2021.4609

6. Orkin A, Gill P, Ghersi D, Campbell L, Sugarman J, Emsley R, et al. Guidelines for reporting trial protocols and completed trials modified due to the COVID-19 pandemic and other extenuating circumstances. *JAMA.* (2021) 326:257. doi: 10.1001/jama.2021.9941

7. Alberti K, Eckel R, Grundy S, Zimmet P, Cleeman J, Donato K, et al. Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; International. *Circulation.* (2009) 120:1640–5. doi: 10.1161/CIRCULATIONAHA.109.192644

8. Martínez-González M, Buil-Cosiales P, Corella D, Bulló M, Fitó M, Vioque J, et al. Cohort profile: design and methods of the PREDIMED-plus randomized trial. *Int J Epidemiol.* (2018) 48:387–8o.

9. Salas-Salvadó J, Díaz-López A, Ruiz-Canela M, Basora J, Fitó M, Corella D, et al. Effect of a lifestyle intervention program with energy-restricted mediterranean diet and exercise on weight loss and cardiovascular risk factors: one-year results of the PREDIMED-Plus trial. *Diabetes Care.* (2018) 42:dc180836.

10. Schröder H, Zomeño M, Martínez-González M, Salas-Salvadó J, Corella D, Vioque J, et al. Validity of the energy-restricted mediterranean diet adherence screener. *Clin Nutr.* (2021) 40:4971–9. doi: 10.1016/j.clnu.2021.06.030

11. Molina L, Sarmiento M, Peñafiel J, Donaire D, Garcia-Aymerich J, Gomez M, et al. Validation of the regicor short physical activity questionnaire for the adult population. *PLoS One.* (2017) 12:e0168148. doi: 10.1371/journal.pone.0168148

12. Martínez-González M, López-Fontana C, Varo J, Sánchez-Villegas A, Martinez J. Validation of the Spanish version of the physical activity questionnaire used in the Nurses' health study and the health professionals' follow-up study. *Public Health Nutr.* (2005) 8:920–7. doi: 10.1079/PHN2005745

13. Ministerio de la Presidencia España. Real Decreto 463/2020, de 14 de marzo, por el que se declara el estado de alarma para la gestión de la situación de crisis sanitaria ocasionada por el COVID-19. *Bol Estado.* (2020) 67:25390–400.

14. Ministerio de Sanidad, Gobierno de España. Plan para la transisción hacia una nueva normalidad. *Bol Estado.* (2020) 53:1689–99.

15. Gobierno de España, ANEXO II- Previsión orientativa para el levantamiento de las limitaciones de ámbito nacional establecidas en el estado de alarma, en función de las fases de transición a una nueva normalidad. *Bol Estado.* (2020) 53:1–9.

16. Ministerio de Sanidad. *Servicios Sociales e Igualdad. Sistema Nacional de Salud. España 2012*. Madrid: Ministerio de Sanidad (2012). p. 16–29.

17. Feldman A, Griffin S, Ahern A, Long G, Weinehall L, Fhärm E, et al. Impact of weight maintenance and loss on diabetes risk and burden: a population-based study in 33,184 participants. *BMC Public Health.* (2017) 17:170. doi: 10.1186/s12889-017-4081-6

18. Williamson D, Bray G, Ryan D. Is 5% weight loss a satisfactory criterion to define clinically significant weight loss? *Obesity.* (2015) 23:2319–20. doi: 10.1002/oby.21358

19. FDA. *Guidance on Conduct of Clinical Trials of Medical Products During COVID-19 Public Health Emergency: Guidance for Industry, Investigators, and Institutional Review Boards*. Silver Spring, MD: FDA (2020).

20. Mignogna C, Costanzo S, Ghulam A, Cerletti C, Donati M, de Gaetano G, et al. Impact of nationwide lockdowns resulting from the first wave of the COVID-19 pandemic on food intake, eating behaviors, and diet quality: a systematic review. *Adv Nutr.* (2021) 13:388–423. doi: 10.1093/advances/nmab130

21. Deschasaux-Tanguy M, Druesne-Pecollo N, Esseddik Y, de Edelenyi F, Allès B, Andreeva V, et al. Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March–May 2020): results from the French NutriNet-Santé cohort study. *Am J Clin Nutr.* (2021) 113:924–38. doi: 10.1093/ajcn/nqaa336

22. He M, Xian Y, Lv X, He J, Ren Y. Changes in body weight, physical activity, and lifestyle during the semi-lockdown period after the outbreak of COVID-19 in China: an online survey. *Disaster Med Public Health Prep.* (2021) 15:e23–8. doi: 10.1017/dmp.2020.237

23. Lin A, Vittinghoff E, Olgin J, Pletcher M, Marcus G. Body weight changes during pandemic-related shelter-in-place in a longitudinal cohort study. *JAMA Netw Open.* (2021) 4:e212536. doi: 10.1001/jamanetworkopen.2021.2536

24. Center for Disease Control and Prevention. *COVID-19 Risks and Vaccine Information for Older Adults*. Atlanta, GA: Center for Disease Control and Prevention (2021).

25. Ruggiero E, Mignogna C, Costanzo S, Persichillo M, Di Castelnuovo A, Esposito S, et al. Changes in the consumption of foods characterising the Mediterranean dietary pattern and major correlates during the COVID-19 confinement in Italy: results from two cohort studies. *Int J Food Sci Nutr.* (2021) 72:1105–17. doi: 10.1080/09637486.2021.1895726

26. Rodríguez-Pérez C, Molina-Montes E, Verardo V, Artacho R, García-Villanova B, Guerra-Hernández E, et al. Changes in dietary behaviours during the COVID-19 outbreak confinement in the Spanish COVIDiet study. *Nutrients.* (2020) 12:1730. doi: 10.3390/nu12061730

27. Ammar A, Brach M, Trabelsi K, Chtourou H, Boukhris O, Masmoudi L, et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: results of the ECLB-COVID19 international online survey. *Nutrients.* (2020) 12:1583.

28. Vanderbruggen N, Matthys F, Van Laere S, Zeeuws D, Santermans L, Van den Ameele S, et al. Self-reported alcohol, tobacco, and cannabis use during COVID-19 lockdown measures: results from a web-based survey. *Eur Addict Res.* (2020) 26:309–15. doi: 10.1159/000510822

29. Papandreou C, Arija V, Aretouli E, Tsilidis K, Bulló M. Comparing eating behaviours, and symptoms of depression and anxiety between Spain and Greece during the COVID-19 outbreak: cross-sectional analysis of two different confinement strategies. *Eur Eat Disord Rev.* (2020) 28:836–46. doi: 10.1002/erv.2772

30. Bonaccio M, Costanzo S, Bracone F, Gialluisi A, Di Castelnuovo A, Ruggiero E, et al. Psychological distress resulting from the COVID-19 confinement is associated with unhealthy dietary changes in two Italian population-based cohorts. *Eur J Nutr.* (2021) 61:1491–505. doi: 10.1007/s00394-021-02752-4

31. Lesser I, Nienhuis C. The impact of COVID-19 on physical activity behavior and well-being of Canadians. *Int J Environ Res Public Health.* (2020) 17:3899. doi: 10.3390/ijerph17113899

32. Tison G, Avram R, Kuhar P, Abreau S, Marcus G, Pletcher M, et al. Worldwide effect of COVID-19 on physical activity: a descriptive study. *Ann Intern Med.* (2020) 173:767–70. doi: 10.7326/M20-2665

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Reliability and validity of the Chinese version of the Sakata Eating Behavior Scale short form and preliminary analysis of the factors related to the score of the scale

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Background: The obesity rate in the Chinese population is increasing and there is a lack of short and reliable scales for measuring obesity-related eating behavior in China. The EBS-SF (Sakata Eating Behavior Scale short form) has only 7 entries and has shown good reliability in studies such as those in Japan.

Objective: To translate the EBS-SF into Chinese, check its reliability, validity and explore the related factors.

Method: The EBS-SF was translated into Chinese. 3,440 residents were investigated and 34 respondents were retested. Item analysis and reliability and validity tests were carried out. Personality characteristics, family health status and depression were investigated using the BFI-10, FHS-SF and PHQ-9 to investigate the factors associated with EBS-SF. The *t*-test, ANOVA and Pearson correlation was used to explore the related factors of its scores.

Result: Among 3,440 residents, 1,748 (50.81%) were male and 1,692 (49.19%) were female; 1,373 (39.91%) were aged 36–50 years. All 7 items were qualified in the item analysis. As for reliability, the Cronbach's α was 0.870, the split-half reliability was 0.830, the test-retest correlation coefficient was 0.868. As for the structural validity, the standardized factor loadings were above 0.50, χ^2 / df = 2.081,GFI = 0.999; NFI = 0.999; RFI = 0.996; RMSEA = 0.018, all qualified. The characteristics, personality, family health and depression were correlated with the score of the Chinese version of EBS short form.

Conclusion: The structural validity and reliability of the Chinese version of the EBS-SF are good and it can be used as a measurement tool to evaluate the eating behavior of Chinese. The scores of the EBS-SF may be related to the sociological characteristics, personality, family health, and depression status.

KEYWORDS

eating behavior, validity, reliability, cross-cultural adjustment, BFI-10, family health

1. Introduction

Over the past four decades, the dietary patterns of Chinese residents have undergone significant changes, with a rapid increase in the consumption of high-sugar and high-calorie foods and a rapid increase in the rates of overweight and obesity in the population. Obesity is increasingly becoming an important public health issue in China. As of 2019 statistics, the national prevalence of obesity is estimated at 6.8%, with obesity rates of 16.4% in adults (1). The development of obesity is closely related to uncontrolled eating behavior (2). Meanwhile, obesity is associated with the onset and progression of various chronic diseases, such as hypertension (3) and diabetes (4), which is very worrying. The prevalence of these chronic diseases rises with the obesity rate, thus significantly increasing the burden on the medical and public health systems of China.

The World Health Organization defines cut-off values for obesity based on the physical assessment such as body mass index (BMI): weight/height squared (kg/m^2) (5, 6). Internationally, assessment methods for the obesity also involved such as nutrition assessment, exercise assesssment (4) and also the use of obesity genes. Obviously, it is not realistic to use any of these single indexes to describe the cause of obesity. And the above tools are more appropriate as therapeutic aids to identify obesity rather than exploring the causes of obesity. A valid assessment in terms of food intake as well as eating behavior seems to contribute to a better understanding of obesity and to give an active life management program.

In studies of the eating behavior of Chinese adults, it has been found that certain specific eating habits may constitute risk factors to obesity, such as the absence of a particular meal in a day. However, this may not be the only eating behavior that has an impact on obesity. There are complex interactions between eating behaviors and psychological, social and other factors. Related research confirms that body fat levels are closely related to eating behavior and that obesity may be driven by diet-related behavioral factors as well as pre-existing environmental and genetic factors (7). Therefore, a comprehensive assessment of eating behaviors is needed to identify specific potential risks for obesity.

Many studies exploring eating behaviors have used validated and reliable questionnaires that provide data tested in populations. For example, the Adult Eating Behavior Questionnaire (AEBQ) has been used all over the world. AEBQ is currently validated in Saudi, Poland, Portugal and China (8–11). The AEBQ has 35 items, using a five-point Likert scale involving eight subscales, which can be further divided into two dimensions of food approach and food avoidance behavior. Although this tool has been widely used and validated, the 35-item scale is very costly in terms of effort and time for the subjects and experimenters.

The thirty-item Sakata Eating Behavior Scale widely used in Japan is divided into seven dimensions: concern cognition of constitution, motivation for eating, substitute eating and drinking, feeling of satiety, eating style, meal contents, and eating rhythm abnormalities (12). Higher scores indicate poorer eating behaviors, which exacerbate obesity. The scale is used in some hospitals in Japan to assess eating behaviors to help patients change their eating behaviors and carry out obesity treatment.

The EBS short form was simplified from the 30-item EBS based on item response theory (13). Among the instruments measuring eating behavior associated with obesity, this is a much shorter scale, containing only seven items from the seven original dimensions. This means that the scale can be used in practice with less time and effort on the part of the user. The total score of the short scale is strongly correlated with the original scale ($r = 0.93$, $P = 0.001$). The EBS short form was validated in 1,032 Japanese adults aged 20–59 years and confirmed its validity.

In China, there is a lack of short scales that can be used in large cross-sectional surveys and identify more potential obesity problems. The EBS short form could be a more useful tool to measure Chinese eating behaviors and help Chinese obese patients to control their eating behavior. Considering the interoperability of Asian food cultures, the use of a simplified Chinese version of the EBS short form in China would be more culturally advantageous than the original scale developed and validated in countries outside of Asia. The objective of this study was to translate the simplified Chinese version of the EBS short form, check its reliability and validity in China and explore the possible influences on its scores.

2. Methods

This study is derived from a large cross-sectional study that callled "2021 China Family Health Index Investigation" (14). The data used in this study are a subset of this national study. The survey is based on multi-stage sampling across the country. When selecting cities, all the provincial capital cities of provinces and autonomous regions, as well as municipalities in China were firstly included. Later, the random-number table was applied to randomly select the non-provincial capital cities of all provinces and autonomous regions in the country. Finally, 120 cities were selected within China. During the second phase of sampling, the population of each city was stratified according to gender, age, and urban-rural distribution, and the sample size of each stratum was 100 people, which was determined according to the

demographic characteristics of the "Seventh National Census in 2021". Convenience sampling was carried out on the premise of meeting quota requirements. After the completion of the sampling, with the favor of the investigator recruited in each city, the investigation was conducted from 10th July 2021 to 15th September 2021. In detail, investigators of each city used the online questionnaire star platform (https://www.wjx.cn/) to distribute questionnaires one-on-one and face-to-face with people in their cities. Then, after the investigator entered the questionnaire number, respondents would complete the questionnaire by clicking on the link. If the respondents held the ability to think but were not able to act to answer the questionnaire, the investigator would help finish the questionnaire based on the offered answers by the participants. After unified training, investigators recruited from various provinces and cities distributed questionnaires to respondents meeting the inclusion and exclusion criteria through field investigation. Prior to the investigation, the investigator would use consistent instructions to explain the research purpose to the respondents, emphasizing the anonymity of the research and obtaining the informed consent of the respondents. During the investigation, the respondents filled out the questionnaire by themselves and then handed it over to the investigator for inspection. If there were omissions or multiple elections, the investigator would communicate with the respondents on the spot whether a by-election or re-election is possible. After the questionnaires were collected, the questionnaires whose filling time was <2 min, incomplete filling and inconsistent filling content were excluded.

2.1. Instruments

2.1.1. The EBS short form

The EBS short form was developed in 2017 by Tayama and Ogawa et al., using item response theory (IRT) based on the Sakata Eating Behavior Scale (EBS) (13). The scale consists of 7 items, including eating rhythm abnormalities, feeling of satiety, eating habits, cognition of constitution, meal content, substitute eating and drinking, and motivation for eating, and each item is scored on a 4-point scale (1 = strongly disagree, 2 = somewhat disagree, 3 = somewhat agree, 4 = strongly agree). The scores of the 7 items were summed up as the total score of the scale, and the higher the respondent's score on this scale, the worse the eating behavior of the respondent.

2.1.2. Other scales

2.1.2.1. The 10-Item short version of the Big Five Inventory (BFI-10)

The 10-Item short version of the Big Five Inventory (BFI-10) was applied to measure the personality characteristics of the respondents. The scale consists of 5 dimensions with 10 items, and each dimension contains 2 items, including Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness, on a 5-point Likert-type scale ranging from 1 (totally disagree) to 5 (totally agree). The full score of each dimension is 10 points, and the higher the score of a personality trait of the respondents, the more significant the personality trait of the respondents is. Several studies have shown that the BFI-10 has good reliability and validity (15–17).

2.1.2.2. The Short-Form of the Family Health Scale (FHS-SF)

The family health level of the respondents was measured by the Short-Form of the Family Health Scale (FHS-SF) (18). The scale was developed by Crandall and Weiss-Laxer et al., and the simplified Chinese version has been validated in the Chinese population by Wang et al. (19). The FHS-SF is derived from the Family Health Scale-Long Form (FHS-LF), and it includes 4 dimensions, which are family social and emotional health process, family healthy lifestyle, family health resources, and family external social support, with a total of 10 items. Each item is scored on a 5-point Likert-type scale, among which items 6, 9 and 10 were scored in reverse. The higher the respondents' score on this scale, the higher the family health of the respondents. In the study, the Cronbach's coefficient of the scale was 0.851.

2.1.2.3. The Patient Health Questionnaire-9 (PHQ-9)

The Patient Health Questionnaire-9 (PHQ-9) was used to measure the depression level of the respondents (20). There are 9 items on the scale, and each item is scored on a 4-point Likert-type scale ranging from 0 (never) to 3 (nearly every day). A total score between 0 and 4 indicates no depression; a total score between 5 and 9 indicates possible mild depression; a total score between 10 and 14 indicates likely moderate depression; a score between 15 and 19 indicates that there may be moderate to severe depression; a total score between 20 and 27 indicates that there may be severe depression. The higher the respondents' score on this scale, the higher the level of depression the respondents may have. In the study, the Cronbach's coefficient of the scale was 0.940.

2.2. Research process

Figure 1 shows the entire process of this study.

2.2.1. Scale translation

2.2.1.1. Translation and back-translation of the scale

Figure 2 shows the process of the scale translation stage.

Translation stage. Expert consultation was used to qualitatively evaluate the content validity of the Chinese version of the scale (21).

Authorization for translation and use was obtained from the developers of the EBS short form, and the scale was translated independently by two masters (1 master in public health and 1 master in English-Chinese translation). Afterward, they compared and discussed the similarities and differences between the 2 translations to form the first draft (called: T1) of the Chinese version of the scale.

Back translation stage. The other 2 masters in English-Chinese translation were invited to back-translate the first draft T1 of the Chinese version of the scale separately without knowing the original English version of the EBS short form. The inconsistencies between the 2 back-translation manuscripts were revised, and a back-translation manuscript was finally formed.

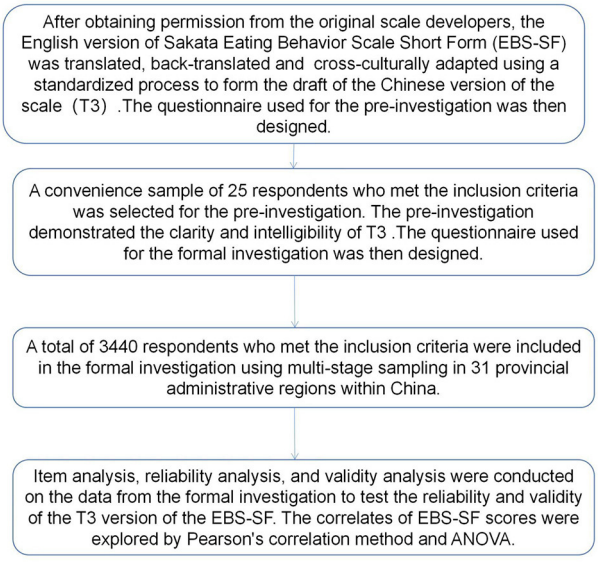

FIGURE 1
Research process of the study.

Audit stage. A master in medicine compared and analyzed the original scale and the back-translated scale, and adjusted and revised the differences between the two scales to form the second draft (called: T2) of the Chinese version of the EBS short form.

2.2.1.2. Cultural adjustment of the scale

The cultural adjustment group was composed of 16 experts (two in each field) from eight fields of psychology, sociology, social medicine, humanistic medicine, nursing, health education, health service management and behavioral epidemiology. All the members of the group are familiar with the process and methods of scale localization. According to the Guidelines for the process of cross-cultural adaptation of self-report measures (22), experts made judgments on the cultural adaptability of each item in the second draft T2 of the Chinese Version of the EBS short form, and made certain modifications based on Chinese expression habits without changing the original meaning. According to the suggestions of experts, the third draft (called: T3) of the Chinese Version of the EBS short form used in the pre-investigation stage was formed.

2.2.2. Pre-investigation

The purpose of the pre-investigation was to finalize the wording of the Chinese version of the questionnaire. In May 2021, a convenient sampling of 25 respondents who met the inclusion criteria was used for a pre-investigation using the general data questionnaire and the third draft T3 of the Chinese version of the EBS short form. For the pre-investigation, we collected only general characteristics of the respondents and tested the respondents with the Chinese version of EBS-SF. Respondents were asked about the clarity and intelligibility of each item after completion and they all indicated that the items were easy to understand. Therefore, the third draft T3 of the Chinese Version of the EBS short form was used for the formal investigation.

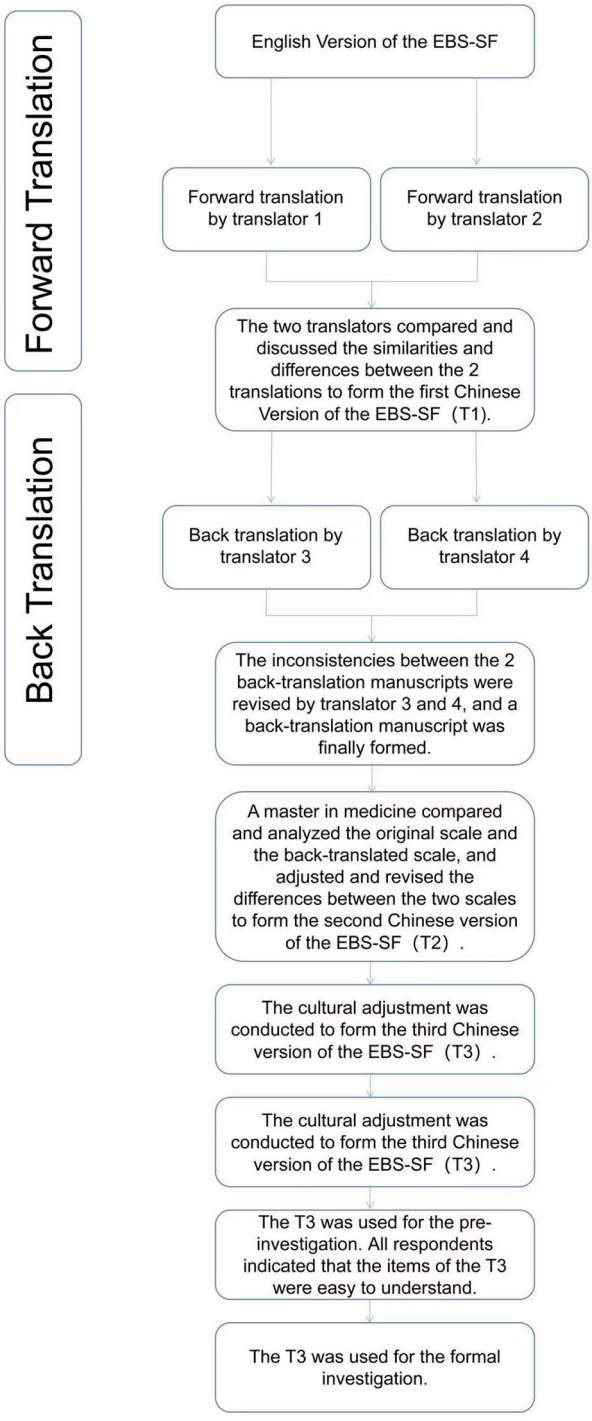

FIGURE 2
The process of the EBS-SF scale translation stage.

2.2.3. Formal investigation

2.2.3.1. Participants of the formal investigation

2.2.3.1.1. Inclusion/exclusion criteria

The questionnaire selected for this research was selected from the questionnaires in "2021 China Family Health Index Investigation" which met the requirements of this research.

The inclusion criteria of the participants were as follows: (1) Based on the original scale population the age ranged from 20 to 59 (13); (2) Had the nationality of the People's Republic of China; (3) China's permanent resident population with an annual abroad time $\leq$ 1 month; (4) Participate in the study voluntarily and fill in the informed consent form; (5) Participants can complete the questionnaire by themselves or with the help of investigators; (6) Participants can understand the meaning of each item in the questionnaire;

The exclusion criteria were as follows: (1) Persons with unconsciousness, eating disorders, or mental disorders; (2) Those who are participating in other similar research projects.

2.2.3.1.2. Investigation method

The surveyors were recruited from online, and the surveyors conducted face-to-face interviews with the respondents and completed the online questionnaire on the spot for submission.

2.2.3.1.3. The characteristics of the respondents

The characteristics of the participants that researchers collected comprised gender, age, marital status, educational level, Per capita monthly household income, current residence (urban / rural), region, occupational status, smoking status, drinking status.

2.2.4. Quality control

The study conducted two rounds of pre-investigation before the formal investigation. Trained investigators distributed questionnaires to respondents and registered their codes one-on-one and face-to-face. Every Sunday evening during the investigation process, members of the research group communicated with the investigators to summarize, evaluate and give feedback on the questionnaires they collected. After the questionnaires were collected, two people conducted back-to-back logic checks and data screening. If singular values were found during data analysis, the original questionnaire must be found and checked with the investigator before proceeding to the next step of the analysis.

2.3. Statistical analysis

Data analysis was performed using SPSS 22.0 and AMOS 21.0. Statistical description of the sociological characteristics of the respondents was carried out using percentage, mean, etc. The correlation coefficient method, CITC method and extreme group method were used for item analysis The correlation coefficient method required those correlations of items with coefficients $r <$ 0.35 or $P > 0.50$ associated with the total scale score be dropped; the extreme group method required that items with t-values obtained using independent sample t-tests in the high (highest 27%) and low (lowest 27%) subgroups be dropped if the differences were not significant (23). In addition, the CITC method requires that if the Cronbach's α of an item increases significantly after deletion, the item will be less internally relevant and should be deleted. Cronbach's α of internal consistency, split-half coefficient and test-retest reliability (intraclass correlation coefficient, ICC) were used for reliability analysis (24), and values $\geq$ 0.70 were considered to be good reliability.

In addition, confirmatory factor analysis was performed using AMOS 21.0 to test the structural validity of the scale. χ^2 / DF $<$ 3, GFI $>$ 0.9, NFI $>$ 0.9, RFI $>$ 0.9 and RMSEA $<$ 0.08 were used as the criteria for good structural validity of the model (25–27). The mean and standard deviation were used to describe the central tendency and dispersion degree of continuous variables. What's more, t-test or ANOVA was used for comparison between groups. After ANOVA, Bonferroni method was used for multiple comparisons. The pearson correlation method was used to analyze the correlation between the scores of other scales and the EBS short form. All data were tested with a two-sided test, and $P < 0.05$ was considered statistically significant unless otherwise stated.

3. Results

3.1. Characteristics of the participants and the score of the EBS short form

The 2021 "China Family Health Index Investigation" started from July 10, 2021 to September 9, 2021. A total of 11,688 questionnaires were distributed, 11,031 valid questionnaires were recovered, and a total of 3,440 cases were sampled based on the data from the 2021 "China Family Health Index Investigation". Among 3,440 participants, 1,748 (50.81%) were male and 1,692 (49.19%) were female; 1,373 (39.91%) were people aged 36–50 years and the marital status of married people was the largest, with 2,278 (66.22%). There were 1,662 cases (48.31%) with a bachelor's degree or above and 1,667 cases (48.46%) with household per capita monthly income below 4,500 yuan. Nearly three-quarters of them live in urban areas, with 2,551 cases (74.16%). More than half of the cases were from the eastern part of the Chinese mainland, with 1,729 cases (50.26%) (Table 1).

The Chinese and English versions of EBS-SF is shown in Supplementary Table 1. The t-test or ANOVA was used to test for differences in the EBS short form scores at each level of sociological variables. The results showed that there were significant differences in the scores of the EBS short form in participants of different ages, marital status, regions, occupational status, smoking status and drinking frequency ($P < 0.05$) (Table 1). The Bonferroni method was further used for the post hoc test of the results of ANOVA (see Supplementary Tables 2–7 for details). The scores of the older age group on this scale are significantly lower than that of the younger age group and the unmarried group were significantly higher than those of the married group; the scores of the western regions were significantly lower than those of the eastern and central regions and student's scores above other occupational status. As for smoking status and drinking frequency, never smoking scored lower than the smokers, and never drinking scored lower than drinking.

The mean score of the total score of the EBS short form was 16.52 $\pm$ 4.604 (Mean $\pm$ SD). See Table 2 for the score of each item in the EBS short form. The item with the highest mean score was "Item 3: eating fast" (2.52 $\pm$ 0.869), while the item with the lowest mean score was "item 7: when I buy food, I am satisfied when I buy more than I need" (2.21 $\pm$ 0.878). In each item, the choice with the largest number of people was "somewhat disagree" (items 2, 6, 7) or "somewhat agree" (items 1, 3, 4, 5), while the choice with the smallest number of people was "strongly agree".

TABLE 1 Sociological characteristics of the participants, the score of the EBS short form and Cronbach's coefficients for each subgroup.

Item		*N* (%)	Cronbach's αcoefficient	The EBS-SF scores		
				Mean ± SD	*t*/*F*	*P*
Gender						
	Male	1,748 (50.81)	0.879	16.57 ± 4.618	0.749	0.454
	Female	1,692 (49.19)	0.862	16.46 ± 4.591		
Age						
	20–25	679 (19.74)	0.868	17.47 ± 4.649	30.227	<0.001
	26–35	802 (23.31)	0.865	17.14 ± 4.524		
	36–50	1,373 (39.91)	0.866	16.17 ± 4.523		
	51–59	586 (17.03)	0.870	15.36 ± 4.514		
Marital status						
	Unmarried	1,052 (30.58)	0.869	17.48 ± 4.609	36.073	<0.001
	Married	2,278 (66.22)	0.868	16.05 ± 4.534		
	Else (divorced or widowed)	110 (3.20)	0.845	16.98 ± 4.557		
Educational level						
	Junior school and below	649 (18.87)	0.866	16.46 ± 4.475	0.201	0.896
	Senior school and middle vocational school	596 (17.33)	0.859	16.42 ± 4.394		
	Junior college	533 (15.49)	0.884	16.54 ± 4.727		
	Bachelor and above	1,662 (48.31)	0.871	16.57 ± 4.690		
Per capita monthly household income, yuan						
	≤4,500 (663 dollars)	1,667 (48.46)	0.861	16.66 ± 4.402	2.197	0.111
	4,501–9,000 (663-1326 dollars)	1,216 (35.35)	0.873	16.30 ± 4.673		
	>9,000 (1,326 dollars)	557 (16.19)	0.885	16.55 ± 5.017		
Place of residence						
	Urban	2,551 (74.16)	0.868	16.51 ± 4.619	−0.176	0.860
	Rural	889 (25.84)	0.877	16.54 ± 4.565		
Region						
	Eastern	1,729 (50.26)	0.875	16.65 ± 4.702	6.173	0.002
	Central	979 (28.46)	0.866	16.68 ± 4.529		
	Western	732 (21.28)	0.861	15.99 ± 4.434		
Occupational status						
	Unoccupied	724 (21.05)	0.842	16.69 ± 4.249	16.895	<0.001
	Employed	1,875 (54.51)	0.873	16.20 ± 4.614		
	Student	701 (20.38)	0.869	17.44 ± 4.648		
	Retired	140 (4.07)	0.910	15.19 ± 5.213		
Smoking status						
	Never smoking	2,651 (77.06)	0.872	16.39 ± 4.630	4.253	0.014
	Smoker	538 (15.64)	0.864	16.95 ± 4.529		
	Ex-smoker	251 (7.30)	0.864	16.90 ± 4.430		
Drinking frequency						
	Never drinking	1,846 (53.66)	0.882	16.12 ± 4.710	15.273	<0.001
	Drinking, but not every week	974 (28.31)	0.842	16.88 ± 4.397		
	Drinking weekly	620 (18.02)	0.866	17.12 ± 4.496		

TABLE 2 Scores of each item in the EBS short form.

Item	Scores (mea ± SD)	Median (lower quartile, upper quartile)	A *N* (%)	B *N* (%)	C *N* (%)	D *N* (%)
1. Eat at all different times	2.31 ± 0.886	2 (2,3)	744 (21.63%)	1,121 (32.59%)	1,336 (38.84%)	239 (6.95%)
2. Do not feel satisfied unless I eat until full	2.25 ± 0.865	2 (2,3)	714 (20.76%)	139 (40.41%)	108 (31.66%)	247 (7.18%)
3. Eat fast	2.52 ± 0.869	3 (2,3)	497 (14.45%)	103 (30.17%)	153 (44.53%)	37 (10.84%)
4. Tend to gain weight more easily than others	2.51 ± 0.934	3 (2,3)	579 (16.83%)	102 (29.85%)	134 (39.04%)	49 (14.27%)
5. Like oily foods	2.36 ± 0.874	2 (2,3)	649 (18.87%)	1,191 (34.62%)	132 (38.63%)	271 (7.88%)
6.Eat if others around me are eating	2.36 ± 0.833	2 (2,3)	542 (15.76%)	135 (39.45%)	128 (37.44%)	253 (7.35%)
7.When buying food, I am not content unless I buy more than necessary	2.21 ± 0.878	2 (2,3)	805 (23.40%)	1,356 (39.42%)	1,040 (30.23%)	239 (6.95%)
Total score	16.52 ± 4.604	17 (14,20)				

A, strongly disagree; B, somewhat disagree; C, somewhat agree; D-strongly agree.

TABLE 3 Corrected item -total correlation of the simplified Chinese version of the EBS short form.

Item	Cronbach's α after item deletion
1. Eat at all different times	0.861
2. Do not feel satisfied unless I eat until full	0.844
3. Eat fast	0.858
4.Tend to gain weight more easily than others	0.861
5. Like oily foods	0.843
6. Eat if others around me are eating	0.846
7. When buying food, I am not content unless I buy more than necessary	0.845

3.2. Item analysis and reliability and validity test of the EBS short form

3.2.1. Item analysis

3.2.1.1. Correlation coefficient method

The correlation analysis between each item and the total score of the questionnaire showed that each item score of the Chinese version of the EBS short form was significantly correlated with the total score of the scale, with correlation coefficients ranging from 0.694 to 0.794 ($P < 0.001$), above 0.35.

3.2.1.2. CITC method

The Corrected item-total correlation (CITC) of the Chinese version of the EBS short form was all above 0.571, and the combination of the deleted Cronbach's α coefficient showed that the internal consistency coefficients did not change much after the deletion of the items (Table 3).

3.2.1.3. Extreme group method

The participants were ranked according to the total score of the scale, with 27% of the participants at both ends of the scale falling into the two extreme groups. The CR values of the high score group ($\geq$ 19 points) and the low score group ($\leq$ 14 points) were all above 3.0 ($P < 0.001$).

3.2.2. Validity analysis

3.2.2.1. Content validity

The content validity of the EBS short form was qualitatively evaluated by the expert consultation method. Experts made a qualitative evaluation of the relevance of each item of the Chinese version of the EBS short form to its measured content. 16 experts (two experts in each field of psychology, sociology, social medicine, humanistic medicine, nursing, health education, health service management, and behavioral epidemiology, all with master's or doctoral degrees). All experts agreed that each item in the scale could reflect the content to be measured, indicating that the Chinese version of the EBS short form had good content validity.

3.2.2.2. Structural validity

The EBS short form consisted of only one dimension, so only validation factor analysis was used to test the structural validity of the scale, and the scale was validated according to the single factor structural model of the original scale, and the model was revised 8 times according to the Modified Index (MI). After the modification, the standardized factor loadings of the validation factor analysis were between 0.55 and 0.80, and the residuals were positive and significant.

The model fit indexes were χ^2 / df = 2.081 < 3, GFI = 0.999 > 0.9, NFI = 0.999 > 0.9, RFI = 0.996 > 0.9, and RMSEA = 0.018 < 0.08, which is known from the fit indexes that the model structural validity is good and met the requirements. The results of the validation factor analysis are shown in Figure 3.

3.2.2.3. Reliability analysis

The Cronbach's α coefficient of the Chinese version of the EBS short form was 0.870, and the split-half reliability was 0.830, which were all above 0.8. A total of 34 participants were selected by convenience sampling and retested at an interval of 2 weeks. We conducted a convenience sampling and retest reliability test based

on respondents' willingness. The test-retest correlation coefficient (ICC) of the scale was 0.868, which was above 0.7.

3.3. The scores of the BFI-10, FHS-SF, and PHQ-9 and their correlation with the scores of the EBS short form

The specific scores of each dimension of BFI-10, FHS-SF and PHQ-9 scale of the participants are shown in Table 4. In BFI-10, the two dimensions with higher scores were agreeableness (7.02 ± 1.532) and conscientiousness (6.92 ± 1.621), and the two dimensions with lower scores were extraversion (6.27 ± 1.591) and neuroticism (5.77 ± 1.478). The overall family health status was good (37.99 ± 6.670). According to the assessment of the depression level of the participants according to their PHQ-9 scores, it was found that of the 3,440 participants, 1,572 had no depression (PHQ-9 score of 0 to 4), 1,171 had possible mild depression (PHQ-9 score of 5 to 9) There were 360 likely to have moderate depression (PHQ-9 score of 10–14), 250 likely to have moderate depression (PHQ-9 score of 15–19), and 87 likely to have severe depression (PHQ-9 score of 20–27).

The scores of the EBS short form were significantly positively correlated with the scores of "neuroticism" ($r = 0.139$, $P < 0.001$) and the PHQ-9 ($r = 0.396$, $P < 0.001$). The scores of "agreeableness" ($r = -0.220$, $P < 0.001$), "conscientiousness" ($r = -0.264$, $P < 0.001$) and the FHS-SF($r = -0.328$, $P < 0.001$) were significantly negatively correlated with the scores of the EBS short form, as shown in Table 4.

4. Discussion

4.1. The Chinese version of the simplified EBS short form has good reliability and validity

In the field of eating behavior research, this study obtained preliminary results in the context of providing a national sample of the Chinese population, and the psychometric characteristics and factor structure of the simplified Chinese version of the EBS short form. The equivalence between the Chinese version of the scale and the original scale was fully ensured through a rigorous scale introduction process, including translation, back translation, expert consultation, and prediction. The good results of item analysis and the good correlation among the items and the total score of the scale illustrate the good reliability of the Chinese version of the EBS short form, the good representation of the items of this scale and the ability to measure eating behavior effectively. After validation factor analysis, sufficient structural validity represented that the original single factor structural model agreed well with the Chinese version of the EBS short form data. The factor loadings of all items in each dimension of the English version of the EBS short form were above 0.6, and the standardized factor loadings of the Chinese version of the factor model were between 0.55 and 0.80, which are more consistent with the original scale. It is generally considered

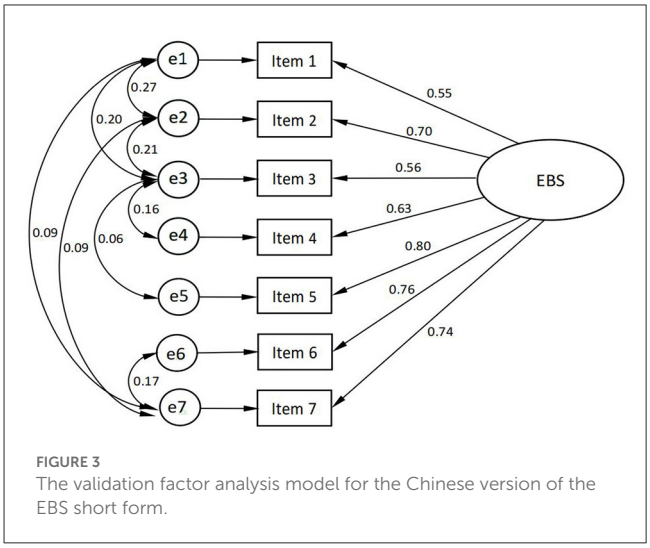

FIGURE 3
The validation factor analysis model for the Chinese version of the EBS short form.

that the Cronbach's α of the total scale is above 0.80, and the test-retest reliability is above 0.7, which means that the reliability of the scale is good. Cronbach's α coefficient and test-retest reliability of the total scale met the measurement requirements, indicating that the Chinese version of the EBS short form has good internal consistency, high reliability, and temporal stability. EBS short form in English with Cronbach's α was 0.830, and Cronbach's α for this study was 0.870, which is close to that of the previous study (13).

4.2. Factors associated with the Chinese version of the EBS short form scores

The EBS short form looks at the differences in eating habits between obese and healthy individuals, with higher scores reflecting worse eating habits. Four aspects were analyzed: personal characteristics, interpersonal networks, personal behavior and social factors.

4.2.1. Personal characteristics

4.2.1.1. Personality traits

The Big Five Personality Inventory, a powerful model for measuring human personality traits, helps us to analyze differences in eating behavior in the population. Our study exploratively found that conscientiousness in the Big Five personality traits may have a significant negative impact on eating behavior, which is similar to the findings of Keller et al. (28). Conscientiousness can lead to more consumption of recommended foods and less consumption of non-recommended foods. In addition, agreeableness is negatively associated with poor eating behavior and relevant to, low emotional under-eating and low emotional overeating (29, 30). What's more, the present study showed a positive association between neuroticism and poor eating behavior, similar to previous studies (31). It could be that neuroticism is associated with emotional eating (32). Emotional instability, impulsiveness and poor self-control are not conducive to good eating habits.

TABLE 4 The scores of the BFI-10, FHS-SF, and PHQ-9 Scale of the participants and their correlation with the scores of the EBS short form.

Scale	Number of entries	Score ranges	Mean ± SD	The scores of the EBS short form
BFI-10				
Extraversion	2	2–10	6.27 ± 1.591	−0.015
Agreeableness	2	2–10	7.02 ± 1.532	−0.220**
Conscientiousness	2	2–10	6.92 ± 1.621	−0.264**
Neuroticism	2	2–10	5.77 ± 1.478	0.139**
Openness	2	2–10	6.42 ± 1.504	−0.031
FHS-SF	10	10–50	37.99 ± 6.670	−0.328**
PHQ-9	9	0–27	6.21 ± 5.700	0.396**

**Represents $P < 0.01$.

4.2.1.2. Age

In this study, age was viewed as a categorical variable, the significantly higher scores on eating behavior among those under 35 years of age in this study compared to those over 35 years of age may be related to the fact that emotional eating is more prevalent in younger age groups (33). Younger populations have a stronger tendency to be more impulsive to attractive food stimuli, have lower self-regulation and seek higher pleasure, thus increasing the likelihood of undesirable eating behavior (30, 34).

4.2.2. Interpersonal networks

4.2.2.1. Marital status

The results showed that married residents scored lower on the EBS short form than unmarried, which is consistent with a previous study (35). This may be because people are encouraged and supervised by their spouses after entering marriage, which promotes healthy eating behavior (36).

4.2.2.2. Family Health

This study showed a significant negative correlation between the EBS short form scores and FHS-SF scores, which is consistent with previous studies (35). A good family health function not only provides sufficient family health resources to help families better meet their daily needs and perform their functions but also promotes emotional communication between family members, therefore, it is helpful to develop good eating habits (18, 37).

4.2.3. Personal behavior

4.2.3.1. Lifestyle

Lifestyles such as smoking and drinking were associated with high EBS short-form scores. This may be related to the fact that alcohol consumption stimulates appetite and even leads to binge eating (38, 39). Quitting smoking may lead to uncontrolled eating as a result of quitting and thus enhancing the stimulatory response to food. Nicotine, on the other hand, has a suppressive effect on one's appetite, which could explain the relationship between smoking and disordered eating habits, for example, adolescents may smoke in the hope of losing weight (40).

4.2.3.2. Emotional processing

We also explored whether depression was associated with eating behavior, with PHQ-9 scale scores showing a significant positive correlation with eating behavior scores. It may be because depression affects a person's motivation to make food choices, thus reducing the likelihood of choosing healthy meals (41). Although this result is consistent with the findings of a larger number of studies on eating behavior, more research is needed to confirm whether depression is associated with eating behavior in the broad sense (42–44).

4.2.4. Socio-demographic characteristics

4.2.4.1. Occupational status

Poor eating behavior was more pronounced in the student group in this study compared to other occupational states. This is similar to the conclusion of Stok (45) that eating behavior usually becomes unhealthy during the transition from adolescence to young adulthood. When students start college, they are faced with new pressures and a lack of time for activity and financial ability, which can have a strong impact on their eating habits and willingness to engage in healthy behaviors (46).

4.2.4.2. Region of residence

Those in the central and eastern regions of the country performed less well in terms of eating behavior than those in the western regions, and some studies have found that residents living in developed regions are more likely to have eating behavior disorders, which is consistent with the results of this study (47). The pace of life in economically developed areas is fast, and there are more diets available for people to choose. In addition, food-related takeaway and express delivery services are more convenient, and poorer eating behavior may be related to these factors.

4.3. Limitations

In this study, we did not set a scalar scale, so we could not give the scalar validity of this scale and other validated scales, which is one of the limitations of this study. The simplified scale has only seven items, and the answer format with fewer items allows

us to complete the test on a larger population. Due to practical difficulties in secondary data collection, the retest reliability of this study was based on a convenience sampling method without using the original study sample, which may be a source of bias.

5. Conclusion

In conclusion, this study demonstrates that the simplified Chinese version of the EBS short form has good psychometric properties and is a valid and reliable tool for assessing eating behavior in Chinese adults. This tool is easy to use in population-based studies because of its self-reported nature and brevity. This study also explored the relationship between personal characteristics such as personality traits or depression status and eating behavior. Although there are some limitations, this study preliminary validated the reliability and validity of the simplified Chinese version of the EBS short form in a national Chinese sample. Future research should focus on the mechanism by which various related factors affect eating behavior, and should also focus on the relationship between the EBS short form score and obesity-related indicators such as BMI, also with the differences in eating behavior between obese and normal people.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Committee of Jinan University, Guangzhou, China (JNUKY-2021-018). The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

LY and YW: directed and supervised the project. PG, XW, LY, and YW: designed research and had primary responsibility for the final content. PG, XW, and JL: drafted the first manuscript. PG, SG, XiaS, FW, and YW: scale translation. PG, SG, WY, YS, and YW: collected the data. PG, WY, YS, and YW: performed the statistical analysis. PG and XW: interpreted the results and wrote the manuscript. PG, XW, XiaS, FW, YN, MY, JZ, SF, QL, XinS, LY, and YW: provided critical revision for important intellectual content of the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1076209/full#supplementary-material

References

1. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet (London, England).* (2020) 396:1223–49.

2. Calvo D, Galioto R, Gunstad J, Spitznagel MB. Uncontrolled eating is associated with reduced executive functioning. *Clin Obes.* (2014) 4:172–9. doi: 10.1111/cob.12058

3. Leggio M, Lombardi M, Caldarone E, Severi P, D'Emidio S, Armeni M, et al. The relationship between obesity and hypertension: An updated comprehensive overview on Vicious Twins. *Hypertens Res.* (2017) 40:947–63. doi: 10.1038/hr.2017.75

4. Aras M, Tchang BG, Pape J. Obesity diabetes. *Nurs Clin North Am.* (2021) 56:527–41. doi: 10.1016/j.cnur.2021.07.008

5. Sisson SB, Campbell JE, May KB, Brittain DR, Monroe LA, Guss SH, et al. Assessment of food, nutrition, and physical activity practices in Oklahoma child-care centers. *J Acad Nutr Diet.* (2012) 112:1230–40. doi: 10.1016/j.jand.2012.05.009

6. WHO. *Obesity Assessment Instruments, American Psychological Association.* American Psychological Association. (2018). Available online at: https://www.apa.org/obesity-guideline/assessment (accessed January 31, 2023).

7. O'Neill BV, Bullmore ET, Miller S, McHugh S, Simons D, Dodds CM, et al. The relationship between Fat Mass, eating behaviour and obesity-related psychological traits in overweight and obese individuals. *Appetite*. (2012) 59:656–61. doi: 10.1016/j.appet.2012.07.017

8. Guzek D, Skolmowska D, Głąbska D. Appetitive traits in a population-based study of polish adolescents within the place-19 study: Validation of the adult eating behavior questionnaire. *Nutrients*. (2020) 12:3889. doi: 10.3390/nu12123889

9. Alruwaitaa MA, Alshathri A, Alajllan L, Alshahrani N, Alotaibi W, Elbarazi I, et al. The Arabic version of the Adult Eating Behavior Questionnaire among Saudi population: translation and validation. *Nutrients*. (2022) 14:4705. doi: 10.3390/nu14214705

10. He J, Sun S, Zickgraf HF, Ellis JM, Fan X. Assessing appetitive traits among Chinese young adults using the adult eating behavior questionnaire: factor structure, gender invariance and latent mean differences, and associations with BMI. *Assessment*. (2019) 28:877–89. doi: 10.1177/1073191119864642

11. Warkentin S, Costa A, Oliveira A. Validity of the adult eating behavior questionnaire and its relationship with parent-reported eating behaviors among adolescents in Portugal. *Nutrients*. (2022) 14:1301. doi: 10.3390/nu14061301

12. Sakata T. *Obesity Treatment Manual*. Tokyo: Ishiyaku Publishers, Inc. (1996) p. 32–7.

13. Tayama, J, Ogawa, S, Takeoka, A, Kobayashi, M, Shirabe S. Item response theory-based validation of a short form of the eating behavior scale for Japanese adults. *Medicine*. (2017) 96:42. doi: 10.1097/MD.0000000000008334

14. Wu Y, Sun X, Wang Y, Ge P, Huan X, Zhang H, et al. (2022). *2021 China Family Health Index Investigation, CFNEWS*. Available online at: https://www.cfnews.org.cn/newsinfo/2685237.html (accessed November 18, 2022).

15. Johann D, Steinbrecher M, Thomas K. Channels of participation: political participant types and personality. *PLOS ONE*. (2020) 15:e0240671. doi: 10.1371/journal.pone.0240671

16. Eichenberg C, Schott M, Schroiff A. Problematic smartphone use—comparison of students with and without problematic smartphone use in light of personality. *Front Psychiatry*. (2021) 11. doi: 10.3389/fpsyt.2020.599241

17. Nikčević AV, Marino C, Kolubinski DC, Leach D, Spada MM. Modelling the contribution of the big five personality traits, health anxiety, and COVID-19 psychological distress to generalised anxiety and depressive symptoms during the COVID-19 pandemic. *J Affect Disord*. (2021) 279:578–84. doi: 10.1016/j.jad.2020.10.053

18. Crandall A, Weiss-Laxer NS, Broadbent E, Holmes EK, Magnusson BM, Okano L, et al. The family health scale: reliability and validity of a short- and long-form. *Frontiers in Public Health*. (2020) 8:587125. doi: 10.3389/fpubh.2020.587125

19. Wang F, Wu Y, Sun X, Wang D, Ming W-K, Sun X, et al. (2022). Reliability and validity of the Chinese version of a short form of the Family Health Scale. *BMC Primary Care*. 23:108. doi: 10.1186/s12875-022-01702-1

20. Levis B, Benedetti A, Thombs BD. Accuracy of patient health questionnaire-9 (PHQ-9) for screening to detect major depression: Individual participant data meta-analysis. *BMJ*. (2019) 365:1476. doi: 10.1136/bmj.l1476

21. Sousa VD, Rojjanasrirat W. Translation, adaptation and validation of instruments or scales for use in cross-cultural health care research: a clear and user-friendly guideline. *J Eval Clin Pract*. (2010) 17:268–74. doi: 10.1111/j.1365-2753.2010.01434.x

22. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*. (2000) 25:3186–91. doi: 10.1097/00007632-200012150-00014

23. Ferketich S. Focus on psychometrics aspects of item analysis. *Res Nurs Health*. (1991) 14:165–8. doi: 10.1002/nur.4770140211

24. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability.. *Psychol Bull*. (1979) 86:420–8. doi: 10.1037/0033-2909.86.2.420

25. MacCallum RC, Browne MW, Sugawara HM. Power analysis and determination of sample size for covariance structure modeling. *Psychol Met*. (1996) 1:130–49. doi: 10.1037/1082-989X.1.2.130

26. Sümer N. *Written Association Models: Basic Conventions and Examples Applications]*. Türk Psikoloji Yazilari. Ankara: Turkish Psychological Society. (2000).

27. Alavi M, Visentin D, Thapa D, Hunt G, Watson R, Cleary M. Chi-square for model fit in confirmatory factor analysis. *J Adv Nurs*. (2020) 76:2209–11. doi: 10.1111/jan.14399

28. Keller C, Siegrist M. Does personality influence eating styles and food choices? direct and indirect effects. *Appetite*. (2015) 84:128–38. doi: 10.1016/j.appet.2014.10.003

29. Sun T, Lin S, Kolodinsky J. Hierarchical trait predictors of healthy diet: a comparison between us and Chinese young consumers. *Int J Consum Stud*. (2014) 38:620–7. doi: 10.1111/ijcs.12133

30. Vollrath ME, Torgersen S, Torgersen L. Associations of children's big five personality with eating behaviors. *BMC Research Notes*. (2018) 11:654. doi: 10.1186/s13104-018-3768-9

31. Elfhag K, Morey LC. Personality traits and eating behavior in the obese: Poor self-control in emotional and external eating but personality assets in restrained eating. *Eat Behav*. (2008) 9:285–93. doi: 10.1016/j.eatbeh.2007.10.003

32. Bruch H. Psychological aspects of overeating and obesity. *Psychosomatics*. (1964) 5:269–74. doi: 10.1016/S0033-3182(64)72385-7

33. Shriver LH, Dollar JM, Calkins SD, Keane SP, Shanahan L, Wideman L. Emotional eating in adolescence: effects of emotion regulation, weight status and negative body image. *Nutrients*. (2020) 13:79. doi: 10.3390/nu13010079

34. Aoun C, Nassar L, Soumi S, Osta NE, Papazian T, Khabbaz LR. The cognitive, behavioral, and emotional aspects of eating habits and association with impulsivity, chronotype, anxiety, and depression: a cross-sectional study. *Front Behav Neurosci*. (2019) 13. doi: 10.3389/fnbeh.2019.00204

35. Mei D, Deng Y, Li Q, Lin Z, Jiang H, Zhang J, et al. Current status and influencing factors of eating behavior in residents at the age of 18~60: a cross-sectional study in China. *Nutrients*. (2022) 14:2585. doi: 10.3390/nu14132585

36. Birmingham WC, Cavallini AQ, Sgro J. Spousal influence: a study of women with eating and body image concerns. *J Health Psychol*. (2019) 26:1339–52. doi: 10.1177/1359105319873946

37. Min HW, Wu YB, Sun XY. Relation of eating behavior and family health and personality traits in adolescents. *Zhong Guo Xue Xiao Wei Sheng*. (2022) 43:1023–7. doi: 10.16835/j.cnki.1000-9817.2022.07.016

38. Fong M, Scott S, Albani V, Adamson A, Kaner E. Joining the dots: Individual, sociocultural and environmental links between alcohol consumption, dietary intake and body weight—a narrative review. *Nutrients*. (2021) 13:2927. doi: 10.3390/nu13092927

39. Caton SJ, Nolan LJ, Hetherington MM. Alcohol, appetite and loss of restraint. *Curr Obes Rep*. (2015) 4:99–105. doi: 10.1007/s13679-014-0130-y

40. Berro J, Akel M, Hallit S, Obeid S. Relationships between inappropriate eating habits and problematic alcohol use, cigarette and waterpipe dependence among male adolescents in Lebanon. *BMC Public Health*. (2021) 21:140. doi: 10.1186/s12889-021-10184-2

41. Ramón-Arbués E, Abad'ıa BM, Granada López JM, Ech'aniz Serrano E, Garcia BP, Vela RJ, et al. Eating behavior and relationships with stress, anxiety, depression and insomnia in university students. *Nutr Hosp*. (2019) 36:1339–45. doi: 10.20960/nh.02641

42. Lazarevich I, Irigoyen Camacho ME, Velázquez-Alva MDC, Zepeda Zepeda M. Relationship among obesity, depression, and emotional eating in young adults. *Appetite*. (2016) 107:639–44. doi: 10.1016/j.appet.2016.09.011

43. Song Y-M, Lee K, Sung J. Genetic environmental relationships between eating behavior and symptoms of anxiety and depression. *Eat Weight Disord*. (2017) 24:887–95. doi: 10.1007/s40519-017-0445-2

44. Eck KM, Byrd-Bredbenner C. Disordered eating concerns, behaviors, and severity in young adults clustered by anxiety and depression. *Brain Behav*. (2021) 11:12. doi: 10.1002/brb3.2367

45. Stok F, Renner B, Clarys P, Lien N, Lakereld J, Deliens T, et al. Understanding eating behavior during the transition from adolescence to young adulthood: a literature review and perspective on future research directions. *Nutrients*. (2018) 10:667. doi: 10.3390/nu10060667

46. Sogari G, Velez-Argumedo C, Gómez M, Mora C. College students and eating habits: a study using an ecological model for healthy behavior. *Nutrients*. (2018) 10:1823. doi: 10.3390/nu10121823

47. Hoek HW, van Hoeken D. Review of the prevalence and incidence of eating disorders. *Int J Eating Dis*. (2003) 34:383–96. doi: 10.1002/eat.10222

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Exploring restaurant and customer needs, barriers, interests, and food choices induced by the COVID-19 pandemic in Tarragona Province (Catalonia, Spain): A cross-sectional study

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Background: COVID-19 has harmed restaurants, but customer preferences remain unknown. This study aims to determine the needs, barriers, interests, and food choice changes in restaurants and customers before and during the COVID-19 pandemic in Tarragona Province (Spain).

Methods: An observational cross-sectional study conducted in spring 2021 collected Mediterranean offerings, food safety, and hygiene information about the pandemic through online surveys and focus group interviews with restaurateurs and customers about the changes in their needs and new barriers.

Results: Fifty-one restaurateurs (44 survey, 7 focus group) and 138 customers (132 survey, 6 focus group) were included. In relation to the economic, emotional, and uncertainty restaurateurs' barriers detected, they implemented measures to tackle it: buy less and more often, reduce restaurant staff and reduce the restaurants offer, among others. Some customers reported changes in their restaurant orders, specifically increasing their takeaway orders. The Mediterranean diet offer (AMed criteria) remained without noticeable changes in any of the criteria. After lockdown, compared to before lockdown, restaurateurs increased their takeaway offerings by 34.1% ($p<0.001$) and their use of digital menus by 27.3% ($p<0.001$) because of customer demand. The use of local products in the menus remained high. The cleaning and disinfection tasks increased by 21.1% ($p=0.022$), and the use of hydroalcoholic solutions increased by 13.7% ($p=0.031$).

Conclusion: In restaurants, the first COVID-19 lockdown increased takeaway orders, sanitation, and digital communication. This study provides valuable information for adapting gastronomic offerings during challenging situations.

KEYWORDS

COVID-19, restaurant, customer, needs, barriers, mediterranean-offer

1. Introduction

Recently, a worldwide pandemic caused by the SARS-CoV-2 virus broke out, various social and mobility restrictions have since been implemented (1), and Spain specifically was hit hard by the COVID-19 pandemic (2).

Before the COVID-19 pandemic, there had been a growing trend toward consuming food outside the home (3, 4), which was motivated by socioeconomic changes such as the increased involvement of women in work and a lack of time at home (5). This trend has been reduced due to the significant negative impact of the pandemic on the restaurant sector and the closure of restaurants (1, 6). An analytical *Google Trends* study showed that during the first months of 2020, which included the pandemic lockdown period, people's interest in restaurants dropped substantially worldwide, while interest in food security and takeaway food increased (7) due to the desire to reduce the risk of exposure to the virus, which led to online food purchases (8).

Although the evidence from Spain and Brazil suggests that SARS-CoV-2 is not transmitted through food (9, 10) and that it spreads primarily through small respiratory droplets in enclosed spaces, in the United States, the restaurant sector experienced a significant revenue shortfall caused by a sharp decline in customer demand and temporary interruptions of processes (2).

Moreover, during the first wave of the COVID-19 pandemic, people were in lockdown, and the changes in their restaurant food choice preferences remain unknown. Focusing on nutritional habits, an observational study from Poland suggests that during the pandemic, most of the population did not change their diet (11). However, 20% of people improved their eating habits with healthier eating, while another 20% of respondents worsened their eating habits (11). In addition, during the first COVID-19 pandemic lockdown, due to the increase in online work and the restrictions implemented, home delivery and takeaway orders increased, while the type of dishes requested did not vary relative to before the pandemic (11). Knowledge of the criteria used by customers when selecting a restaurant is critical for understanding food consumption trends (3). Therefore, to improve the ability of restaurant owners to respond adequately to customers, they must understand the behaviors of and factors influencing the decisions of consumers in the restaurant sector (3).

Despite the current negative circumstances arising from the COVID-19 pandemic, these circumstances have provided an opportunity to improve the resilience of the sector, defined as the ability to plan and prepare to adapt and recover from adverse situations (10). Two studies from Brazil and China highlighted that a common way for restaurants to adapt and reduce the impact of the COVID-19 pandemic was to increase their takeaway and food delivery offerings (10, 12). Thus, restaurants continued to offer their services and support at least some of their workers (10, 12).

To our knowledge, the present study is the first to attempt to determine the real impact of the COVID-19 pandemic on restaurants at a regional level.

Our hypothesis is that the needs, barriers, interests, and food choices of restaurants and customers differ before and during the current COVID-19 pandemic.

The main objective of this study was to determine the changes in restaurant and customer needs, barriers, interests, and food choices before and during the current COVID-19 pandemic in Tarragona Province (Spain). The specific objectives of this study were to identify the changes that restaurants and customers underwent before and during the current COVID-19 pandemic, specifically those related to food safety and food hygiene.

2. Materials and methods

2.1. Design and study population

The present study is an observational cross-sectional study that was conducted from April to June 2021 in Tarragona Province, Catalonia (Spain).

The study population was the owners of restaurants located in Tarragona Province and customers. The recruitment of restaurants was carried out by email and telephone calls, while customer recruitment was carried out by social networks. In addition, to ensure a proportionate number of restaurants was selected in each area, the number of inhabitants in the 10 counties of Tarragona Province was taken into consideration (13). Therefore, more restaurants were sampled from counties with more inhabitants (14).

In the restaurant sector, there were some restrictions such as a limit of customers inside the restaurant, a limit of the customers per table, 2 m between tables and limitations on the opening hours, and perimeter lockdown with their important consequences of society mobility. To determine the changes in customer and restaurant needs, barriers, interests, and food choices experienced by restaurateurs suffering under the circumstances of the COVID-19 pandemic, the following approaches were used:

a. An online survey that referred to the period before and during the current COVID-19 pandemic situation was conducted with the two study populations, restaurateurs and customers, to obtain quantitative information on the changes of interest. This type of quantitative approach identifies the total changes made by restaurateurs and customers.
b. Focus groups, formatted as a structured debate between a group of participants who could freely contribute their opinions and directed by a moderator (15) and in which questions were asked that referred to the period before and during the current COVID-19 pandemic situation, were arranged to provide qualitative information. The focus groups included members of the two populations, restaurateurs and customers, to identify their needs, barriers and changes implemented from the COVID-19 pandemic. This type of qualitative approach provides the reason for the changes in the needs of and barriers experienced by restaurateurs and customers.

This cross-sectional study followed the guidelines in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (16) (Supplementary material 1) and the Consolidated Criteria for Reporting Qualitative Research (COREQ; Supplementary material 2) (17). The protocol for this study was approved by the Ethics Committee of the Pere Virgili Institute (ref. 056/2021). All participants provided signed informed consent before their participation.

2.2. Inclusion and exclusion criteria

For the restaurants, the inclusion criteria were as follows: (1) being a restaurant, hotel with a restaurant or camping ground including restaurant; (2) being located within Tarragona Province (Catalonia, Spain); (3) having a menu that includes dishes with local and seasonal foods; and (4) having signed the informed consent before the study. The restaurant exclusion criteria were as follows: (1) being a fast-food or ethnic restaurant; (2) offering only one type of product; and (3) belonging to a food chain. The restaurateurs of the included restaurants answered the survey and participated in the focus group. The restaurateurs were recruited through emails and phone calls.

Regarding restaurant customers, the inclusion criteria were as follows: (1) being over 18 years of age and a customer of restaurants located in Tarragona Province (Catalonia, Spain); (2) signing the informed consent before the study; (3) accepting the data protection conditions; and (4) accepting the privacy policy. The exclusion criterion for customers was failing to meet at least one inclusion criterion. Customer recruitment was performed through social networks.

2.3. Outcomes

The principal outcome was Mediterranean food offerings as assessed by the criteria for obtaining a Mediterranean Diet (AMed) accreditation (18). The AMed accreditation for restaurants that guarantees the offering of a menu based on the Mediterranean diet is led by the General Directorate of Public Health in the Department of Health of the Government of Catalonia.

The AMed accreditation contains a total of 17 criteria, 9 mandatory and 8 optional criteria. In the present study, to assess Mediterranean food offerings, 12 of the 17 AMed criteria were used, all 9 mandatory criteria and 3 of the 8 optional criteria, as shown in Figure 1 (available at www.amed.cat, accessed on 20 February 2021). Twelve of the 17 criteria were evaluated, but for the purpose of achieving the primary outcome, only the nine mandatory criteria were considered: (1) olive oil is used in dressings, and olive oil or high oleic sunflower are used for cooking; (2) 25% of the first course offerings are vegetables and/or legumes; (3) whole-grain products are included; (4) 50% of the second course offerings are based on fish, seafood, or lean meat; (5) 50% of the dessert offerings are based on fresh fruit (whole or prepared); (6) dairy desserts without added sugar are offered; (7) free non-packaged drinking water is offered; (8) wine, beer, and cava are measured in glasses or individual units; and (9) culinary preparations that do not require the addition of large amounts of fat and culinary techniques that use little or no fat are used. The 3 optional criteria analyzed were (1) including proposals of traditional and local cuisine, (2) prioritizing side dishes of vegetables and legumes, and (3) prioritizing fresh seasonal and local foods. The reason to select only 3 to 8 optional criteria was to prioritize the most adequate criterion to show changes in food restaurant offerings. Moreover, the criteria related to offering virgin olive oil in restaurant tables were excluded because the government had limited it for the COVID-19 pandemic situation.

The outcomes related to the AMed criteria before and during the current COVID-19 pandemic were reported at the same time.

The secondary outcomes from before and during the current COVID-19 pandemic included in this study were as follows:

Restaurants:

a. Provision of services and food safety and hygiene (19).
b. Barriers and needs: supplying healthy foods, using local products, addressing food allergies, and maintaining food hygiene and safety.

Customers:

a. Consumption habits, evaluation of the supply of dishes corresponding to the Mediterranean diet in the restaurant, and restaurant selection criteria.
b. Barriers and needs: restaurant visits, restaurant choice, perceptions of healthy food offerings, and management of food allergens.

2.4. Data collection

Data were collected through online surveys and focus groups with both restaurateurs and customers. Two different surveys were designed, one for restaurateurs and one for customers, which were answered during April–May 2021 and included questions related to the situation before and during the COVID-19 pandemic.

2.4.1. Surveys

All surveys (restaurateur and customer) were answered in online format.

The restaurateur survey was not anonymous; however, the data were treated anonymously using a code that was known only to one researcher. This survey was created by the authors and has 3 separate sections:

a. General information about the restaurant: name of the restaurant; type of establishment (restaurant, hotel, or camping ground); property characteristics (location, dimensions, capacity, terrace layout, type of ventilation, number of workers); last year's assessment (billing, reductions in personnel and temporary filing of occupation regulation applications, reductions in orders to suppliers, increases in expenses due to additional measures, financial aid); services offered before and after the COVID-19 pandemic (local product dishes, dishes without food allergens, vegetarian/vegan dishes, payment and order methods, menu formats, type of dishes consumed in the restaurant and as takeaway). This section included 23 questions that allowed us to describe the type of restaurant and its characteristics, while the last questions of this section responded to the changes made by restaurants during and after the COVID-pandemic. Questions were designed by the authors following the rules imposed by the government to determine the main changes made by restaurants;
b. The 12 selected Amed criteria (18) as "yes" or "no" answers, explained above;
c. Hygiene and food safety issues as "yes" or "no" answers. This section referred to the 4 key points of hygiene and food safety of restaurants: cross-contamination, processes, cleaning and

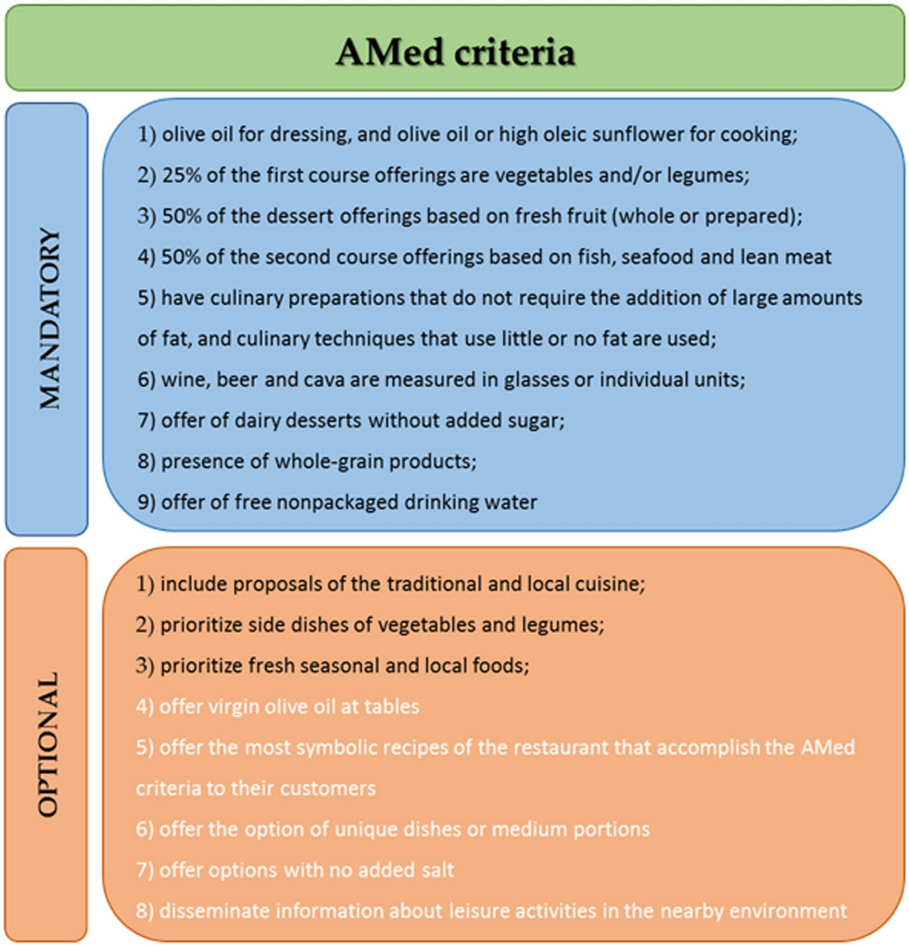

FIGURE 1
AMed criteria. The black quotes were the included in the analysis, and the white quotes were excluded.

disinfection, and management. The questions of this section were based on "Guide to Good Practices for the Hygiene of Restaurants" (19), published by the Government of Catalonia and officially recognized by the competent authorities of Catalonia in matters of food safety. The customer survey was completely anonymous, and there was no question about personal information; therefore, it was not possible to identify the person responding to the survey. This survey had two different sections:

a. Sociodemographic data. This section included 5 questions: sex, age, location, food allergy, or food intolerance, and whether customers had any difficulty finding restaurants with free allergen options.
b. Consumption habits, interests, and food choices questions were designed by the authors by adapting questions from the findings of this publication (11) to our local environment. This section included 20 questions referring to food allergy diagnoses and suitable restaurants; food consumption behaviors: type of restaurants visited frequently; location of restaurants; frequency of restaurant visits or takeaway food orders; reasons for decreases in frequency; knowledge of the AMed accreditation; perceptions of each AMed criteria satisfied by the restaurant menu offerings (Mediterranean offerings) and 2 extra questions about food-allergen and vegetarian/vegan option perceptions by customers; and customer criteria for restaurant selection: advertising, price, variety and type of dishes offered, presentation, service, hygiene in the establishment, environment, and customer evaluations published by other customers.

2.4.2. Focus groups

The focus groups were focused on (1) 6–12 restaurateurs (2 focus group sessions were conducted) and (2) 6–12 customers (1 focus group session was conducted) using the Teams online platform in line with the COVID-19 measures established by the competent local authorities. Each focus group session lasted 90 min. The attendees included one moderator, one study researcher and the restaurateur or customer participants.

The restaurateur and customer focus groups were organized around previously defined questions. Each focus group included the following six sections: (1) presentation of the participants; (2) presentation of the problem; (3) identification of barriers and needs; (4) food offerings (local products)/customer behavior regarding food; (5) food hygiene and safety; and (6) solutions from restaurateurs/solutions for restaurateurs provided by customers.

In addition, the moderator provided some examples to ensure participation and understanding of the questions. Furthermore, two interactive platforms, menti.com and Kahoot, were used to encourage interactions among the participants. At the end of each of the six sections, the moderator summarized the discussion, and the participants were requested to confirm the information. Moreover, the focus group was recorded in audio format, and the researcher assistant took notes on the spot. Then, the focus group recordings were transcribed for analysis, and a report was made available to participants to confirm what they had discussed during the session.

2.5. Sample size

The sample size calculation was based on the main variable: the 9 compulsory AMed criteria for restaurants (18). A standard deviation (SD) of ±1.6 was assumed, drawing upon the preliminary results of a cross-sectional study developed in the same area (20). A two-tailed alpha risk of 0.05, a two-tailed beta risk of 0.2, and a difference equal to or greater than 1 point in the AMed criteria score were considered for calculating the sample size of restaurants. A follow-up loss rate of 20% was estimated, considering the high number of restaurants that have closed due to the COVID-19 pandemic (13, 14). Additionally, the 10 counties were classified into 2 groups: 5 counties with fewer than 50,000 inhabitants and 5 counties with more than 50,000 inhabitants. Thus, 36 restaurants were needed considering the number of inhabitants per 10 counties, proportionally. The sample size was calculated using GRANMO software (21).

The restaurant customer sample size was not calculated because the principal variables, the 9 compulsory AMed criteria, are related to restaurants.

The focus group sample size was estimated based on the available evidence (22). The recommendation is that there should be between 6 and 8 participants in focus groups for noncommercial topics because more than 10 participants make it difficult for the focus group to develop. We over-recruited participants for the focus groups due to the possibility that someone did not attend. For this reason, our range of sample sizes was 6 to 12 participants in each focus group.

2.6. Data analysis

2.6.1. Quantitative data

Categorical variables are reported as percentages, and continuous variables are reported as the mean ± SD. The McNemar test for categorical variables was used to compare the changes between the period before and the period during the pandemic. For comparison between restaurant vs. takeaway options during the same period of the pandemic, the Chi-squared test was used. The significance level was fixed at $p < 0.05$. The statistical program SPSS version 27 was used (IBM Corp. Released 2020. IBM SPSS Statistics, Version 27.0. Armonk, NY: IBM Corp).

2.6.2. Qualitative data

The focus groups were qualitatively analyzed using thematic analysis (23) to identify topics and themes, and the steps stated were followed to avoid researcher bias. The transcriptions of focus groups were reviewed, coded by open coding and then inductive methods, and discussed by two reviewers (MB-M, JQ). For interpretation of the focus group results, three different methods were used (24). First, the raw data, i.e., the exact words the participants said, were categorized according to the frequency with which something was said. Second, the descriptive information, i.e., a summary of the comments, was subsequently prepared by the analyst researcher who took notes during the focus group. Data were interpreted as raw data in summary form. Finally, the third method was the interpretive method, which consisted of the analyst researcher providing an interpretation of the data to help clarify the information obtained from the focus group.

3. Results

A total of 51 restaurateurs and 138 customers participated. Of the 51 restaurateurs, 44 participated in the survey and 7 in the focus group, whereas of the 138 customers, 132 participated in the survey and 6 in the focus group. Three online focus group sessions were conducted, 2 with restaurateurs and 1 with customers.

3.1. Results of the restaurant survey

3.1.1. Characteristics of restaurants as described in the restaurant survey

Of the 44 restaurants represented by the restaurateurs, most were located in the two most inhabited counties of Tarragona Province in Catalonia, Tarragonès (31.8%, $n = 14$) and Baix Camp (25%, $n = 11$). The most frequent establishments were restaurants (88.6%, n = 39), followed by hotels (6.8%, $n = 3$) and camping grounds (4.5%, $n = 2$). Regarding the ventilation used by the restaurants, 65.9% ($n = 29$) used air conditioners, and 15.7% ($n = 7$) did not have ventilation.

Regarding marketing and communication media, most restaurants used social networks (90.9%, $n = 40$) both before and during the COVID-19 pandemic. Posters, leaflets, and brochures for menus were used before and during the pandemic.

As an important consequence of the first wave of the COVID-19 pandemic in restaurants, 31.8% ($n = 14$) of restaurateurs had to throw away food, and 43.2% ($n = 19$) gave food away (data not shown in tables).

Table 1 shows the main changes undergone by restaurants due to the COVID-19 pandemic. Takeaway food orders increased significantly by 34.1% (47.7% ($n = 21$) to 81.8% ($n = 36$); $p < 0.001$). Additionally, the percentage of dishes with local products was maintained at a high level, approximately 90% before and during the current COVID-19 pandemic.

Regarding restaurant menu formats, the use of digital menus increased significantly by 27.3% (6.8% ($n = 3$) to 34.1% ($n = 28$); $p < 0.001$).

Additionally, the use of single-serving condiment packages increased by 61.4% (9.1% ($n = 4$) to 70.5% ($n = 31$); <0.001), and the use of single-use napkins increased by 20.5% (54.5% ($n = 24$) to 75% ($n = 33$); $p = 0.004$), whereas the use of cloth napkins, salthakers, and oil cruets decreased ($p < 0.05$), as shown in Table 1.

TABLE 1 Restaurants' characteristics changes due to COVID-19.

	Variables	Before COVID n=44% (n)	Currently COVID# n=44% (n)	p-value*
Dishes offered	Dishes with local products	93.2 (41)	90.9 (40)	1
	Dishes without food allergens	88.4 (38)	86.0 (37)	1
	Vegetarian/vegan dishes	83.7 (36)	81.4 (35)	1
	Takeaway food	47.7 (21)	81.8 (36)	<0.001
Payment	Payment by credit card	100 (43)	95.3 (41)	_
	Payment with *bizum*	13.6 (6)	29.5 (13)	0.16
Menu format and demand	Menu in digital format	6.8 (3)	34.1 (28)	<0.001
	Use of ICT for the customer to place the order	4.5 (2)	13.6 (6)	0.219
	Use of ICT to write the customer's choice	11.4 (5)	20.5 (9)	0.125
Sales	Sales	31.8 (14)	34.1 (15)	1
Changes in the tables	Cleaning dishes and cutlery at a temperature > 80°C	95.5 (42)	95.5 (42)	1
	Delivery of metal cutlery in sterilized bag	2.3 (1)	11.4 (5)	0.125
	Delivery of single-use cutlery	9.1 (4)	22.7 (10)	0.031
	Delivery of cloth napkins	52.3 (23)	38.6 (17)	0.031
	Delivery of single-use napkins	54.5 (24)	75 (33)	0.004
	Condiments available to customers as salt shakers and oil cruet	79.5 (35)	43.2 (19)	0.002
	Condiments available to customers in a single-dose format	9.1 (4)	70.5 (31)	<0.001

ICT: information and communication technology. #Currently COVID-19 pandemic situation. *McNemar test.

3.1.2. AMed criteria results from the restaurant survey

According to the survey responses regarding the AMed criteria, of the 44 restaurants, only 4.5% (n = 2) had the AMed accreditation, 22.7% (n = 10) did not have the AMed accreditation but knew it, and 72.7% (n = 32) did not know the AMed accreditation (data not shown in tables).

Table 2 shows the results regarding the AMed criteria as reported by the restaurateurs. AMed criteria have not shown changes in any of the criteria studied before and after the COVID-19 pandemic. Focusing on the 9 mandatory AMed criteria, 100% (n = 44) of restaurants provided olive oil for dressing and olive oil or high oleic sunflower for cooking and provided seasonal and local products before the COVID-19 pandemic and continued to do so during the pandemic. In contrast, half or fewer of the restaurants satisfied the three mandatory criteria: (1) Offer dairy desserts without added sugar, (2) Prioritize side dishes of vegetables and legumes, and (3) Offer free non-packaged drinking water, and these results were unchanged during the pandemic, as shown in Table 2.

3.1.3. Hygiene and food safety results from the restaurant survey

As the supplementary table (Supplementary material 3) shows, the number of restaurants that cleaned the goods reception area frequently, specifically, the number of restaurants cleaning that area ≥ 2 times/day, increased by a significant 21.1% (72.1 (n = 31) to 93.2 (n = 41); p = 0.022). In addition, during the COVID-19 pandemic, the use of a hydroalcoholic solution, specifically for disinfecting cooking utensils, increased by a significant 13.7% from its level before the pandemic (6.3 (n = 3) to 20.5 (n = 9); p = 0.031). The other items, which remained unchanged, are described in Supplementary material 3.

3.2. Results of the restaurateur focus group

A total of 7 restaurateurs participated in the focus group session, which lasted 90 min. During the session, after introducing the participants and moderator, 5 topics were discussed.

3.2.1. Problems due to COVID-19 in the restaurant sector

The restaurateurs were not satisfied with the way the authorities handled the COVID-19 situation in the restaurant sector. The restaurateurs believed that the measures imposed on this sector harmed employers, workers, and suppliers more than in other sectors where the measures were less stringent. (a) In addition, the lack of clarity in the messages issued by the administration and the short time that the restaurateurs had to adapt to the new measures, which were constantly changing, was a problem for them. (b) Moreover, some measures were difficult to implement, such as maintaining the required distance between customers (c).

a. "There have been many people affected by the issue. It has been economic chaos for many people, not just for employers, but for workers who have stopped earning, for suppliers who have not been able to serve, and many other things."
b. "The measures have been too strong, but at the same time they have made us dizzy, because it was now yes, now no, now this way, now this other way, and so on. Many have fallen, others have endured as best we could, but it has been almost a year and a half where almost no one has been able to make a profit."
c. "The tables must be separated by 2 m. However, customers at the same table must be 1 m apart. The problem is that anyone has

TABLE 2 Mandatory and optional AMed criteria fulfilled by the included restaurants reported by restaurateurs.

AMed criteria	Before COVID *n*=44% (*n*)	Currently COVID# *n*=44% (*n*)	*p*-value*
AMed mandatory criteria[1]			
1. Olive oil for dressing, and olive oil or high oleic sunflower for cooking	100 (44)	97.7 (43)	---
2. 25% of the first course offerings are vegetables and/or legumes	95.5 (42)	93.2 (41)	1.000
3. 50% of the dessert offerings based on fresh fruit (whole or prepared)	95.5 (42)	93.2 (41)	1.000
4. 50% of the second course offerings based on fish, seafood and lean meat	93.2 (41)	90.9 (40)	1.000
5. Have culinary preparations that do not require the addition of large amounts of fat, and culinary techniques that use little or no fat are used	88.6 (39)	86.4 (38)	1.000
6. Wine, beer and cava are measured in glasses or individual units	86.4 (38)	90.9 (40)	0.500
7. Offer of dairy desserts without added sugar	54.4 (24)	56.8 (25)	1.000
8. Presence of whole-grain products	43.2 (19)	40.9 (18)	1.000
9. Offer of free non-packaged drinking water	25.0 (11)	29.5 (13)	0.500
Number of total AMed compulsory criteria fulfilled per restaurant (mean ± SD)[3]	6.8 ± 1.17	6.7 ± 1.47	
AMed optional criteria[2]			
10. Include proposals of the traditional and local cuisine	100 (44)	97.7 (43)	---
11. Prioritize side dishes of vegetables and legumes	93.2 (41)	93.2 (41)	1.000
12. Prioritize fresh seasonal and local foods	87.7 (43)	95.5 (42)	1.000

SD, Standard Deviation; AMed, Mediterranean Diet offer. 1: 9 compulsory AMed criteria; 2: 3 optional AMed criteria assessed from the 8 described in the Mediterranean Accreditation; 3: 12 total AMed criteria assessed from the total 17 AMed criteria. *McNemar test. #Currently COVID-19 pandemic situation.

accomplished the measures because these are impossible to accomplish."

3.2.2. Barriers of restaurateurs

The main barrier was the restrictions imposed by the authorities, specifically the national and municipal lockdown, and the rapid changes in limitations meant that large amounts of food, especially fresh products, had to be given away.

In addition, other important barriers were (1) economic, as the number of customers significantly decreased and consequently the income of the restaurateurs; (2) emotional barriers, such as anxiety, depression, demotivation, or fear of being infected and having to close their restaurant and of not having an income; and (3) not being able to provide good customer services because the limitations placed on hours and the number of customers prevented them from predicting how many people they could hire or how much food they would need. These barriers are described in Figure 2 with some examples from the focus group transcriptions.

Due to the barriers mentioned above, the restaurateurs needed to increase their income and reduce their costs; for this reason, the restaurateurs implemented certain measures such as buying food daily instead of weekly or reducing the restaurant staff, eliminating daily menus and reducing the number of dishes and products supplied to provide better service (d)(e).

In addition, other measures included web page updates and providing menus in QR format. Other tactics included commercializing their menus in supermarkets, providing takeaway services, or delivering food to nearby towns. (f) However, the restaurateurs commented that it was easier to make fast food for takeaway orders than local dishes.

d. "We cannot have a daily menu with only two people working. It has been necessary to reduce the staff, we have limited the supply, it is a lot of things. We are continuously making special offers to attract the people."
e. "What we have had to do is to buy daily. Before, I used to place orders twice a week and now we make a forecast for the next day, and especially with the fresh products, we buy them daily, precisely so that what has happened to us does not happen again."
f. "We had never offered takeaway food, and having to close, being in such a small town, it has been very good for us. I took the car and went through the Ribera d'Ebre and Terra Alta distributing, and that has helped us a lot, but in the long run, it is not an option that we value."

3.2.3. Food offered (local products)

The main restaurants provided healthy traditional and Mediterranean cuisine. The restaurants used local products, especially fruits, vegetables, and fish, and they did not have any problems obtaining products during the lockdown. (g) Although restaurateurs did not observe any changes in the demand for special dishes, they stated that more people are vegetarian or have food intolerances. All of them found that takeaway food was not a problem for these special cases (h).

g. "We work with seasonal and km 0 products, so nothing has changed for us."
h. "I have not noticed a change; there are more and more people who have special diets. Some diets are voluntary, such as veganism or vegetarianism, or the thousand variants that there are, or forced diets, such as people who have various allergies.

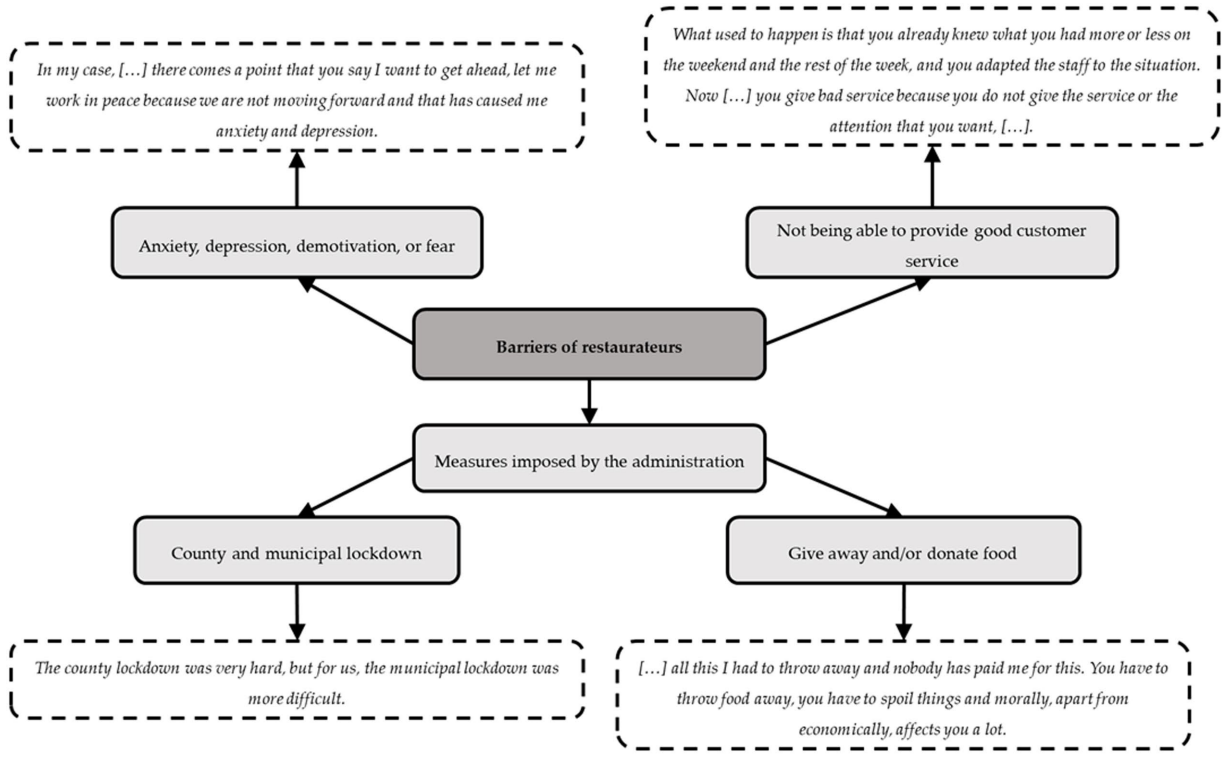

FIGURE 2
Barriers of restaurateurs.

However, we have to offer gluten-free bread, have a supply that considers these people, if not you further reduce the number of people who can come to your establishment."

3.2.4. Food hygiene and safety

Regarding food hygiene and safety, all the restaurateurs agreed that they handled and worked with foods in the same way as before COVID-19. Focusing on food delivery, they did not use isothermal bags to deliver the food, and only two restaurateurs included some instructions about the handling and storage of the delivered food (i).

i. "The temperature chain can be broken. On New Year's Eve, we had more than 100 daily meals, all takeaway and delivery. In addition, everything had to be heated later. However, we always give daily meals with an instruction sheet that explains how each dish should be heated and presented."

3.2.5. Solutions from restaurateurs

The possible solutions ideated by the restaurateurs were to reinvent themselves, generate income from atypical sources, and reduce expenses (j)(k)(l).

j. "Anyway, we have passed through it, we are enduring it, we are tired of enduring it, and the only solution is for it to end, for the restrictions to end and they let us work."
k. "It can help the people, that the COVID [lockdown] ends and that people come because the administration will not help with anything."
l. "It seems to me that we have to learn from each situation and adapt ourselves."

3.3. Results of the customer survey

3.3.1. Characteristics of customers as described in the customer survey

A total of 132 restaurant customers in Tarragona Province answered the survey, which focused on the differences in their choices before and during the current COVID-19 pandemic. Related to demographic characteristics, most were located in three counties of Tarragona Province in Catalonia, 59.1% ($n = 78$) in Baix Camp, 13.6% ($n = 18$) in Montsià, and 12.9% ($n = 17$) in Tarragonès. Of the 132 customers, 34.1% ($n = 45$) were men, and 65.9% ($n = 87$) were women, with a mean age of 41.7 ± 14.6 years.

3.3.2. Characteristics of restaurant choices from the customer survey

Concerning the use of different digital formats to become aware of different options during the pandemic, specifically the use of marketing and communication media, the number of customers who selected restaurants through the use of social media significantly increased by 6% (37.9% ($n = 50$) to 43.9% ($n = 58$); $p = 0.008$), while the tendency to use websites for this purpose increased by 17.4% (41.7% ($n = 55$) to 59.1% ($n = 78$); $p = 0.052$). In addition, the number of customers with a preference for ordering from a digital menu increased by 57.5% since the start of the COVID-19 pandemic (20.5% ($n = 27$) to 78.0% ($n = 103$) $p < 0.001$). Regarding the method of

payment, the number of customers who preferred to pay by credit card rather than by cash increased by 6.8% (84.1% ($n = 111$) to 90.9% ($n = 120$); $p = 0.012$).

Regarding the type of restaurant chosen by customers, after the start of the COVID-19 pandemic, the number of customers who preferred restaurants in rural areas over those in urban areas increased by 15.1% (22% ($n = 29$) to 37.1% ($n = 49$); $p < 0.001$). Moreover, the number of customers with a preference for terraces over indoor restaurant seating increased by 37.8% due to the pandemic (41.7% ($n = 55$) to 79.5% ($n = 105$); $p < 0.001$). In addition, the number of customers who reported eating outside of the home at least once a week decreased by 30.3% (74.2% ($n = 98$) to 43.9% ($n = 58$); $p < 0.001$), while the frequency of ordering food for takeaway out at least once a week increased by 12.9% after the start of the COVID-19 pandemic (6.8% ($n = 9$) to 19.7% ($n = 26$) $p < 0.001$).

3.3.3. Customer preferences for in-restaurant or takeaway dishes from the customer survey

Focusing on customer preferences for in-restaurant or takeaway food, there were no significant changes between the period before and the period during the current COVID-19 pandemic, as Table 3 shows. However, customers preferred to order the following types of food as takeaway orders rather than in-restaurant orders in the current COVID-19 pandemic situation: themed dishes from different countries [restaurant: 41.7% ($n = 55$) vs. takeaway: 59.8% (n = 79); $p < 0.001$), fast food (restaurant: 10.6% (n = 14) vs. takeaway: 28.0% ($n = 37$); $p < 0.001$], and dishes suitable for those with allergies [restaurant: 3.9% ($n = 5$) vs. takeaway: 4.5% ($n = 6$); $p < 0.001$]. Instead, the dishes that customers chose more frequently for consumption in the restaurant than for takeaway included seasonal vegetable-based dishes [restaurant: 30.3% ($n = 40$) vs. takeaway: 6.1% ($n = 8$); $p < 0.001$] and vegetarian dishes [restaurant: 9.8% ($n = 13$) vs. takeaway: 6.8% ($n = 9$); $p < 0.001$].

3.3.4. Perceptions of each AMed criteria satisfied by the restaurant menu offerings (mediterranean offerings)

Table 4 describes the perceptions of each AMed criterion accomplished by the dishes offered. The use of olive oil for cooking and dressing was the most highly valued by 99.2% ($n = 131$) of customers, followed by the use of fresh, local, and seasonal foods, with 98.5% ($n = 130$) of customers valuing positively the accomplishment of this criterion, and the pro-vision of traditional dishes and/or typical local dishes, with 95.5% ($n = 126$) of customers valuing positively the

TABLE 3 Preferences and comparison of dishes in the restaurant or takeaway.

Variables	Dishes chosen more often in the restaurant				Dishes chosen more often to takeaway or delivery				*p*-value restaurant vs. to takeaway currently COVID #$
	Gender	Before COVID *n*=132% (*n*)	Currently COVID# *n*=132% (*n*)	*p*-value*	Gender	Before COVID *n*=132% (*n*)	Currently COVID# *n*=132% (*n*)	*p*-value*	
Traditional dishes	Total	81.8 (108)	80.3 (106)	0.625	Total	26.5 (35)	23.5 (31)	0.219	0.438
	Men	97.8 (44)	97.8 (44)	1	Men	33.3 (15)	31.1 (14)	1	1.000
	Women	73.6 (64)	71.3 (62)	0.625	Women	23.0 (20)	19.5 (17)	0.375	0.768
Dishes based on seasonal vegetables	Total	29.5 (39)	30.3 (40)	1	Total	6.1 (8)	6.1 (8)	1	<0.001
	Men	28.9 (13)	26.7 (12)	1	Men	6.7 (3)	4.4 (2)	1	0.467
	Women	29.9 (26)	32.2 (28)	0.5	Women	5.7 (5)	6.9 (6)	1	<0.001
Country themed food	Total	40.9 (54)	41.7 (55)	1	Total	56.1 (74)	59.8 (79)	0.125	<0.001
	Men	33.3 (15)	33.3 (15)	1	Men	55.6 (25)	55.6 (25)	1	0.027
	Women	44.8 (39)	46.0 (40)	1	Women	56.3 (49)	62.1 (54)	0.125	0.008
Vegetarian dishes	Total	9.8 (13)	9.8 (13)	1	Total	6.8 (9)	6.8 (9)	1	<0.001
	Men	4.4 (2)	4.4 (2)	1	Men	6.7 (3)	4.4 (2)	1	0.001
	Women	12.6 (11)	12.6 (11)	1	Women	6.9 (6)	8.0 (7)	1	<0.001
Dishes suitable for allergy sufferers	Total	5.3 (7)	3.8 (5)	0.5	Total	4.5 (6)	4.5 (6)	1	<0.001
	Men	2.2 (1)	2.2 (1)	1	Men	2.2 (1)	2.2 (1)	1	0.022
	Women	6.9 (6)	4.6 (4)	0.5	Women	5.7 (5)	5.7 (5)	1	<0.001
Fast food	Total	13.6 (18)	10.6 (14)	0.219	Total	30.3 (40)	28.0 (37)	0.508	<0.001
	Men	20.0 (9)	13.3 (6)	0.25	Men	31.1 (14)	26.7 (12)	0.625	0.035
	Women	10.3 (9)	9.2 (8)	1	Women	29.9 (26)	28.7 (25)	1	<0.001
Others	Total	0.8 (1)	1.5 (2)	1	Total	6.1 (8)	5.3 (7)	1	0.104
	Men	2.2 (1)	4.4 (2)	1	Men	8.9 (4)	8.9 (4)	1	0.172
	Women	0.0 (0)	0.0 (0)	-	Women	4.6 (4)	3.4 (3)	1	-

*McNemar test; Chi^2 test. # Currently COVID-19 pandemic situation.

TABLE 4 Perceptions of each AMed criteria satisfied by the restaurant menu offerings (Mediterranean offerings).

Variables	Satisfied perceptions *n*=132% (*n*)
Olive oil for dressing, and olive oil or high oleic sunflower for cooking	99.2 (131)
Prioritize fresh seasonal and local foods	98.5 (130)
Include proposals of the traditional and local cuisine	95.5 (126)
Prioritize side dishes of vegetables and legumes	89.4 (117)
25% of the first course offerings are vegetables and/or legumes	87.9 (116)
50% of the second course offerings based on fish, seafood, and lean meat	87.1 (115)
Offer of free non-packaged drinking water	85.6 (113)
50% of the dessert offerings based on fresh fruit (whole or prepared)	81.8 (108)
Have culinary preparations that do not require the addition of large amounts of Fat, and culinary techniques that use little, or no fat are used	81.8 (108)
Offer of dairy desserts without added sugar	77.3 (99)
Wine, beer, and cava are measured in glasses or individual units	68.2 (90)
*Include dishes without food allergens	67.4 (89)
Presence of whole-grain products	66.7 (88)
*Include dishes Vegetarian/vegan dishes	57.6 (76)

*Two extra questions regarding food-allergens and vegetarian/vegan options were included.

accomplishment of this criterion. On the other hand, although the supply of vegetarian/vegan dishes, dishes without allergens, and whole grains was not highly valued by the restaurant customers, more than 50% positively valued the accomplishment of these criteria.

3.4. Results of the customer focus group

A total of 6 customers participated in the focus group, which lasted 90 min. During the focus group, after introducing the participants and moderators, 5 topics were discussed.

3.4.1. Problems due to COVID-19 in the restaurant sector

The feelings that customers had during the pandemic were the loss of and longing for social relationships and freedom, uncertainty, fear of contracting and spreading the disease, insecurity when going to public places such as supermarkets and restaurants, and anxiety about not knowing when the situation would end. (a) Despite these feelings, they agreed that the restaurant sector was severely affected, especially economically, by the harsh restrictions (b).

a. "I would also say that there has been a lot of social discomfort. On the one hand, you saw many people who were very afraid to go into public places, go to the supermarket, go to any bar, of meeting people for fear of contracting the disease, and on the other hand, you also saw people who were angry with the curfew due to the new schedules, which changed from time to time."
b. "We are a country in which we spend a lot of time on the streets because it is sunny, and we have a lot of daylight hours. Many times, we meet in a bar with friends and all these economic dynamics have perhaps been little contemplated, there was also all the pressure that for the first time we were all threatened by an unknown enemy. Therefore, mistrust has increased and this has led to very drastic measures."

3.4.2. Barriers of customers

The customers stated that they enjoy going to restaurants not only to eat but also for the experience, i.e., meeting other people, not needing to cook, and disconnecting from responsibilities. However, all this was interrupted by the COVID-19 pandemic. In this context, the main barriers that the focus group participants faced as customers were the restrictions and limitations; consequently, they preferred ordering takeaway food and being at home, and they were more selective regarding the restaurants they went to. They prioritized those that they already knew or those in which they had more confidence or that had outside areas. Figure 3 presents a summary of these barriers and some example transcriptions. On the other hand, age was also an important factor because younger peoplve were impatient to return to restaurants as before the pandemic, whereas older people exhibited insecurity and concern about easing the restrictions.

3.4.3. Behaviors related to food in restaurants

In this section, behaviors related to foods, healthy choices, and takeaway preferences were discussed. Regarding food behavior, when the customers went to a restaurant, they preferred more elaborate dishes over those they could cook in their homes, usually with simple techniques. The customers positively valued offerings of healthy dishes from restaurants, which allowed them to make choices in line with their preferences. Moreover, the customers stated that there was an increase in the number of people interested in local products, minimally processed or unprocessed food, and sustainability. (c) Concerning takeaway food, all participants increased their demand for takeaway food during the pandemic. They believe that over the next year, there will continue to be high demand for takeaway food (d).

c. "I believe that now this problematic period is, for restaurateurs, being combined with sustainability, going local, the km 0 movement, all of it. I go to the restaurant and order more elaborate things, but they can be very healthy, and, for example,

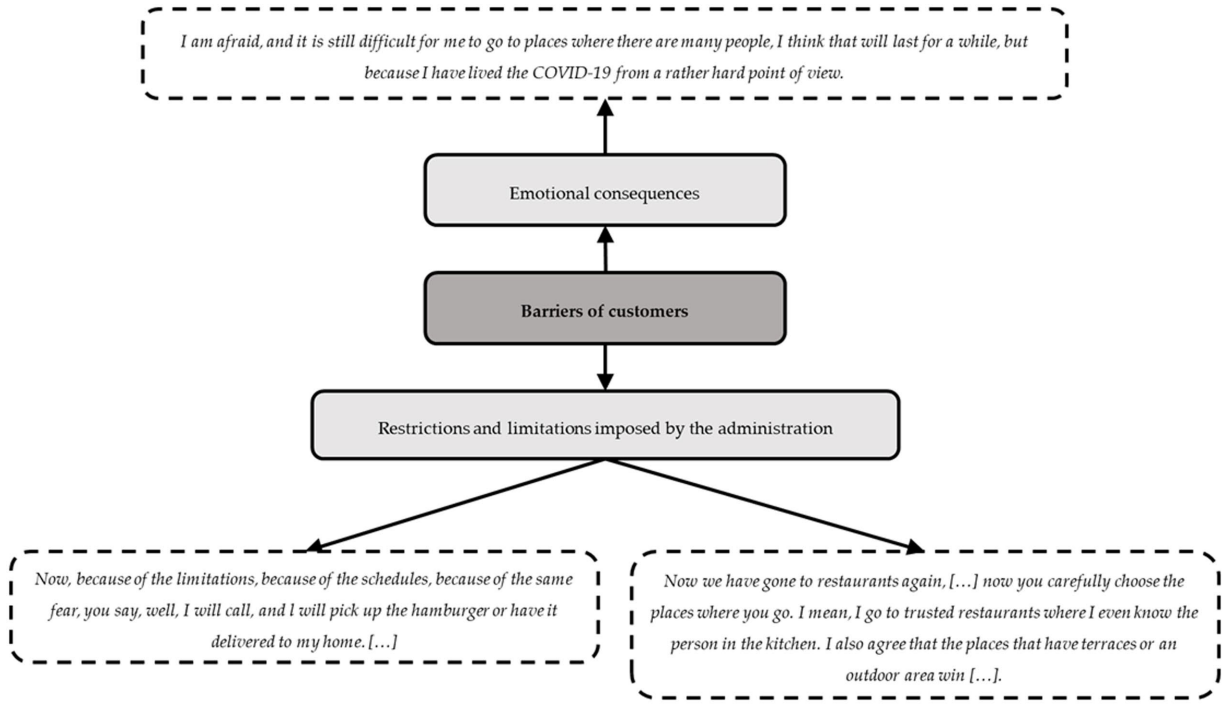

FIGURE 3
Barriers of customers.

I prefer that mushrooms come from here and not from I do not know where."

d. "Before, I would already order takeaway food, but as a result of the pandemic, it has become much more accentuated, and I think we will still have another year of high demand for takeaway food."

3.4.4. Food hygiene and safety

The customers felt comfortable with the measures and precautions that were taken by all staff at the restaurants. They stated that it would be interesting to maintain some of the changes made by restaurants beyond the COVID-19 pandemic, such as the use of a mask during service, as there are other pathogens in circulation, and it would be a way to increase safety. (e) Regarding takeaway food, customers explained that they had never been instructed on how to handle and preserve their food; however, it would be something they would value highly if it were done (f).

e. "Yes, I wanted to say that I do not miss anything; in contrast, I believe that there are hygienic things that have come to stay and that are not bad at all because COVID-19 is not the only disease that exists."

f. "No, in my case they have not given me instructions on how to preserve or cook the food, but it would be a nice touch."

3.4.5. Solutions for restaurateurs provided by customers

The customers explained that some establishments increased their self-service offerings or provided discount vouchers for people who worked nearby. As possible suggestions and solutions, the customers proposed trust and information as key factors needed for them to return to restaurants. They believed that it would be interesting for restaurants to advise and inform customers about the way that they work and about their monitoring of the COVID-19 security measures. (g) They also believed that it was important for restaurants to maintain their essence and take care of the close relationships with customers, waiting times between dishes, the volume of the music, and avoiding placing large groups in the center of the restaurant (h).

g. "I think that the key word is information, to give information to the customers, do it well, advise you to do it well and give information, and show us that they do it well."

h. "And I believe that the personal touch that each restaurateur has in their kitchen should not be lost, I mean, they should maintain this because of course, each place has its touch and people go for something that they have and they like. In addition, they cannot lose it."

3.5. Needs and interests of restaurateurs and customers

In this results section, different needs and interests were identified through the significant results from the surveys and from the frequency of certain ideas in the focus group discussions with the restaurateurs and customers. Figure 4 presents their needs and interests, including those related to self-security and consumption trends such as local food, among others.

4. Discussion

The present cross-sectional study examined the impact of the COVID-19 pandemic on restaurants and their customers through information provided by restaurateurs and customers on a survey and in focus group discussions before and during the current COVID-19 pandemic. This study confirms the hypothesis that the needs, barriers, interests, and food choices of restaurants and customers have changed during the current COVID-19 pandemic.

According to the results, due to the COVID-19 pandemic, customers significantly decreased the frequency with which they went to restaurants while increasing their purchase of takeaway food, and at the same time, restaurants significantly increased their takeaway offerings. Most likely, this may be because of uncertainty, fear, and insecurity related to the pandemic situation, as they commented in the focus group. In this line, a narrative review highlighted a few directions for optimizing the at-home multisensory dining experience due to the takeaway format increasing during and after the pandemic (25).

Moreover, customers preferred to access menus in digital form and pay with cards rather than cash, leading to the need for restaurateurs to adapt. In the same way, restaurants increased their use of digital menus, although currently, only 28 of the 44 total restaurants who answered the survey offer a digital menu. Because restaurant menus are one of the most important types of marketing to promote business, and as we mentioned before, customers prefer menus in digital form, restaurants could improve their menus in digital form with an innovative approach (26).

A 2018 report about the behavioral habits and trends related to restaurants in Catalonia stated that 78% of subjects between 18 and 75 years of age ate outside of their home at least once a week (27). In the present study, even though the data focused only on restaurants in Tarragona Province, which was currently under COVID-19 pandemic restrictions, 43.9% of customers ate outside their home at least once a week, whereas 74.2% before the COVID-19 pandemic, in the same line as the 2018 report.

Regarding restaurant menu information, the results of the present study show that 59.1% of customers now use websites to obtain information. Our results are in accordance with a 2018 report that stated that 35.2% of people, especially young people (48.7%), search for information about restaurants on the Internet (27). Given this new demand, restaurants should consider maintaining updated websites to attract customers.

In the present results regarding Mediterranean offerings, some of the AMed criteria for restaurants, which include the use of olive oil, vegetable dishes, fruit desserts, and local products, among others, were positively perceived by customers. These results are in line with other studies that tried to help restaurateurs better adapt their menus to the Mediterranean diet or healthier diets by giving personalized directions to restaurateurs regarding the dishes listed on their menus. Such instructions included introducing more side vegetables, offering fruit for dessert, and using extra virgin olive oil for different types of cooking (20, 28–30). Additionally, the pandemic resulted in some changes to customer preferences, and restaurateurs could be interested in acting on those changes, such as by offering more vegetarian/vegan or allergen-free dish choices. The fact that our customer respondents increased their demand for local products could indicate an increasing awareness of the importance of sustainability for the planet (31).

In the present study, the results regarding hygiene and food safety, especially as they related to COVID-19, indicate that the restaurateurs increased their use of a hydroalcoholic solution and were much stricter about cleaning and disinfecting the restaurant and surfaces. In addition, the frequency with which restaurateurs cleaned significantly increased by 21.1%. Specifically, the number of restaurateurs who cleaned ≥2 times/day, particularly in the goods reception area, increased, a change highly valued by customers. Moreover, according to the focus groups, restaurateurs and customers were worried and awarded the importance of hygiene and food safety because customers were comfortable with new hygiene and food safety measures implemented by the restaurateurs. Currently, according to the Centers for Disease Control and Prevention (CDC), customers have tips to avoid food poisoning

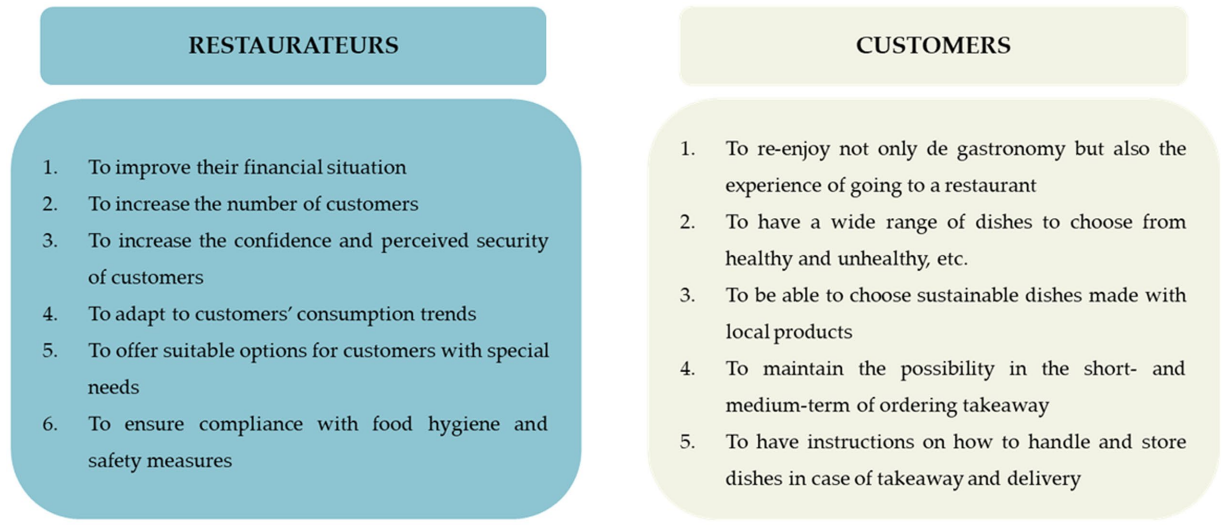

FIGURE 4
Needs and interests of restaurateurs and customers.

while eating out (32), and restaurants have information in some reports that highlights state food safety practices (33). This information goes in the same line as the results of the present study, highlighting that the present study shows information more specific to the local population. Additionally, in 2020, the guidelines published by the Catalan Food Safety Agency and the Technical Report of the European CDC (34, 35) became much stricter regarding the cleaning of rooms, facilities, surfaces and utensils, offices, furniture, changing rooms, hygienic service areas, and areas of frequent contact with the hands as measures to prevent the spread of SARS-CoV-2. Moreover, the recommended authorized disinfectant products were required to be registered in the Register of Nonagricultural Pesticides or Biocides or in the Official Register of Biocides of the General Directorate of Public Health, Quality and Innovation of the Ministry of Health (34, 35).

However, for general preventive cleaning and disinfection in restaurants, cleaning with water and detergents and the use of common disinfectant products was described as sufficient, but not in situations in which a possible case of COVID-19 was suspected (34, 35). In this context, in the present study, the use of a hydroalcoholic solution for disinfecting cooking utensils increased significantly by 13.7% from the period before to the period during the COVID-19 pandemic, although the most common option is to clean with hot soapy water. This motivation for cleaning is consistent with global recommendations to reduce the number of infections (36).

On the one hand, in the present study, the main barriers facing restaurateurs, detected through the focus groups, were verified, such as the measures imposed by the administration, the county and municipal lockdowns, and the limitations on hours and capacity, inducing a bad economic situation after the start of the COVID-19 pandemic, and emotional consequences such as anxiety or depression among the restaurateurs. One of the main concerns of our restaurateur respondents was their current economic situations, which were difficult because they had many economic losses due to the very restrictive regulations on restaurants that were constantly changing. The main restrictions were the absolute closure of all restaurants, restrictions on hours of operations, the requirement to provide exclusively outdoor seating such as terraces, limits on the numbers of tables and people, and reductions in restaurant capacity, depending on the wave of the pandemic (37).

On the other hand, in line with the focus group, the main barriers experienced by our customer respondents were the restrictions and limitations and the emotional consequences. In the present study, we verified that most of the customers reported a loss of social relationships and freedom after the start of the pandemic. This is justified because in Spain, the cultural practice of eating outside the home is driven by pleasure and social interactions with friends and family (38). In Spain, food is considered a means of socialization between individuals (38), and due to the pandemic, this has been very limited.

Finally, on the basis of the results of surveys and focus groups of the present cross-sectional study, some solutions could be implemented to enhance the COVID-19 consequences, such as reducing costs and offering discounts or reinventing themselves but taking into account customer preferences and comfort. Additionally, based on the needs and interests of restaurateurs and customers, some proposals for how restaurateurs can improve and adapt to new demands include increasing social media and technology in their sector, maintaining and updating hygiene and food security measures, maintaining and increasing AMed criteria according to customers' preferences, improving takeaway services, and strengthening restaurant essence (Table 5).

TABLE 5 Proposals to improve and adapt to the new demands faced by restaurateurs.

For restaurateurs	
Social media and technology	Promote the use of social media and websites to advertise the restaurant and inform customers about its menu.
	Increase the use of information and communication technology (ICT) for viewing the daily menu and placing orders, and have other alternatives for customers less familiar with ICT.
Hygiene and food security	Review and, if necessary, adapt to the measures recommended by the food safety agency about cleaning the different surfaces of the restaurant.
	Highlight the restaurant's compliance with the security measures.
	Ensure a safe distance between tables and customers, and prioritize seating on terraces and in well-ventilated areas of the restaurant whenever possible.
	Maintain the use of masks among dining room and kitchen staff and the additional hygiene practices after the COVID-19 pandemic ends.
Mediterranean offerings, customer food preferences	Promote and use local and seasonal products.
	Try to incorporate vegetarian/vegan dishes, allergen-free dishes, and whole grain products, as more than 50% of customers value these options.
	Include and promote dishes adapted to meet special needs and preferences. Obtain advice from professionals if necessary because such offerings increase customer confidence.
	Maintain and strengthen the essence of each restaurant despite the COVID-19 measures; customers go to restaurants not only for the food but also for the experience.
Takeaway and delivery instructions	Incorporate and maintain the demand for takeaway and delivery food and increase offerings of country themed and traditional food.
	Include some handling, cooking, and preservation instructions for takeaway and delivery food.
	Maintain the temperature chain (cold/heat) for delivery dishes.
	Consider the use of sustainable materials for takeaway and delivery.
Environment and the essence of the restaurant	Improve customer comfort by focusing on the service, the food, and the atmosphere of the restaurant.

This study has some limitations. First, this cross-sectional study reflects the COVID-19 situation only in restaurants located in Tarragona Province; however, considering that the COVID-19 restrictions on restaurants have been applied in other geographic areas, the results could be generalizable. Second, the use of self-reported answers to online surveys could make it easy to doubt the quality of the answers. However, the collection of qualitative and quantitative information allows us to obtain more information about the needs and interests of restaurateurs and customers in the current COVID-19 pandemic situation. Third and finally, the restaurateurs and consumers who participated in the focus groups may have felt pressure from their peers, which could have affected their answers.

In contrast, as a strength, this cross-sectional study is the first to assess the impact of COVID-19 on restaurants in Catalonia and Spain. For this reason, it is necessary for restaurateurs to implement the above proposals to adapt to the current situation as a way to reduce the negative impact of the pandemic and for researchers to continue investigating these issues.

5. Conclusion

In restaurants, the first COVID-19 lockdown increased takeaway orders, increased sanitation, and improved digital communication with customers, while customers highly valued the use of local foods. Therefore, this study provides valuable information on how to adapt gastronomic offerings during this challenging situation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the Pere i Virgili Institute (ref. 056/2021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MB-M, JQ, ST, EL, LT, and RS substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work, drafting the work or revising it critically for important intellectual content, provide approval for publication of the content, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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References

1. Davahli MR, Karwowski W, Sonmez S, Apostolopoulos Y. The hospitality industry in the face of the COVID-19 pandemic: current topics and research methods. *Int J Environ Res Public Health*. (2020) 17:7366. doi: 10.3390/ijerph17207366

2. Song HJ, Yeon J, Lee S. Impact of the COVID-19 pandemic: evidence from the U.S. restaurant industry. *Int J Hosp Manag*. (2021) 92:102702. doi: 10.1016/j.ijhm.2020.102702

3. Chua BL, Karim S, Lee S, Han H. Customer restaurant choice: an empirical analysis of restaurant types and eating-out occasions. *Int J Environ Res Public Health*. (2020) 17:6276. doi: 10.3390/ijerph17176276

4. Rincón-Gallardo PS, Zhou M, Da Silva GF, Lemaire R, Hedrick V, Serrano E, et al. Effects of menu labeling policies on transnational restaurant chains to promote a healthy diet: a scoping review to inform policy and research. *Nutrients*. (2020) 12:1544. doi: 10.3390/nu12061544

5. Bes-Rastrollo M, Basterra-Gortari FJ, Sánchez-Villegas A, Marti A, Martínez JA, Martínez-González MA. A prospective study of eating away-from-home meals and weight gain in a Mediterranean population: the SUN (Seguimiento Universidad de Navarra) cohort. *Public Health Nutr*. (2010) 13:1356–63. doi: 10.1017/S1368980009992783

6. Priyadarshini I, Mohanty P, Kumar R, Son LH, Chau HTM, Nhu VH, et al. Analysis of outbreak and global impacts of the COVID-19. *Healthcare*. (2020) 8:148. doi: 10.3390/healthcare8020148

7. Mayasari NR, Ho DKN, Lundy DJ, Skalny AV, Tinkov AA, Teng IC, et al. Impacts of the COVID-19 pandemic on food security and diet-related lifestyle behaviors: an analytical study of Google trends-based query volumes. *Nutrients*. (2020) 12:3103. doi: 10.3390/nu12103103

8. Leone LA, Fleischhacker S, Anderson-Steeves B, Harper K, Winkler M, Racine E, et al. Healthy food retail during the COVID-19 pandemic: challenges and future directions. *Int J Environ Res Public Health*. (2020) 17:7397. doi: 10.3390/ijerph17207397

9. Romeo-Arroyo E, Mora M, Vázquez-Araújo L. Consumer behavior in confinement times: food choice and cooking attitudes in Spain. *Int J Gastron Food Sci*. (2020) 21:100226. doi: 10.1016/j.ijgfs.2020.100226

10. de Freitas RSG, Stedefeldt E. COVID-19 pandemic underlines the need to build resilience in commercial restaurants' food safety. *Food Res Int*. (2020) 136:109472. doi: 10.1016/j.foodres.2020.109472

11. Czarniecka-Skubina E, Pielak M, Sałek P, Głuchowski A, Kobus-Cisowska J, Owczarek T. Use of food services by consumers in the SARS-CoV-2 pandemic. How the eating habits of consumers changed in view of the new disease risk factors. *Nutrients*. (2021) 13:2760. doi: 10.3390/nu13082760

12. Kim J, Kim J, Wang Y. Uncertainty risks and strategic reaction of restaurant firms amid COVID-19: evidence from China. *Int J Hosp Manag*. (2021) 92:102752. doi: 10.1016/j.ijhm.2020.102752

13. Institut d'Estadística de Catalunya. (2021). Població a 1 de gener. Comarques i Aran, àmbits i províncies. Available at: https://www.idescat.cat/indicadors/?id=aec&n=15224 (Accessed 8 September 2021).

14. Institut d'Estadística de Catalunya. Restaurants. Comarques i Aran. (2005). Available at: https://www.idescat.cat/pub/?id=res&n=350&t=200500&by=com (Accessed 9 December 2021).

15. Breen RL. A practical guide to focus-group research. *J Geogr High Educ*. (2006) 30:463–75. doi: 10.1080/03098260600927575

16. The EQUATOR Network. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. (2021). Available at: https://www.equator-network.org/reporting-guidelines/strobe/ (Accessed 8 September 2021).

17. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care*. (2007) 19:349–57. doi: 10.1093/intqhc/mzm042

18. Agència de Salut Pública de Catalunya. (2021). Generalitat de Catalunya. Amed Alimentació Mediterrània. Available at: http://amed.cat/restauradors.php (Accessed 8 September 2021).

19. Agència Catalana de Seguretat Alimentària. *Generalitat de Catalunya. Guía de prácticas correctas de higiene para restaurantes* Barcelona: Agència Catalana de Seguretat Alimentària (2015).

20. Mandracchia F, Llauradó E, Valls RM, Tarro L, Solà R. Evaluating Mediterranean diet-adherent, healthy and allergen-free meals offered in Tarragona Province restaurants (Catalonia, Spain): a cross-sectional study. *Nutrients*. (2021) 13:2464. doi: 10.3390/nu13072464

21. Institut Municipal d'Investigació Mèdica. Sample size and power calculator GRANMO. (2012). Available at: https://www.imim.es/ofertadeserveis/software-public/granmo/ (Accessed 9 September 2021).

22. Krueger RACM. *Focus groups: A practical guide for applied research. 5th* ed. California: Thousand Oaks (2015).

23. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. (2006) 3:77–101. doi: 10.1191/1478088706qp063oa

24. McMillan SS, King M, Tully MP. How to use the nominal group and Delphi techniques. *Int J Clin Pharm*. (2016) 38:655–62. doi: 10.1007/s11096-016-0257-x

25. Spence C, Youssef J, Levitan CA. Delivering the multisensory experience of dining-out, for those dining-in, during the Covid pandemic. *Front Psychol*. (2021) 12:683569. doi: 10.3389/fpsyg.2021.683569

26. Şahin E. An evaluation of digital menu types and their advantages. *J Tour Gastron Stud*. (2020) 8:2374–86. doi: 10.21325/jotags.2020.716

27. Generalitat de Catalunya. *Departament d'Empresa i Coneixement*. Hàbits de comportament i tendències: Estudi de la Restauració a Catalunya (2018).

28. Tarro L, Aceves-Martins M, Tiñena Y, Parisi JL, Blasi X, Giralt M, et al. Restaurant-based intervention to facilitate healthy eating choices and the identification of allergenic foods at a family-oriented resort and a campground. *BMC Public Health*. (2017) 17:393. doi: 10.1186/s12889-017-4333-5

29. Ritchie L, Lessard L, Harpainter P, Tsai M, Woodward-Lopez G, Tracy T, et al. Restaurant kids' meal beverage offerings before and after implementation of healthy default beverage policy statewide in California compared with citywide in Wilmington. *Delaware Public Health Nutr*. (2022) 25:794–804. doi: 10.1017/S1368980021001245

30. Petimar J, Zhang F, Rimm E, Simon D, Cleveland L, Gortmaker S, et al. Changes in the calorie and nutrient content of purchased fast food meals after calorie menu labeling: a natural experiment. *PLoS Med*. (2021) 18:e1003714. doi: 10.1371/journal.pmed.1003714

31. Barbour L, Lindberg R, Woods J, Charlton K, Brimblecombe J. Local urban government policies to facilitate healthy and environmentally sustainable diet-related practices: a scoping review. *Public Health Nutr*. (2022) 25:471–87. doi: 10.1017/S1368980021004432

32. Centers for Disease Control and Prevention. Food safety and eating out. (2023). Available at: https://www.cdc.gov/foodsafety/communication/eatingout.html (Accessed 16 February 2023).

33. Centers for Disease Control and Prevention. Food safety prevention status reports. (2016). Available at: https://www.cdc.gov/nceh/ehs/news/features/2016/food-safety-psr.html (Accessed 16 February 2023).

34. Agencia Catalana de Seguridad Alimentaria. Recomendaciones de limpieza y desinfección de instalaciones en empresas alimentarias para la prevención del coronavirus. (2020). Available at: https://acsa.gencat.cat/es/detall/article/Recomendaciones-de-limpieza-y-desinfeccion-de-instalaciones-en-empresas-alimentarias-para-la-prevencion-del-coronavirus (Accessed 5 October 2021).

35. European Centre for Disease Prevention and Control. *Disinfection of environments in healthcare and non-healthcare settings potentially contaminated with SARS-CoV-2*. Stockholm: European Centre for Disease Prevention and Control (2020).

36. Centers for Disease Control and Prevention. Guidelines for environmental infection control in health care facilities. (2003) Available at: https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html# (Accessed 27 February 2023).

37. National Center for Immunization and Respiratory Diseases (U.S.). Division of viral diseases. Considerations for restaurants and bars, COVID-19. (2021). Available at: https://stacks.cdc.gov/view/cdc/88184 (Accessed 6 October 2021).

38. Díaz-Méndez C, García-Espejo I. Eating out in Spain: motivations, sociability and consumer contexts. *Appetite*. (2017) 119:14–22. doi: 10.1016/j.appet.2017.03.047

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Diet quality and associated factors in Brazilian undergraduates during the COVID-19 pandemic

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Background: Diet quality is associated with psychobiological, psychological, biological, and physiological factors of individuals, and in the context of prolonged stress, such as the COVID-19 pandemic, it can lead to a worsening of the quality of food for undergraduates. This study aimed to analyze diet quality and associated factors in Brazilian undergraduates.

Methods: Data were collected from 4,799 undergraduate students from all Brazilian regions, from August 2020 to February 2021. The online questionnaire contained socioeconomic variables, the ESQUADA scale to assess diet quality, self-referred changes in weight, the Brazilian food insecurity scale (EBIA), sleep assessment and the perceived stress scale. Unconditional multiple logistic regression analysis was performed to study variables associated with poor and very poor diet quality.

Results: Most of participants presented a good diet quality (51.7%), while 9.8% had a poor or very poor diet quality and only 1.1% had an excellent diet quality. 58.2% of undergraduates reported to have an increase in weight during the pandemic and 74.3% of the students presented elevated stress during the pandemic. Logistic regressions showed students who gained weight during the pandemic presented the highest AOR=1.56 (95% CI=1.12–2.20) for poor or very poor diet quality. The elevated perceived stress was also associated with a higher AOR=2.85 (95% CI=1.71–4.74) for poor or very poor diet quality.

Conclusion: Most of the studied undergraduates presented a good diet quality. Nevertheless, poor/very poor diet quality was associated with higher perceived stress and weight gain. Our study indicated that policies should beaimed at the socioeconomically most vulnerable undergraduates, those in a situation of food and nutritional insecurity, high perceived stress, and who gained weight during the pandemic.

KEYWORDS

nutrition, perceived stress, food security, sleep assessment, SARS-CoV-19

1. Introduction

Adequate nutrition is a fundamental aspect of promoting and protecting health, as it determines the health conditions of individuals, in addition to being consistently associated with chronic diseases that affect the world population (1). Also, diet quality is related to better health conditions, immunity, and coping with diseases (2–5).

Studies have shown that undergraduate students are more prone to nutritionally unbalanced diets because of the student routine, living alone, having few cooking skills, or food insecurity (6–8). Undergraduates tend to have food choices that are easier to acquire and/or prepare, which, on the other hand, are foods with a higher energy density (6, 9). Thus, evaluating diet quality is important in undergraduates. Also, many university students depend on meals offered by University Restaurants, which had their activities suspended during the COVID-19 lockdowns (10) The validated diet quality scale (ESQUADA) evaluates diet in a broader context, including the consumption of fresh, minimally processed, and ultra-processed foods and dietary practices (such as cooking, and substituting meals for snacks) (11). Thus, using this instrument could give important light on assessing diets and policy planning for undergraduates.

Eating habits and behaviors can be changed due to sociobiological, psychological, biological and physiological factors (12), and studies have shown that situations with a context of prolonged stress, such as the COVID-19 pandemic, impact all these factors (13, 14). In addition, social distancing caused changes in the behavior of individuals (15), and eating behavior was also affected by the economic and social crisis associated with the health emergency (16).

The restrictions caused by the COVID-19 pandemic may have committed to maintaining of a healthy and varied diet, reducing the consumption of fresh foods such as fruits, vegetables and fish, increasing the preference for ready-to-eat and ultra-processed foods rich in fats, sugars and salt (17). Furthermore, studies show that psychological and emotional responses to social distancing can increase the risk of developing dysfunctional eating behaviors; because people may be more likely to seek rewards and gratifications physiologically associated with food consumption to contrast and respond to the negative experience associated with increased stress (18, 19).

The literature is quite limited considering the assessment of undergraduates' diet quality, especially during the COVID-19 pandemic. However, with the closing of university restaurants, the transition to remote classes, and social, economic, and mental changes, there is a need to understand undergraduate students' diet quality and associated factors in the context of a health emergency. Therefore, this study aimed to assess the diet quality and associated factors in undergraduates from Brazilian universities. The hypothesis under study was that undergraduates' poorer diet quality was associated with worse nutritional status, food insecurity, altered sleep duration, and higher perceived stress.

Abbreviations: UFAC, Federal University of Acre; UFRN, Federal University of Rio Grande do Norte; UFMT, Federal University of Mato Grosso; USP, University of São Paulo; UFPR, Federal University of Paraná; ESQUADA, Diet Quality Scale; EBIA, Brazilian Food Insecurity Scale; PSS, Perceived Stress Scale.

2. Methods

2.1. Ethics

Each center approved the study protocol from local institutional ethics review boards at: the Federal University of Acre (CAAE 36814320.9.0000.5010, #4.267.655), Federal University of Rio Grande do Norte (CAAE: 35918620.7.0000.5292, #4.391.606), Federal University of Mato Grosso (CAAE 36582820.0.0000.8124, #4.242.364), University of São Paulo (CAAE 36402820.9.0000.5421, #4.232.859), and the Federal University of Paraná (CAAE 36250320.2.0000.0102, #4.256.436). All participants recorded consent online to participate in the study.

2.2. Study design and participants

This is a cross-sectional study, with data collection from August 2020 to February 2021, corresponding to half of the first wave and the beginning of the second wave of COVID-19 in Brazil. This study is part of a multicenter project carried out at universities in five different states, covering the five regions of Brazil: Acre, Rio Grande do Norte, Mato Grosso, São Paulo and Paraná. The project is entitled "Food insecurity, nutritional status and lifestyle in the academic community during the COVID-19 pandemic – BRAZUCA COVID" and was carried out at the Federal University of Acre – UFAC, Federal University of Rio Grande do Norte – UFRN, Federal University of Mato Grosso – UFMT, University of São Paulo – USP, and the Federal University of Paraná – UFPR. Students regularly matriculated in undergraduate courses in public universities were eligible for the study. During the data collection period, the number of students enrolled in the studied universities were: 31,911 at UFAC, 38,478 at UFRN, 15,891 at UFMT, 59,779 at USP, and 29,406 at UFPR.

An online questionnaire was created on the Google Forms platform and sent to the students' institutional emails. The questionnaire was a compilation of socioeconomic variables (including sex, race/color, self-referred changes in weight, family income, and income change during the pandemic) and the Diet Quality Scale (ESQUADA) scale to assess diet quality (11), the Brazilian food insecurity scale (EBIA) (20), sleep assessment (21) and the perceived stress scale (22), totaling 108 questions. The sample was of convenience with non-probabilistic sampling.

2.3. Diet quality assessment

The diet quality scale (ESQUADA) was applied to assess the students' diet quality (11). The ESQUADA originally presents 25 items on dietary practices (such as replacing meals with snacks and the habit

of cooking) and the consumption of fresh, minimally processed, and ultra-processed food. It evaluates diet quality, not measuring the nutritional value but other important aspects of food, bringing a more global view of diet quality that is not just nutritional. The scale items present alternative answers covering frequency, location, and food consumed. The items on the ESQUADA include polytomous and dichotomous responses, but all are ordinal; they have categories ordered according to alignment with the worst or best quality of the diet (11).

The ESQUADA presented better accuracy in the continuum of diet quality between scores −2 and + 2, confirmed goodness-of-fit (RMSEA = 0.01; SRMSR = 0.02; CIF = 0.99 and TLI = 0.99), and adequate empirical reliability (0.70). In addition, differential behavior was not identified for any item, considering age and sex (11). For validation of the ESQUADA scale, the item response theory (IRT) analyses was used, which allows the selection of items from the larger set of questions without jeopardizing the score estimate, according to the IRT's principle of invariance (23). Thus, considering the use of the IRT to validate the ESQUADA, 15 items from the scale were selected for the present study. Items with more discrimination of diet quality, more participation in the description of ESQUADA levels, and no similarity with questions already included in the online questionnaire due to content or placement of the scale were selected.

The ESQUADA score scale was constructed by grouping into levels indicative of the cumulative trait of diet quality. The scores estimated on a scale with a mean equal to 0 and standard deviation equal to 1 were analyzed and categorized into five levels of diet quality: "very poor" (scores ≤ −2); "poor" (scores > −2 and ≤ −1), "good" (scores > −1 and ≤ 0,5); "very good" (scores >0,5 and ≤ 2,5); and "excellent" (scores >2,5) (11).

2.4. Self-referred changes in weight

Self-referred changes in weight during the pandemic were registered in the online form as a categorical variable (no; yes, for less; yes, for more; I do not wish to inform).

2.5. Food insecurity assessment

Food insecurity was assessed using the adapted and validated Brazilian food insecurity scale (EBIA) (Cronbach's alpha = 0.91) (24, 25). This scale measures food insecurity by evaluating the influence of money scarcity on food availability and consumption of adults and children living in the house. The EBIA's application and analysis have demonstrated that there are common aspects across different sociocultural contexts of food insecurity represented in the scale, including the (1) psychological component – anxiety or doubt about the future availability of food in the house to meet the needs of the locals; (2) food quality – impairment of socially established preferences about foods and its variety at home; (3) quantitative reduction of food among adults; (4) quantitative reduction in children's diet; and (5) hunger – when someone does not eat all day due to lack of money to buy foods (26–28).

The scale is based on the sum of positive responses to 14 polytomous questions. Scores are organized within cutoff points equivalent to graded theoretical constructs on food security: food security (total score = 0), mild food insecurity (in households with people <18 years old, total score from 1 to 5; households without people <18 years old, total score 1 to 3), moderate food insecurity (in households with children under 18 years old, total score 6 to 9; households without people under the age of 18 years old, total score 4 to 5) and severe food insecurity (in households with people <18 years old, total score 10–14; households without people <18 years old, total score 6–8).

2.6. Sleep assessment

Sleep assessment was performed through the questions: "On a weekday, what time do you usually sleep?," "On a weekday, what time do you usually wake up?," "On weekends, what time do you usually wake up?," "What time do you usually sleep?" and "On weekends, what time do you usually wake up?" before and during the pandemic.

Sleep duration was estimated by the weighted average of sleep time during the week (difference between bedtime and waking up during the week) and at the weekend (difference between bedtime and waking up on the weekend), using the equation: [(weekday sleep duration x 5) + (weekend sleep duration x 2)]/7 (21).

2.7. Perceived stress

Perceived stress was evaluated using the perceived stress scale – PSS (29), a version with 10 polytomous items, validated for the Brazilian population (Cronbach's alpha = 0.86) (22) and categorized as mild (scores ≤13), moderate (scores between 14 and 19), and high (scores ≥20) (30). It is a self-reported measure to assess the degree to which situations in a person's life are classified as stressful.

2.8. Statistical analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences SPSS®, version 11.5 (SPSS Inc. Chicago, IL) and Graph Pad Prism version 3.0 (Graph Pad Software, San Diego, CA).

The normality of the quantitative variables was tested using the Kolmogorov–Smirnov test to present data as means (SD) or medians (Q1 – Q3). Categorical variables were presented through frequency distribution, and associations were evaluated using the Chi-square test. For quantitative data without normal distributions, the Kruskal-Wallis test and the Dunns *post hoc* test were used. Given the large size of the studied sample, the significance level was set at 1% to avoid type 1 errors.

Primarily, bivariate analysis explored the effect of a single variable on diet quality assessment with the unadjusted odds ratios (OR) and their respective 95% confidence intervals (95% CI). Then, logistic regression models were calculated, considering the dichotomized ESQUADA classification as a dependent variable (1 = very poor /poor diet quality; 0 = good / very good / excellent diet quality). The adjustment of the final model was guaranteed by observing the Omnibus test, with p values less than 0.05, and the Hosmer and Lemeshow test, considering p values greater than 0.05. Thus, as independent variables, the final model included

self-reported changes in weight, food insecurity, sleep assessment during the weekend before the pandemic, and perceived stress. Sex, age and study site were used in the final model as adjustment variables. The adjusted odds ratios (AOR) and their respective 95% CI were presented, variables with Wald test's p values <0.01 were those considered to significantly contribute in the model. The significance level was set at 1% to avoid type 1 errors, given the large sample size.

3. Results

A total of 4,872 undergraduates of the studied public universities responded to the questionnaire; 140 responses were excluded from this study due to non-response, incomplete or inconsistent responses, totaling 4,732 participants. Of these, 673 were from UFAC, 870 from UFRN, 145 from UFMT, 2074 from USP, and 970 from UFPR (Figure 1).

The sociodemographic and eating characteristics of the undergraduates is shown in Table 1. The median age was 22.0 (20.0–26.0) years, and the questionnaire was mostly answered by women (66.1%). Family income was mainly around 1–6 minimum wages, and 47.9% of undergraduates reported a reduction in family income during the pandemic. Considering weight change, 47.9% of undergraduates had an increase in weight during the pandemic. Most undergraduates rated their health status before the pandemic as good or regular (74.9%), and only 4.7% of participants rated it as poor or very poor. On the other hand, during the pandemic, 24.4% of the students reported poor or very poor health conditions. The Brazilian food insecurity scale showed that 37.8% of students presented food insecurity, with 4.4% of students classified as severe. In addition, the pandemic's sleeping time increased during the week and decreased on the weekend. The perceived stress showed that 74.3% of the students presented elevated stress during the pandemic (Table 1).

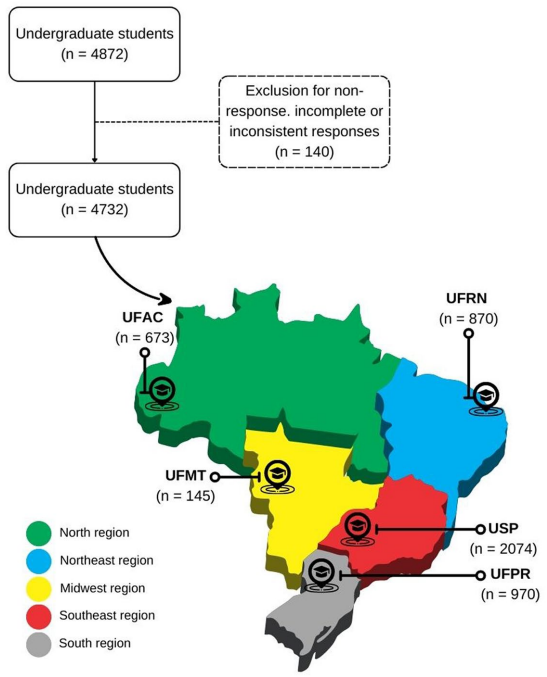

FIGURE 1
Flowchart of studied undergraduates (n=4,732), considering the study sites. UFAC – Federal University of Acre, UFRN – Federal University of Rio Grande do Norte, UFMT – Federal University of Mato Grosso, USP – University of São Paulo, UFPR – Federal University of Paraná.

Considering diet quality, according to the answers provided by the undergraduates, 9.8% of the students were classified as having a poor or very poor diet quality, while 51.7% had a good diet quality and only 1.1% had an excellent diet (Figure 2). The bivariate association analysis (Table 2) showed that most undergraduates with very poor or poor diet quality increased weight during the pandemic (Chi-square test, $p < 0.001$). None of the undergraduates with severe food insecurity in their households presented excellent diet quality (Chi-square test, $p < 0.001$). In addition, undergraduates with poor or very poor diet quality had an elevated perceived stress, 82.8 and 84.8%, respectively (Chi-square test, $p < 0.001$; Table 2).

Logistic regressions (Table 3) further explored the observed associations, where students who gained weight during the pandemic had an AOR = 1.59 (95% CI = 1.13–2.24) for poor or very poor diet quality. In addition, elevated perceived stress was also associated with diet quality with an AOR = 2.89 (95% CI = 1.74–4.82) for poor or very poor diet quality.

4. Discussion

This study aimed to assess the diet quality and associated factors in undergraduates from Brazilian universities. Most of the studied undergraduates presented good diet quality. This result might be explained by the fact that undergraduates might have given more attention to food preparation during lockdowns and that some went back to their parents' homes, away from the university campus, to reduce expenses with housing and food (31, 32), thus having more assistance to prepare/consume a diet with good quality. Nevertheless, a considerable number of undergraduates had poor or very poor diet quality, which was associated with weight gain during the pandemic and perceived stress. Regarding the latter, it was notable that most undergraduates rated their perceived stress as very high during the pandemic.

Undergraduates who gained weight also demonstrated poor or very poor diet quality. In the ESQUADA scale, poor or very poor diet quality are the levels with more frequent consumption of ultra-processed foods (11, 33). Studies have shown that consuming foods with high energy density, such as ultra-processed and fast foods, is associated with weight change in undergraduates (34, 35). In addition, increased consumption of ultra-processed foods and weight gain can increase the incidence of chronic noncommunicable diseases (36). Furthermore, there was an increase in food prices in the Brazilian market, mainly for staple foods such as rice, beans, vegetables, fruits, and meats, which already preceded the pandemic and intensified even more (37). In March 2021, the value of the basic food basket in Brazil cost around R$ 626 (around $ 121), showing an increase of 20.7% compared to March 2020. Therefore, with the pandemic's social and economic impacts and the increase in staple foods price, purchasing power worsened, especially for the most vulnerable families, leading to an increase in the consumption of processed and ultra-processed foods, which with the increase in the price of staple foods, are

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TABLE 1 Sociodemographic, eating characteristics and associated factors of the studied undergraduates (*n*=4,799).

Characteristics	Total *n* (%) or median (Q1 – Q3)
	Median (Q1 – Q3)
Age	22.0 (20.0–26.0)
Sex	*n* (%)
Male	1,628 (33.9)
Female	3,171 (66.1)
Family income in minimum wages[a]	*n* (%)
None	132 (2.7)
0–1	708 (14.8)
1–3	1,473 (30.7)
3–6	1,040 (21.7)
6–9	536 (11.2)
9–12	332 (6.9)
12–15	218 (4.5)
>15	322 (6.7)
NI/NWI	38 (0.8)
Family income change during the pandemic	*n* (%)
No	1985 (41.4)
Yes, for less	2,302 (47.9)
Yes, for more	466 (9.7)
NI/NWI	46 (1.0)
Weight change during the pandemic	*n* (%)
No	596 (12.4)
Yes, for less	1,322 (27.6)
Yes, for more	2,670 (55.6)
NI/NWI	211 (4.4)
Health status before the pandemic	*n* (%)
Very good	980 (20.4)
Good	2,343 (48.9)
Regular	1,244 (26.0)
Poor	189 (3.9)
Very poor	37 (0.8)
Health status during the pandemic	*n* (%)
Very good	476 (10.0)
Good	1,407 (29.4)
Regular	1730 (36.2)
Poor	895 (18.7)
Very poor	270 (5.7)
Food security classification	*n* (%)
Food security	2,893 (60.3)
Mild food insecurity	1,242 (25.9)
Moderate food insecurity	360 (7.5)
Severe food insecurity	209 (4.4)
NI/NWI	95 (2.0)
Sleep assessment in minutes	Median (Q1 – Q3)
Weed during pandemic	480 (420–600)
Weekend during pandemic	510 (450–570)
Week before the pandemic	450 (390–500)
Weekend before the pandemic	540 (480–600)
Perceived stress	*n* (%)
Low	436 (9.1)
Moderate	797 (16.6)
Elevated	3,566 (74.3)

[a]The minimum wage in Brazil is R$ 1,100, around $ 212. NI/NWI: Not informed/did not wish to inform.

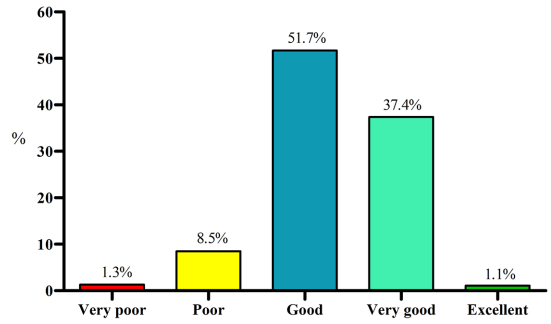

FIGURE 2
Diet quality assessment in undergraduates (*n*=4,799), assessed using the diet quality scale (ESQUADA). Chi-square test, $p<0.001$.

becoming increasingly cheaper (38), further affecting the diet quality of the undergraduates.

In Brazil, since 2012, with the enactment of the Quota Law (39), which reserves vacancies for undergraduate courses for students in public schools or who have a monthly income *per capita* ≤1.5 minimum wages (the minimum wage in Brazil is R$ 1,100, around $ 212) or who declare themselves black, brown, or indigenous, there was an increase in the inclusion of socio-demographically vulnerable students in university (40), which may corroborate for a lower purchasing power of Brazilian undergraduates.

Our research has shown that undergraduates with high perceived stress are 2.9 times more likely to have poor or very poor diet quality. Stress is a condition that threatens a person's physical and emotional well-being and prevents progress, so that the person to react physiologically, behaviorally, cognitively, and emotionally to that state of stress (41).

Thus, searching for energy and sugar rich diets that activate the pleasure zones is related to a stress-coping strategy (42). A study in the United Kingdom applied a food frequency questionnaire and the perceived stress scale in 3,706 undergraduates. In the study, the greater consumption of sweets, snacks, and fast foods was significantly associated with a greater perception of stress in female undergraduates, and a reduction in the consumption of fruits, salads, and cooked

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TABLE 2 Diet quality of undergraduates (n=4,799) according to anthropometric, food variables, sleep and stress during the pandemic.

Variable	Total *N* (%)	Very poor *N* (%)	Poor *N* (%)	Good *N* (%)	Very good *N* (%)	Excellent *N* (%)	Chi-square test *p* value
Weight change during the pandemic							
No	596 (13.0)	4 (6.6)	38 (9.5)	284 (11.9)	262 (15.5)	8 (15.7)	<0.001
Yes, for less	1,322 (28.8)	14 (23.0)	77 (19.3)	618 (25.9)	587 (34.7)	26 (51.0)	
Yes, for more	2,670 (58.2)	43 (70.5)	284 (71.2)	1,483 (62.2)	843 (49.8)	17 (33.3)	
Total	4,588 (100.0)	61 (100.0)	399 (100.0)	2,385 (100.0)	1,692 (100.0)	51 (100.0)	
Variable	Total *N* (%)	Very poor *N* (%)	Poor *N* (%)	Good *N* (%)	Very good *N* (%)	Excellent *N* (%)	Chi-square test *p* value
Food security classification							
Food security	2,893 (61.5)	30 (48.4)	233 (57.7)	1,401 (57.4)	1,189 (68.1)	40 (81.6)	<0.001
Mild food insecurity	1,242 (26.4)	22 (35.5)	113 (28.0)	712 (29.2)	388 (22.2)	7 (14.3)	
Moderate food insecurity	360 (7.7)	5 (8.1)	32 (7.9)	224 (9.2)	97 (5.6)	2 (4.1)	
Severe food insecurity	209 (4.4)	5 (8.1)	26 (6.4)	105 (4.3)	73 (4.2)	0 (0.0)	
Total	4,704 (100.0)	62 (100.0)	404 (100.0)	2,442 (100.0)	1747 (100.0)	49 (100.0)	
Variable	Total Median (Q1 – Q3)	Very poor Median (Q1 – Q3)	Poor Median (Q1 – Q3)	Good Median (Q1 – Q3)	Very good Median (Q1 – Q3)	Excellent Median (Q1 – Q3)	Kruskal-Wallis test *p* value
Sleep assessment in minutes							
Week during pandemic	480 (420–540)	510 (420–540)	510 (420–540)	510(420–540)	510(420–540)	510(420–540)	0.504
Weekend during pandemic	510 (450–570)	540 (480–600)	525 (457–570)	510 (450–570)	510(450–550)	480(472–540)	0.036
Week before the pandemic	450 (390–500)	450 (420–532)	450 (400–510)	450 (390–510)	450 (390–480)	445(412–480)	0.345
Weekend before the pandemic	540 (480–600)	540 (480–600)	540 (480–600)	540 (480–600)	540 (480–600)	495[a] (450–540)	<0.001
Variable	Total *N* (%)	Very poor *N* (%)	Poor *N* (%)	Good *N* (%)	Very good *N* (%)	Excellent N (%)	Chi-square test *p* value
Perceived stress							
Low	436 (9.1)	1 (1.6)	17 (4.1)	170 (6.8)	235 (13.2)	13 (25.0)	<0.001
Moderate	797 (16.6)	10 (15.6)	47 (11.4)	391 (15.7)	336 (18.9)	13 (25.0)	
Elevated	3,566 (74.3)	53 (82.8)	350 (84.5)	1929 (77.5)	1,208 (67.9)	26 (50.0)	
Total	4,799 (100.0)	64 (100.0)	414 (100.0)	2,490 (100.0)0	1779 (100.0)	52 (100.0)	

[a]Dunns post hoc test indicated $p < 0.001$ when compared to the other groups.

vegetables was observed in referred stressful situations in both female and male (43).

Some studies have shown that with the social distancing measures during the pandemic, there was a reduction in the consumption of healthier foods and an increase in higher energy foods in undergraduates around the world, even causing binge eating associated with high-stress situations and anxiety (14, 44–46). In Brazil, it was no different, in adults aged between 18 and 29 there was a proportional increase in the consumption of unhealthy foods during the lockdown (47). With social distancing, Brazilian universities experienced the transition from face-to-face to remote learning, where students saw the need to study inmates in their homes. As a result, undergraduates mentioned that the restrictions of the pandemic caused an increase in stress and anxiety (48).

The shift to remote learning impacted undergraduates. Dash et al. (49) observed high psychological distress in tertiary students during the pandemic. In the study, better diet quality was also significantly correlated with fewer symptoms of psychological distress. The increased perceived stress in our study might be explained by reduced social interactions and access to student residency services, increasing academic and financial pressures, and altering the lifestyles of these undergraduates (49, 50). Increased stress has been associated with increased intake of foods with high energy density, rich in sugars and saturated fats, and reduced vegetable intake (44–46), which indicates poorer diet quality. This fact might explain that, in our study, most undergraduates with very poor or poor diet quality increased weight during the pandemic.

Although the logistic regression models did not demonstrate an association of poorer diet quality with food insecurity in our study, it is not possible to completely refute the initial hypothesis (that undergraduates' poorer diet quality was associated with food insecurity), considering that the bivariate analysis showed an association of students with the poorest diet quality presenting food insecurity in their households during the pandemic. Also, in a study

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TABLE 3 Logistic regressions for variables associated with poor or very poor diet quality in Brazilian undergraduates during the COVID-19 pandemic.

Independent variables	ESQUADA classification			
	OR (95% CI)	*p* value	AOR (95% CI)	*p* value
Weight change during the pandemic				
No	–		–	
Yes, for less	0.98 (0.67–1.43)	0.896	0.86 (0.58–1.26)	0.855
Yes, for more	1.84 (1.32–2.57)	<0.001	1.59 (1.13–2.24)	0.008
Food security classification				
Food security	–		–	
Mild food insecurity	1.22 (0.98–1.52)	0.076	1.11 (0.88–1.39)	0.376
Moderate food insecurity	1.15 (0.79–1.65)	0.463	0.98 (0.67–1.44)	0.930
Severe food insecurity	1.74 (1.16–2.60)	0.007	1.45 (0.94–2.23)	0.088
Sleep assessment in minutes				
Weekend before the pandemic	1.00 (0.99–1.01)	0,887	1.00 (0.99–1.01)	0.609
Perceived stress				
Low	–		–	
Moderate	1.78 (1.04–3.08)	0.036	1.81 (1.03–3.18)	0.038
Elevated	2.96 (1.82–4.79)	<0.001	2.89 (1.74–4.82)	<0.001

*ESQUADA: Diet quality scale. The ESQUADA classification was dichotomized to become a dependent variable (1 = very poor/poor diet quality; 0 = good/very good/excellent diet quality). OR: crude odds ratio, from bivariate analysis; AOR: adjusted odds ratio, considering all variables in the model. Sex, age and study site were included as adjustment variables.

carried out at the University of Michigan (51) students who were in a situation of food insecurity presented a higher consumption of added total sugars, sugary drinks and a lower intake of fruits, vegetables, and fiber, when compared to undergraduates with food security. Other previous studies conducted in the United States of America have also demonstrated an association between poor or very poor diet quality and food insecurity status in undergraduates (52, 53). Furthermore, in previous analyses, considering the same population (8), undergraduates with a better diet quality were less likely to be inserted into a context of food and nutritional insecurity. In the present study, none of the undergraduates with severe food insecurity in the household presented an excellent diet quality.

Protecting the poorest groups from poor diet quality involves keeping food prices stable so they can access more nutritious food regularly. However, with the economic and political crisis that worsened during the pandemic, such action has become increasingly tricky (37), leading to global increased food insecurity. In this sense, Brazil is back on the hunger map. Within 2 years of the pandemic, the number of Brazilians who have nothing to eat has almost doubled, totaling 33.1 million (54), 14 million more Brazilians compared to 2020 (55). Our data showed that 47.9% of undergraduates had a reduction in family income during the pandemic, which may corroborate the restriction in food purchasing power in undergraduates' households. Furthermore, greater food insecurity can act as a multiplier of the pandemic burden due to its negative consequences on health (56). Therefore, it is necessary to implement strategies aimed at guaranteeing access to food among the most vulnerable populations so that the impacts of the pandemic on health and nutrition can be mitigated (57). As an example of strategies that can be adopted, there are public policies aimed at ultra-processed foods, which involve regulation of the biochemical and nutritional composition of ultra-processed foods, products, and the drivers of food standards (58). Thus, the aim is to reduce consumption and the proportion of ultra-processed foods in countries with high consumption.

The factors associated with poor diet quality must be explored and understood because those most vulnerable undergraduates, even when eating at university restaurants, might have access to university cafeterias, where, in Brazil, purchasing healthy meals is more expensive, compromising diet quality (51). Moreover, this scenario may have been even more affected by the closing of university restaurants during the pandemic, where even if there were university scholarships for food aid that remained in the pandemic context, access to healthy foods rich in vitamins, fibers, and minerals was still more limited to students who lived in some degree of food insecurity.

Some limitations of the present study should be mentioned. First, the online data collection might have restricted the participation of those who did not have good access to the internet. However, contact with undergraduates took place through institutional email correspondence. In addition, in February 2021, when data collection ended, public universities already had support measures aimed at students, such as grants for acquiring internet and/or electronic equipment such as a notebook to ensure the monitoring of online classes for the most vulnerable. Furthermore, non-probabilistic sampling may have caused a selection bias because the motivation to participate in the research may have been greater in those undergraduates most affected by the pandemic. On the other hand, identifying and understanding these individuals were part of the research. Still, we were restricted to the students' self-reported data. Therefore, there may be an underestimation or overestimation of the results.

The study's strengths are the measurement of diet quality, food insecurity, and perceived stress concomitantly, allowing the

observation of the demonstrated associations. In addition, data collection was conducted in universities in all Brazilian regions.We observed the diet quality of undergraduates in the face of a health emergency. Thus, it was possible to see which factors can associate with diet quality during the scenario of a pandemic. The results can contribute to the planning of public policies for this group of individuals, who may be experiencing social, economic, mental, and health difficulties due to the pandemic, which can directly and negatively impact education, in addition to preparing the public policies to face possible future scenarios of health emergencies such as a pandemic.

5. Conclusion

Our data showed that most of the studied undergraduates presented a good diet quality. Nevertheless, there was a considerable proportion of undergraduates with poor or very poor diet quality; and poor/very poor diet quality was associated with higher perceived stress and weight gain.

It is necessary to improve diet quality, especially for younger generations like most undergraduates. In Brazilian university students, our study indicated that policies should be directed to the most vulnerable, those in a situation of food and nutritional insecurity, high perceived stress, and who gained weight during the pandemic. Further studies should include food and nutrition education programs, access to healthy food in the studied population, and which factors lead to food choices in situations of increased stress and anxiety.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethical review boards at: the Federal University of Acre (CAAE 36814320.9.0000.5010, #4.267.655), Federal University of Rio Grande do Norte (CAAE: 35918620.7.0000.5292, #4.391.606), Federal University of Mato Grosso (CAAE 36582820.0.0000.8124, #4.242.364), University of São Paulo (CAAE 36402820.9.0000.5421, #4.232.859), and the Federal University of Paraná (CAAE 36250320.2.0000.0102, #4.256.436). The patients/participants provided their written informed consent to participate in this study.

Author contributions

DM, BM, TS, CL, PMR, BG, PRR, DH, SC, BS, and AR: designed research. LG and BM: analyzed data. LG, BM, CL, PMR, BG, PRR, TS, DH, SC, BS, TD, FAM, and AR: conducted research. DM: resources. LG and BM: wrote paper. CL, PMR, BG, PRR, TS, DH, SC, BS, AR, and DM: review and edited. DM: project administration and funding acquisition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. (2019) 393:1958–72. doi: 10.1016/S0140-6736(19)30041-8

2. Mazidi M, Kengne AP. Higher adherence to plant-based diets are associated with lower likelihood of fatty liver. *Clin Nutr*. (2019) 38:1672–7. doi: 10.1016/j.clnu.2018.08.010

3. Merino J, Joshi AD, Nguyen LH, Leeming ER, Mazidi M, Drew DA, et al. Diet quality and risk and severity of COVID-19: a prospective cohort study. *Gut*. (2021) 70:2096–104. doi: 10.1136/gutjnl-2021-325353

4. de Morais AH, Aquino JS, da Silva-Maia JK, Vale SHL, Maciel BLL, Passos TS. Nutritional status, diet and viral respiratory infections: perspectives for severe acute respiratory syndrome coronavirus 2. *Br J Nutr*. (2021) 125:851–62. doi: 10.1017/S0007114520003311

5. Satija A, Bhupathiraju SN, Spiegelman D, Chiuve SE, Manson JE, Willett W, et al. Healthful and unhealthful plant-based diets and the risk of coronary heart disease in U.S. adults. *JACC Adv*. (2017) 70:411–22. doi: 10.1016/j.jacc.2017.05.047

6. Bernardo GL, Jomori MM, Fernandes AC, Proença RPC. Food intake of university students. *Rev Nutr*. (2017) 30:847–65. doi: 10.1590/1678-98652017000600016

7. de Borba TP, da Silva MV, Jomori MM, Bernardo GL, Fernandes AC, Proença RPC, et al. Self-efficacy in cooking and consuming fruits and vegetables among Brazilian

university students: the relationship with sociodemographic characteristics. *Br Food J*. (2021) 123:2049–65. doi: 10.1108/BFJ-04-2020-0311

8. Maciel BLL, Lyra CO, Gomes JRC, Rolim PM, Gorgulho BM, Nogueira PS, et al. Food insecurity and associated factors in Brazilian undergraduates during the COVID-19 pandemic. *Nutrients*. (2022) 14:358. doi: 10.3390/nu14020358

9. Jomori MM, Proença RPC, Echevarria-Guanilo ME, Bernardo GL, Uggioni PL, Fernandes AC. Construct validity of Brazilian cooking skills and healthy eating questionnaire by the known-groups method. *Br Food J*. (2017) 119:1003–16. doi: 10.1108/BFJ-10-2016-0448

10. Araujo TA, Medeiros LA, Vasconcelos DB, Dutra LV. (In)segurança alimentar e nutricional de residentes em moradia estudantil durante a pandemia do covid-19. *Segurança Alimentar e Nutricional*. (2021) 28:e021010. doi: 10.20396/san.v28i00.8661200

11. Santos TSS, de Moura Araújo PH, de Andrade DF, da Costa Louzada ML, de Assis MAA, Slater B. Two validity evidences of the ESQUADA and Brazilians' dietary quality levels. *Rev Saude Publica*. (2021) 55:1–14. doi: 10.11606/s1518-8787.2023057002397err

12. Leng G, Adan R, Belot M, Brunstrom J, de Graaf K, Diskson S. The determinants of food choice. *Proc Nutr Soc*. (2017) 76:316–27. doi: 10.1017/S002966511600286X

13. Eşer Durmaz S, Keser A, Tunçer E. Effect of emotional eating and social media on nutritional behavior and obesity in university students who were receiving distance education due to the COVID-19 pandemic. *J Public Health (Bangkok)*. (2022):1–10. doi: 10.1007/s10389-022-01735-x

14. Rubio-Tomás T, Skouroliakou M, Ntountaniotis D. Lockdown due to COVID-19 and its consequences on diet, physical activity, lifestyle, and other aspects of daily life worldwide: a narrative review. *Int J Environ Res Public Health*. (2022) 19:6832. doi: 10.3390/ijerph19116832

15. Yang H, Bin P, He AJ. Opinions from the epicenter: an online survey of university students in Wuhan amidst the COVID-19 outbreak. *J. Chin. Gov.* (2020) 5:234–48. doi: 10.1080/23812346.2020.1745411

16. FAO. *Adressing the Impacts of COVID-19 in FOOD Crises*. Rome: FAO (2020).

17. di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. *J Transl Med*. (2020) 18:229. doi: 10.1186/s12967-020-02399-5

18. Singh M. Mood, food, and obesity. *Front Psychol*. (2014) 5:925. doi: 10.3389/fpsyg.2014.00925

19. van Strien T. Causes of emotional eating and matched treatment of obesity. *Curr Diab Rep*. (2018) 18:35. doi: 10.1007/s11892-018-1000-x

20. IBGE. *Pesquisa Nacional por Amostra de Domicílios*. Rio de Janeiro: Segurança Alimentar (2014). 133 p.

21. Oliveira G. Agregação dos fatores de risco cardiovascular: álcool, fumo, excesso de peso e sono de curta duração em adolescentes do estudo ERICA Aggregation of cardiovascular risk factors: alcohol, smoking, excess weight, and short sleep duration in adolescent. *Cadernos de saúde pública / Ministério da Saúde, Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública*. (2019) 35:1–12. doi: 10.1590/0102-311x00223318

22. Siqueira Reis R, Ferreira Hino AA, Romélio Rodriguez Añez C. Perceived stress scale: reliability and validity study in Brazil. *J Health Psychol*. (2010) 15:107–14. doi: 10.1177/1359105309346343

23. Hambleton R, Swaminsthan H, Rogers HJ. *Fundamentals of Item Response Theory*. California: SAGE Publications (1991).

24. Pérez-Escamilla R, Segall-Corrêa AM, Kurdian Maranha L, Sampaio MFA, Marín-León L, Panigassi G. An adapted version of the U.S. Department of Agriculture food insecurity module is a valid tool for assessing household food insecurity in Campinas, Brazil. *J Nutr*. (2004) 134:1923–8. doi: 10.1093/jn/134.8.1923

25. Segall-Corrêa AM, Marin-León L, Melgar-Quiñonez H, Pérez-Escamilla R. Refinement of the Brazilian household food insecurity measurement scale: recommendation for a 14-item EBIA. *Rev Nutr*. (2014) 27:241–51. doi: 10.1590/1415-52732014000200010

26. Swindale A, Bilinsky P. Development of a universally applicable household food insecurity measurement tool: process, current status, and outstanding issues. *J Nutr*. (2006) 136:1449S–52S. doi: 10.1093/jn/136.5.1449S

27. Coates J, Frongillo EA, Rogers BL, Webb P, Wilde PE, Houser R. Commonalities in the experience of household food insecurity across cultures: what are measures missing? *J Nutr*. (2006) 136:1438S–48S. doi: 10.1093/jn/136.5.1438S

28. IBGE. Pesquisa nacional por amostra de Domicílios - Suplemento de segurança alimentar. Segurança Alimentar. Rio de Janeiro; (2006).

29. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. (1983) 24:385. doi: 10.2307/2136404

30. Cohen S. Perceived stress in a probability sample of the United States In: . *The social psychology of health*. Thousand Oaks, CA: Sage Publications, Inc (1988). 31–67.

31. Souza Pinho MJ, Meneses Fernandes K, Rocha de oliveira R. Educação, tecnologias e covid-19: o que nos dizem os estudantes. *Olhares Revista do Departamento de Educação da Unifesp*. (2020) 8:97–111. doi: 10.34024/olhares.2020.v8.11042

32. Montagna Da Silveira A, Lúcia Costa De Oliveira A, Pereira FF, Rosso Bicca R. *Pedagogical Experiences in Times of Social Isolation: Thoughts regarding the Action of the Study CORE of BRAZILIAN Architecture*. Projectare: revista de arquitetura e urbanismo. (2020) 10:7–24.

33. Monteiro CA, Cannon G, Lawrence M, Louzada MLC, Machado PP. *Ultra-Processed Foods, Diet Quality, and Health Using the NOVA Classification System*. Rome: FAO (2019).

34. Morassut RE, Tian C, Meyre D. Identifying factors associated with obesity traits in undergraduate students: a scoping review. *Int J Public Health*. (2020) 65:1193–204. doi: 10.1007/s00038-020-01458-4

35. Silva DMC, Santos TSS, Conde WL, Slater B. Nutritional status and metabolic risk in adults: association with diet quality as assessed with esquada. *Rev Bras Epidemiol*. (2021) 24:24. doi: 10.1590/1980-549720210019

36. Monteiro CA, Moubarac JC, Levy RB, Canella DS, Louzada MLC, Cannon G. Household availability of ultra-processed foods and obesity in nineteen European countries. *Public Health Nutr*. (2018) 21:18–26. doi: 10.1017/S1368980017001379

37. Daufenback V, Coelho DEP, Bógus CM. Sistemas Alimentares e violações ao Direito Humano à Alimentação Adequada. *Segurança Alimentar e Nutricional*. (2021) 28:e021005–5. doi: 10.20396/san.v28i00.8661745

38. Maia EG, dos Passos CM, Levy RB, Bortoletto Martins AP, Mais LA, Claro RM. What to expect from the price of healthy and unhealthy foods over time? The case from Brazil. *Public Health Nutr*. (2020) 23:579–88. doi: 10.1017/S1368980019003586

39. BRASIL. *Decreto nº 7.824, de 11 de outubro de 2012. Regulamenta a Lei nº 12.711, de 29 de agosto de 2012, que dispõe sobre o ingresso nas universidades federais e nas instituições federais de ensino técnico de nível médio*. Brasil: Diário Oficial da União (2012).

40. Souza SA. A expansão recente do ensino superior. *Cadernos de Estudos e Pesquisas em Políticas Educacionais*. (2021) 3:48. doi: 10.24109/27635139.ceppe.v3i4.4892

41. Lazarus RS, Folkman S. *Stress, Appraisal, and Coping*. Berlin: Springer (1984).

42. Yönder Ertem M, Karakaş M. Relationship between emotional eating and coping with stress of nursing students. *Perspect Psychiatr Care*. (2021) 57:433–42. doi: 10.1111/ppc.12599

43. el Ansari W, Adetunji H, Oskrochi R. Food and mental health: relationship between food and perceived stress and depressive symptoms among university students in the United Kingdom. *Cent Eur J Public Health*. (2014) 22:90–7. doi: 10.21101/cejph.a3941

44. Flaudias V, Iceta S, Zerhouni O, Rodgers RF, Billieux J, Llorca PM, et al. COVID-19 pandemic lockdown and problematic eating behaviors in a student population. *J Behav Addict*. (2020) 9:826–35. doi: 10.1556/2006.2020.00053

45. Gallo LA, Gallo TF, Young SL, Moritz KM, Akison LK. The impact of isolation measures due to COVID-19 on energy intake and physical activity levels in Australian university students. *Nutrients*. (2020) 12:1865. doi: 10.3390/nu12061865

46. Papier K, Ahmed F, Lee P, Wiseman J. Stress and dietary behaviour among first-year university students in Australia: sex differences. *Nutrition*. (2015) 31:324–30. doi: 10.1016/j.nut.2014.08.004

47. Malta DC, Szwarcwald CL, Barros MBA, Gomes CS, Machado ÍE, Souza Júnior PRB, et al. A pandemia da COVID-19 e as mudanças no estilo de vida dos brasileiros adultos: um estudo transversal, 2020. *Epidemiologia e Serviços de Saúde*. (2020) 29:e2020407. doi: 10.1590/s1679-49742020000400026

48. Husky MM, Kovess-Masfety V, Swendsen JD. Stress and anxiety among university students in France during Covid-19 mandatory confinement. *Compr Psychiatry*. (2020) 102:152191. doi: 10.1016/j.comppsych.2020.152191

49. Dash S, Bourke M, Parker AG, Dadswell K, Pascoe MC. Lifestyle behaviours and mental health and wellbeing of tertiary students during COVID-19 lockdown in Australia: a cross-sectional study. *Compr Psychiatry*. (2022) 116:152324. doi: 10.1016/j.comppsych.2022.152324

50. Burns D, Dagnall N, Holt M. Assessing the impact of the COVID-19 pandemic on student wellbeing at universities in the United Kingdom: a conceptual analysis. *Front Educ (Lausanne)*. (2020) 5:5. doi: 10.3389/feduc.2020.582882

51. Mei J, Fulay AP, Wolfsn JA, Leung CW. Food insecurity and dietary intake among college students with unlimited meal plans at a large, Midwestern university. *J Am Diet Assoc*. (2021) 121:2267–74. doi: 10.1016/j.jand.2021.04.009

52. el Zein A, Shelnutt KP, Colby S, Vilaro MJ, Zhou W, Greene G, et al. Prevalence and correlates of food insecurity among U.S. college students: a multi-institutional study. *BMC Public Health*. (2019) 19:660. doi: 10.1186/s12889-019-6943-6

53. Martinez SM, Grandner MA, Nazmi A, Canedo ER, Ritchie LD. Pathways from food insecurity to health outcomes among California university students. *Nutrients*. (2019) 11:1419. doi: 10.3390/nu11061419

54. PENSSAN. *II VIGISAN: Inquérito Nacional sobre Insegurança Alimentar no Contexto da Pandemia da Covid-19 no Brasil*. Berlin: Springer (2022).

55. PENSSAN. *VIGISAN: Inquérito Nacional sobre Insegurança Alimentar no Contexto da Pandemia da Covid-19 no Brasil*. Berlin: Springer (2021).

56. Smith MD, Wesselbaum D. COVID-19, food insecurity, and migration. *J Nutr*. (2020) 150:2855–8. doi: 10.1093/jn/nxaa270

57. Ribeiro-Silva RC, Pereira M, Campello T, Aragão É, Guimarães JMM, Ferreira AJ, et al. Covid-19 pandemic implications for food and nutrition security in Brazil. *Ciencia e Saude Coletiva*. (2020) 25:3421–30. doi: 10.1590/1413-81232020259.22152020

58. Scrinis G, Monteiro C. From ultra-processed foods to ultra-processed dietary patterns. *Nat Food*. (2022) 3:671–3. doi: 10.1038/s43016-022-00599-4

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Network analysis of eating disorder and depression symptoms among university students in the late stage of COVID-19 pandemic in China

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Background: Eating disorders (EDs) and depression are common in university students, especially during the COVID-19 pandemic. The aim of this study was to elucidate characteristics of EDs and depression symptoms networks among Chinese university students in the later stage of the COVID-19 pandemic in China.

Methods: A total of 929 university students completed the SCOFF questionnaire measuring EDs and Patient Health Questionnaire with 9 items (PHQ-9) measuring depression in Guangzhou, China. The network model was applied to identify central symptoms, bridge symptoms, and important connections between SCOFF and PHQ-9 using R studio. The subgroup analyses of both genders in medical and non-medical students were further explored.

Results: In the networks of the whole sample, central symptoms included "Loss of control over eating" (EDs) and "Appetite changes" (depression). The bridge connections were between "Loss of control over eating" (EDs) and "Appetite changes" (depression), between "Deliberate vomiting" (EDs) and "Thoughts of death" (depression). "Appetite changes" (depression) and "Feeling of worthlessness" (depression) were central symptoms in both subgroups of medical and non-medical students. "Fatigue" (depression) was the central symptom in the female and medical students group. The edge between "Loss of control over eating" (EDs) and "Appetite changes" (depression) acted as a bridge in all subgroups.

Conclusion: Social network approaches offered promising ways of further understanding the association between EDs and depression among university students during the pandemic of COVID-19 in China. Investigations targeting central and bridge symptoms would help to develop effective treatments for both EDs and depression for this population.

KEYWORDS

social network analysis, eating disorder, depression, COVID-19, Chinese students

Introduction

The global pandemic caused by the coronavirus disease 2019 (COVID-19) since December 2019 has had significant repercussions, disrupting daily life and causing physical and mental health concerns. Alongside quarantine and isolation measures (1), this crisis has led to an upsurge in psychological distress, such as eating disorders (EDs) and depression, among the general population (2). EDs are disabling, potentially lethal, and expensive mental health conditions that significantly compromise physical health and disrupt psychosocial functioning (3). Negative attitudes toward weight, body shape, and eating habits play a crucial role in the development and maintenance of EDs (3). EDs were prevalent among university students, as evidenced by previous studies (4–6). A recent meta-analysis of 15 cross-sectional studies with 41,956 Chinese university students reported a depression prevalence rate of 27% during the COVID-19 pandemic (7).

EDs and depression often co-occur, as evidenced by research on both clinical and non-clinical populations. Specifically, non-clinical studies have shown that students at risk for EDs tend to have higher depression scores than their counterparts without EDs risk (8), while a clinical study found that almost 20% of EDs patients had comorbid major depression and nearly half reported clinically significant depressive symptoms (9). A survey conducted during the COVID-19 pandemic among Italian college students also revealed a positive association between psychological problems such as depression, anxiety, and tension, and EDs symptoms such as interoceptive awareness and binge eating behaviors, regardless of gender differences (10).

EDs and depression have a bi-directional relationship. In non-clinical samples, eating pathology significantly predicted depression, possibly due to the failure to achieve an idealized physical ideal or weight gain caused by binge eating (11). Depression, on the other hand, could predict the development of eating pathology as a compensatory mechanism to reduce negative affect (12). Notably, depression has different effects on the development of EDs in male and female adolescents. For females, depression has a direct impact on body dissatisfaction and EDs symptoms, while for males, it has a greater moderating effect on sociocultural influences (13). Low self-esteem and self-directedness are also linked to the development of EDs via depression (13). The "common-cause" model posits that cognitive inefficiency underlies both depression and EDs, leading to their comorbidity (14).

Network analysis is an increasingly utilized model for exploring comorbidity between disorders in psychopathology research (15). In network approaches, disorders are viewed as systems of causally interconnected symptoms rather than being solely dependent on latent variables (15), which indicates that these problems interact with and influence each other (16–18). Therefore, these systems can be represented, analyzed, and studied in their full complexity. Moreover, network modeling has the added philosophical benefit of rejecting the unrealistic notion that symptoms of a single disorder have a singular causal background (15). According to network theory, the nodes in the network represent symptoms of disorders. Central nodes are those that are more important than others within the framework (19). Important symptoms in a disorder could be detected by computing three centrality indices, namely strength (measuring direct connections between symptoms), closeness (measuring indirect connections), and betweenness (measuring the importance of a symptom in the average path between two other symptoms) (19). Identifying these key symptoms can aid in the selection of ideal treatment targets and inform clinical treatment decisions (18). In addition, edges, which represent relationships between two symptoms, are another vital element in the network. These edges vary in terms of their edge weights or strength of linkages (19). Among all nodes, bridge symptoms identified through bridge centrality computation are considered potential pathways through the comorbidity of two disorders (17). The identification of bridge symptoms is valuable in making treatment of comorbid disorders more targeted and problem-focused.

Several studies have utilized network analysis to examine EDs both in clinical and non-clinical samples. Within non-clinical samples, cognitive symptoms related to shape and weight concern, such as "shape overvaluation," "weight dissatisfaction," and "desiring weight loss," emerged as highly central symptoms in the EDs network (20–22) and some clinical samples (23, 24). However, rather than "body dissatisfaction" and "drive for thinness", "interoceptive awareness" and "ineffectiveness" were found to be central to the EDs networks in other clinical samples (25). Network analysis has also been used to examine depression in different populations. In adolescents, core symptoms in depression networks included "sadness," "self-hatred," "loneliness," "self-deprecation," and "feeling like a failure" (26–28). During the COVID-19 pandemic, "loss of energy," "psychomotor problems," and "guilt feelings" were identified as the three central symptoms in the depression network in the community in Macao (29).

Existing research on EDs and depression using network analysis has primarily focused on early adolescent samples. In the clinical samples, certain physical symptoms such as "restlessness," "low self-esteem," and "feeling overwhelmed" have been identified as bridge symptoms linking EDs to depression (24). In non-clinical adolescent samples, core symptoms of EDs have been identified as the desire to lose weight (30, 31), dissatisfaction with shape and weight (31), and preoccupation with shape or weight (31). On the other hand, core depressive symptoms of depression in these non-clinical samples included feeling "depressed," "lonely," and experiencing "low energy" (31). Furthermore, additional bridge symptoms connecting EDs and depression in these non-clinical samples include "feeling like a failure" (30), "irritable," (31) "social eating," (31) and "depressed" (31). However, the generalizability of the above-mentioned results to university student populations is uncertain, especially during the COVID-19 pandemic when a significant increase in these disorders has been reported (32, 33). It is worth noting that female university students have been found to be at higher risk of developing EDs (8, 34).

A deeper understanding of the intricate relationship between EDs and depression could greatly improve the efficacy of interventions in educational and clinical settings. However, there is a notable lack of network analysis examining the symptoms of EDs and depression specifically during the COVID-19 pandemic. Given the unique characteristics of Chinese university students, it is crucial to investigate the underlying mechanisms that contribute to the co-occurrence of

Abbreviations: EDs, Eating disorders; PHQ-9, Patient Health Questionnaire with 9 items; CHNS, the China Health and Nutrition Survey; CS, correlation stability; CBT-E, enhanced cognitive-behavioral therapy.

EDs and depression. To the best of our knowledge, this study represents one of the pioneering efforts to explore the comorbidity between EDs and depression among Chinese university students, particularly within the context of COVID-19 pandemic.

Therefore, in this study, we approached social network analysis to investigate the central and bridge symptoms between EDs and depression symptoms among Chinese university students during the later stage of the COVID-19 pandemic. We also examined the potential differences in subgroups of male and female students, as well as medical and non-medical students.

Methods

Participants and procedure

A cross-sectional survey using structured questionnaires was performed among university students in Guangzhou, China. The data was collected from October 2020 to December 2020, when COVID-19 was under control and alleviated in China. An online questionnaire (wjx.cn, which is one of the most popular online survey platforms in China) was distributed to university students via WeChat groups and WhatsApp messaging application with the snowball sampling method. A total of 929 participants completed the survey. The present study was approved by the ethics committee of Jinan University, and all participants provided e-written informed consents prior to participation. Participant characteristics are provided in Table 1.

Measurements

Demographics information

Demographic information was collected, including age, gender, major, educational level, and BMI (Formula: $\mathrm{BMI}=\frac{\mathrm{weight}\,(\mathrm{kg})}{\mathrm{height}^2\,(m^2)};\mathrm{kg}/m^2$).

Eating disorders symptoms

Eating disorder symptoms were assessed with the SCOFF questionnaire (35). SCOFF is an acronym derived from the first letter of the focus word in each of the five eating-related items that focus on the core features of anorexia nervosa and bulimia nervosa. The five SCOFF questions were: "Do you make yourself Sick because you feel uncomfortably full?," "Do you worry you have lost Control over how much you eat?," "Have you recently lost more than One stone in a 3-month period?," "Do you believe yourself to be Fat when others say you are too thin?," and "Would you say that Food dominates your life?." Each item rates on a dichotomous score of yes ("1") or no ("0"). The scores on each item were then added up, resulting in a total score ranging from 0 to 5. A score of ≥2 was considered indicative of anorexia nervosa or bulimia. The SCOFF questionnaire has been validated in the Chinese population (36) and was used in the China Health and Nutrition Survey (CHNS) in 2015 (37). In the present study, the Cronbach's alpha of this scale was 0.7, indicating good reliability.

Depression symptoms

The individual's depression symptoms were measured using the Patient Health Questionnaire with 9 items (PHQ-9) (38), which anchors to the past 2 weeks. Each item is rated on a four-point scale ranging from 0 (not at all) to 3 (nearly every day), with a higher score indicating a greater frequency and intensity of depression symptoms. An example item is "How often have you been bothered by feeling down, depressed, or hopeless?." The total score ranges from 0 to 27, with higher scores representing more severe depression symptoms. The Chinese version of the PHQ-9 has been found to have good psychometric properties among university students in previous studies (39, 40). In our sample, the Cronbach alpha was 0.91, suggesting excellent reliability.

Data analysis

Descriptive statistics were analyzed for the demographic variables and scores of questionnaires and scales, using SPSS 23.0. Continuous variables were presented with means, standard deviations (SDs), and ranges. Network models depicting the structure of EDs and depression symptoms and interactions between them were computed using R studio. As all consenting participants were prompted to complete all items, there was no missing data.

We constructed separate network models for EDs and depression items in five samples: the entire sample, as well as subgroups of male and female students, and medical and non-medical students.

TABLE 1 Participant characteristics (*N*=931).

		N	Mean	SD	Range
Age (years)	Total	927	21.03	2.614	17–50
	Males	298	21.55	3.427	17–50
	Females	629	20.79	2.082	17–36
	Medical students	596	20.68	2.273	17–36
	Other major	331	21.66	3.040	17–50
BMI (kg/m^2)	Total	927	21.17	3.591	13.79–42.34
	Males	298	22.71	3.661	15.78–34.33
	Females	629	20.43	3.318	13.79–42.34
	Medical students	596	21.44	3.619	13.79–37.59
	Other major	331	20.67	3.49	14.68–42.34

SD, Standard Deviations.

Visualization of the network model was generated using the *qgraph* package in R (41). The graphic LASSO method was used to construct a network of regularized partial correlations between nodes (19). Thinker lines represent stronger relationships between symptoms. Solid lines denote positive relationships and dashed lines denote negative relationships.

The stability and accuracy of each network model were estimated using the *bootnet* package in R, with 1,000 case-dropping bootstraps. Significant differences between edge weights were tested with a 95% confidence interval. To assess the strength centrality index, a correlation stability coefficient (CS-coefficient) was used (19), with a recommend value over 0.25 and preferably greater than 0.5 (19). The *goldbricker* function in R was used to identify nodes measuring the same underlying construct, with a threshold set at 0.25. All pairs of nodes falling below this threshold were considered "bad pairs."

We calculated and visualized centrality indices (e.g., strength, closeness, betweenness) of nodes using the *centralityPlot* function in the *bootnet* package in R (19). Strength centrality was used to identify the most central symptoms, as it has been found to be the most reliable measure of centrality (42). Centrality difference-tests were conducted via the *bootnet* package in R to assess significant differences in symptoms strength (19). To examine comorbidity between the two disorders, bridge symptoms were identified using the *bridge* function in the *networktools* package in R, which allowed us to identify which items were most interconnected across EDs and depression symptoms (43).

Result

Network structures of eating disorders and depressive symptoms

The networks displayed in Figure 1 showed the relationships between EDs and depression symptoms for the whole population, subgroups of male and female students, and medical and non-medical students. Table 2 showed the corresponding symptoms of each node in Figure 1 and reported the SDs and means of the EDs and depression symptoms scores.

The network for the whole population showed the strongest edges were found within the inter-community in EDs and depression. In the EDs community, they were et2 (Loss of control over eating) and et4 (Feeling fat), et2 (Loss of control over eating) and et5 (Food domination), et2 (Loss of control over eating) and et1 (deliberate vomiting). In the depression community, they were ep8 (Motor) and ep9 (Thoughts of death), ep6 (Worthless) and ep2 (Sad mood), ep3 (Sleep) and ep4 (Fatigue), which were the most positive correlations.

However, the symptoms significantly connected to et2 (Loss of control overeating) varied among the four subgroups. Among male students, et4 (Feeling fat) and et5 (Food domination) were directly linked to et2 (Loss of control over eating). Among female students, et1 (Deliberate vomiting) was directly linked to et2 (Loss of control overeating). For both medical students and non-medical students, et1 (Deliberate vomiting) and et4 (Feeling fat) were directly linked to et2 (Loss of control over eating). The item of et1 (Deliberate vomiting) was also intensely linked to et5 (food domination) in medical students.

The connections between depression symptoms showed significant differences among the four subgroups. Among male students, ep8 (Motor) was directly linked to ep9 (Thoughts of death), while ep3 (Sleep) was directly linked to ep4 (Fatigue). Among female students, ep7 (Concentration) and ep9 (Thoughts of death) were strongly linked to ep8 (Motor). Among medical students, ep2 (Sad mood) and ep9 (Thoughts of death) were intensely linked to ep6 (Worthless), while ep3 (Sleep) was linked to ep4 (Fatigue). For non-medical students, ep8 (Motor) was intensely linked to ep9 (Thoughts of death) while ep1 (Anhedonia) was linked to ep4 (Fatigue).

Centrality comparison between nodes

Regarding centrality analysis (Figure 2), we evaluated the importance of each node based on its calculated scores. In the EDs networks, et2 (Lose control over eating) was consistently identified as the most central symptom in terms of centrality strength, betweenness, and closeness across all five networks. In addition, only the whole sample and female students subgroups' networks had the second-highest betweenness centrality symptom—et1 (Sickness on feeling full), compared with other groups.

Among depression symptoms, ep5 (Appetite changes) was the most central node in terms of centrality strength in the network of the whole sample, as well as having the highest closeness and betweenness in four subgroups' networks.

Other significant nodes varied among gender and major subgroups' networks. In both gender subgroups' networks, ep8 (Psychomotor agitation/retardation) had the highest strength in males, and ep4 (Fatigue) had the highest strength in females. Regarding networks of different majors, both medical students' and non-medical students' networks had ep5 (Appetite changes) and ep6 (Feeling of worthlessness) as the most central nodes in terms of strength. Additionally, in the medical students' network, ep4 (Fatigue) had the second-highest strength, while ep8 (Psychomotor agitation/retardation) had the second-highest closeness and betweenness.

Stability of centrality indices and accuracy of nodes

The strength stability of all networks with 95% confidence intervals via bootstrap was satisfactory (Supplementary Figures 1–5), the total group had a CS (cor = 0.7) of 0.75, the female and medical students had a CS (cor = 0.7) of 0.749, and the male and non-medical students had a CS (cor = 0.7) of 0.595. The *'goldbricker'* function in R studio was employed to evaluate the bootstrap difference of each paired node, discovering no "bad pairs." (Supplementary Figures 6–10).

Edge comparisons and bridge symptoms identifications

The network bridge connections were displayed in Figure 3. The edge between et2 (Loss of control over eating) and ep5 (Appetite changes) was the strongest bridge in all networks of EDs and depression. The edge weight was 0.2050 in the network of the whole sample, 0.2228 in the male group, 0.1613 in the female group, 0.1886 in the medical students' group, and 0.1782 in the non-medical

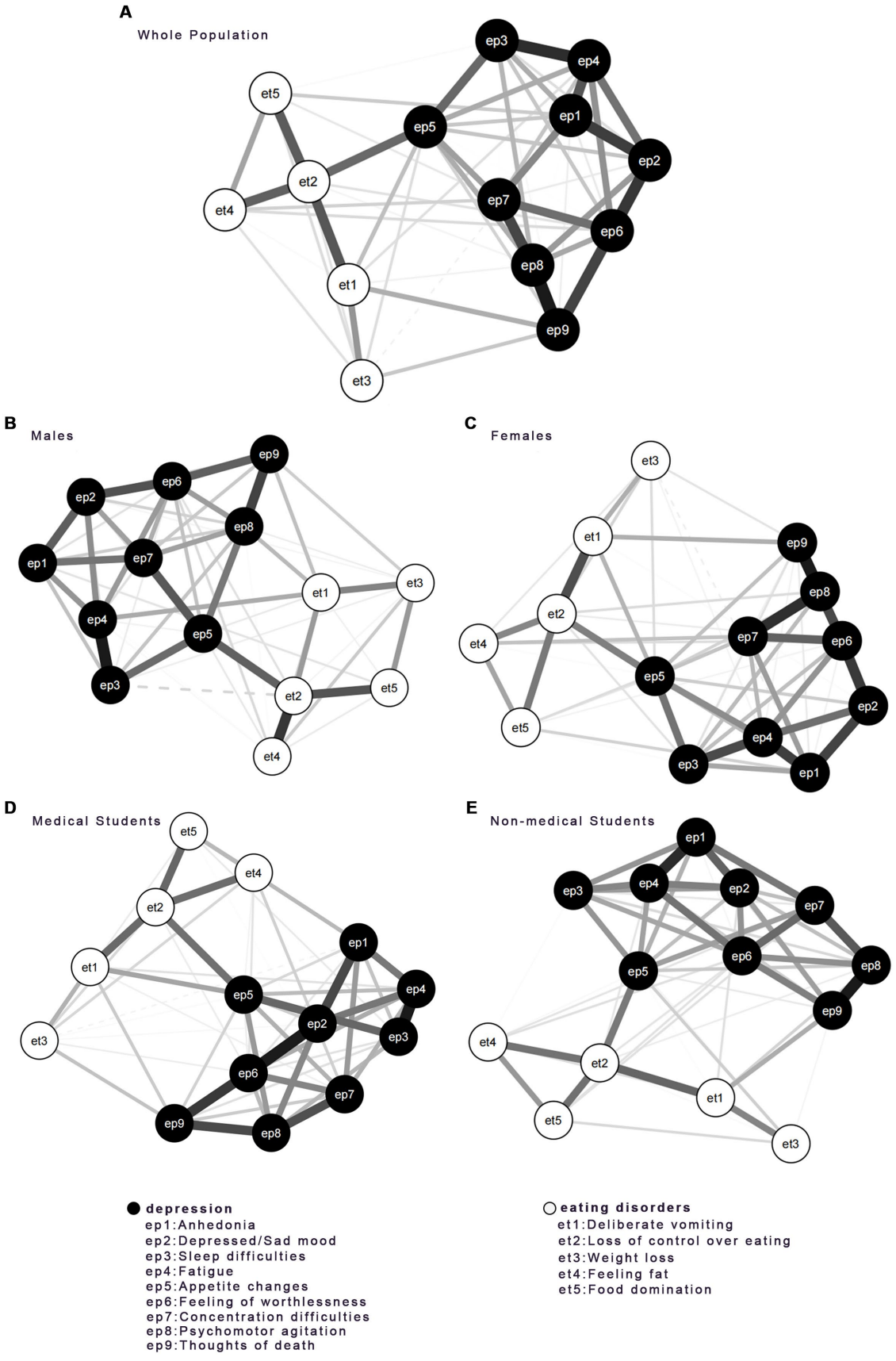

FIGURE 1
Networks of EDs and Depression for **(A)** the whole population, **(B)** males, **(C)** females, **(D)** medical students, and **(E)** non-medical students. EDs community was shown in white and depression items were shown in black. The thickness of the line depicted edge strength.

TABLE 2 Item, item content, item abbreviations, means and standard deviations for SCOFF and PHQ-9 items.

Item	Item content	Item abbreviation	*M*	SD
et1	Sickness on feeling full	Deliberate vomiting	1.16	0.36
et2	Lose control over eating	Loss of control over eating	1.30	0.46
et3	Lose weight	Weight loss	1.12	0.32
et4	Thoughts of being fat	Feeling fat	1.38	0.48
et5	Food domination	Food domination	1.40	0.49
ep1	Anhedonia	Anhedonia	1.94	0.88
ep2	Depressed or sad mood	Sad mood	1.85	0.83
ep3	Sleep difficulties	Sleep	1.88	0.95
ep4	Fatigue	Fatigue	2.09	0.89
ep5	Appetite changes	Appetite	1.77	0.90
ep6	Feeling of worthlessness	Worthless	1.76	0.90
ep7	Concentration difficulties	Concentration	1.92	0.93
ep8	Psychomotor agitation/retardation	Motor	1.53	0.83
ep9	Thoughts of death	Death	1.40	0.77

M, Mean; SD, Standard Deviations.

students' group. Other bridge connections were: et1 (Deliberate vomiting) and ep9 (Thoughts of death) in the whole sample, edge weight = 0.1006; et1 and ep4 (Fatigue) in the male group, edge weight = 0.1174; et1 (Deliberate vomiting) and ep8 (Psychomotor agitation/retardation) in the male group, edge weight = 0.0976; et1 (Deliberate vomiting) and ep9 (Thoughts of death) in the female group, edge weight = 0.0996; et1 (Deliberate vomiting) and ep5 (Appetite changes) in the female group, edge weight = 0.0934; et1 (Deliberate vomiting) and ep5 (Appetite changes) in the medical students group, edge weight = 0.1107; et1 (Deliberate vomiting) and ep9 (Thoughts of death) in the non-medical students group, edge weight = 0.1095.

Bridge symptoms elucidated the associations between EDs and depression (see Figure 4). The bridge symptoms in all groups, et2 (Loss of control over eating) (EDs) and ep5 (Appetite) (depression), might be efficacious targets in the prevention and treatment of the comorbidity of EDs and depression for university students with different genders and majors. Moreover, there was a variance in bridge symptoms across different groups. Ep6 (Feeling of worthlessness) (depression) served as a bridge symptom in the network of the whole sample. Et1 (Deliberate vomiting) (EDs) was the bridge symptom in the medical student group and the male group.

Discussion

To the best of our knowledge, this is the first network analytic study of the comorbidity between EDs and depression among Chinese university students in the later stage of the COVID-19 pandemic in China. Through our analysis, we identified several crucial symptoms and edges, which offer potential targets and pathways for interventions. The observed comorbidity between EDs and depression partially aligns with the findings from a network analysis conducted among Chilean university students (44), which additionally highlighted the central role of physical anxiety symptoms in EDs.

Bridge symptoms

Across the network of EDs and depression in the overall sample, we detected three key bridge symptoms, namely "Loss of control over eating" (EDs), "Appetite changes" (depression), and "Feeling of worthlessness" (depression). Among them, "Loss of control over eating" and "Appetite changes" also acted as bridge symptoms in the networks of subgroups of male, female, medical, and non-medical students, which corroborated their central roles in the link between EDs and depression. This result was consistent with the prior research exploring the associations between fear of losing control over eating and depressive symptoms among young adults in the United States (45). Individuals with greater endorsement of depression symptoms were more likely to lose control over eating. It has been reported that the odds of overeating increased during the COVID-19 pandemic (46). Emotional eating refers to the tendency to overeat as a reaction to negative feelings or stress. Negative feelings such as distress and depression could be a leading cause of the insurgency of emotional hunger (47). Factors of isolation, lack of stimuli, and food routines changing, which emerged and worsened during the lockdown of COVID-19, might influence people's ability to control their eating habits (48). Such changes, including overeating, could increase students' depression symptoms due to the worries about their health and fitness. Early identification and intervention of cognitive features like "Loss of control over eating" may therefore help reduce the risk of developing EDs and depression.

The depressive symptom of "Feeling of worthlessness" was a bridge symptom between EDs and depression, which was consistent with the findings in a previous study in Iranian adolescents and young adults (30), where "Feeling like a failure" showed the highest bridge centrality between depression and disordered eating. This was further supported by network analysis on mental health in patients with EDs (49). According to the model of schemas in the eating disorders posted by Waller et al., food restriction acted as the primary avoidance and bingeing acted as the secondary avoidance of the distress

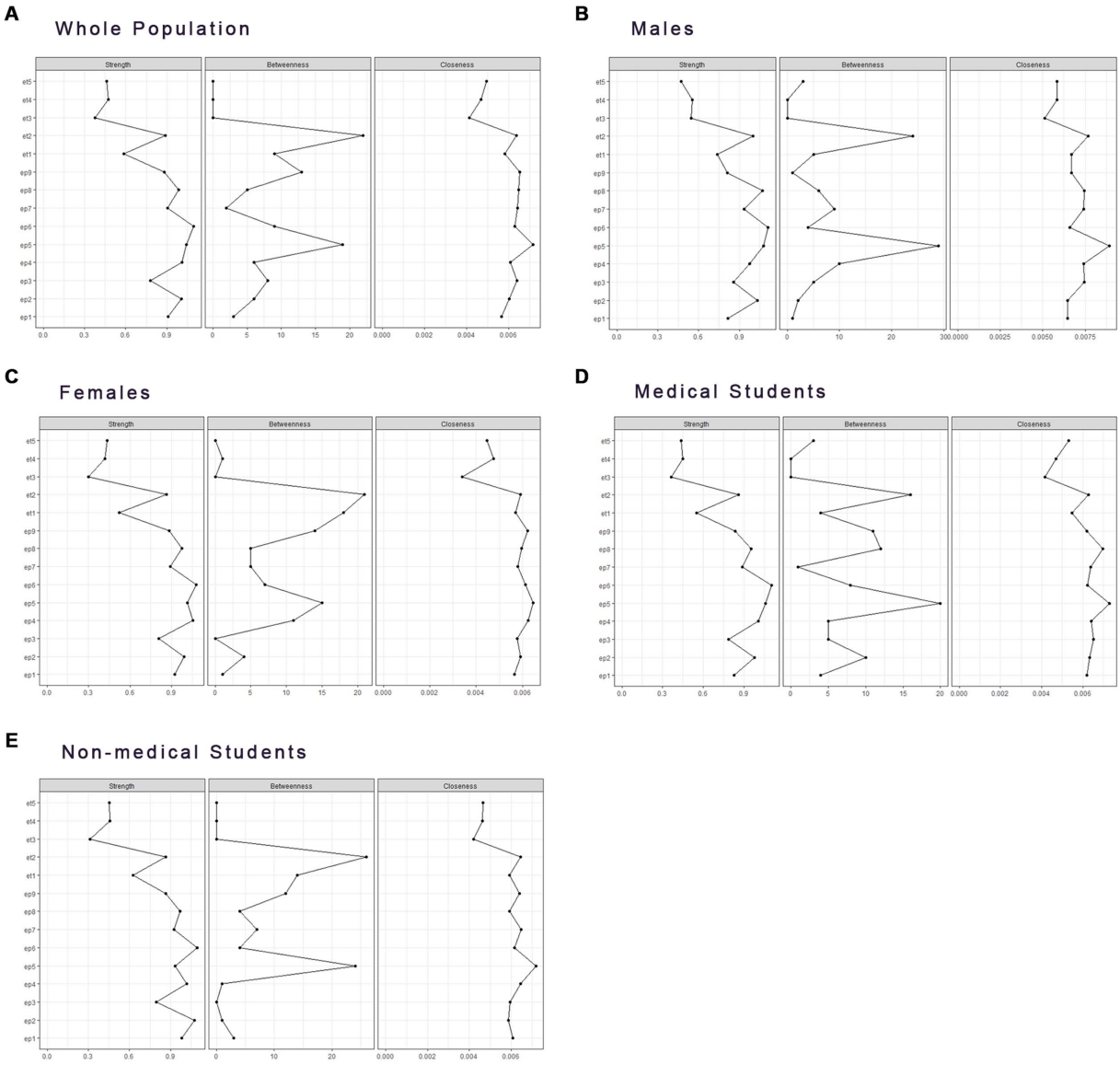

FIGURE 2
Centrality index of networks between EDs and Depression for **(A)** the whole population, **(B)** males, **(C)** females, **(D)** medical students, and **(E)** non-medical students.

associated with negative self-brief (50). Thus, students feeling worthless were at high risk of developing disordered eating. Enhanced cognitive-behavioral therapy (CBT-E) has been developed to target feelings of worthlessness for EDs, which was confirmed in the previous findings (51).

For male students and medical students, it was observed that "Deliberate vomiting" (EDs) was a bridge symptom between EDs and depression. During the COVID-19 pandemic, Chinese male students were found to receive less social support when compared with females, which was associated with high levels of mental distress (e.g., depression, anxiety, and stress symptoms) (52). Females received more support due to their willingness to express their problems and stress, larger social networks (53), more sources to draw support, more satisfaction with friends, and the general acknowledgment that females need more protection than males (54). Additionally, staying up late playing games was more common in male students, which played a role in the development of irregular life rhythms, unhealthy eating habits, and gastrointestinal discomfort. Therefore, negative moods including depression and gastrointestinal distress both increased the odds of "Deliberate vomiting" in male students. To alleviate the level of EDs symptoms (e.g., vomiting) and depression symptoms in male students, more social support, targeting psychological interventions, and guidance on healthy life rhythm are needed. The COVID-19 pandemic has had a particularly strong impact on the educational integrity of medical programs. While lecture-based teaching was transitioned to an online format, clinical exposure and experiment learning were not as easily replicated. Difficulties in adjusting to the examination and curricular restructuring led to increased psychological distress, anxiety, and depression about the academic burden among medical students. Other sources of stress and depression include the possibility of being fast-tracked to the frontline or deployed to other areas of the health

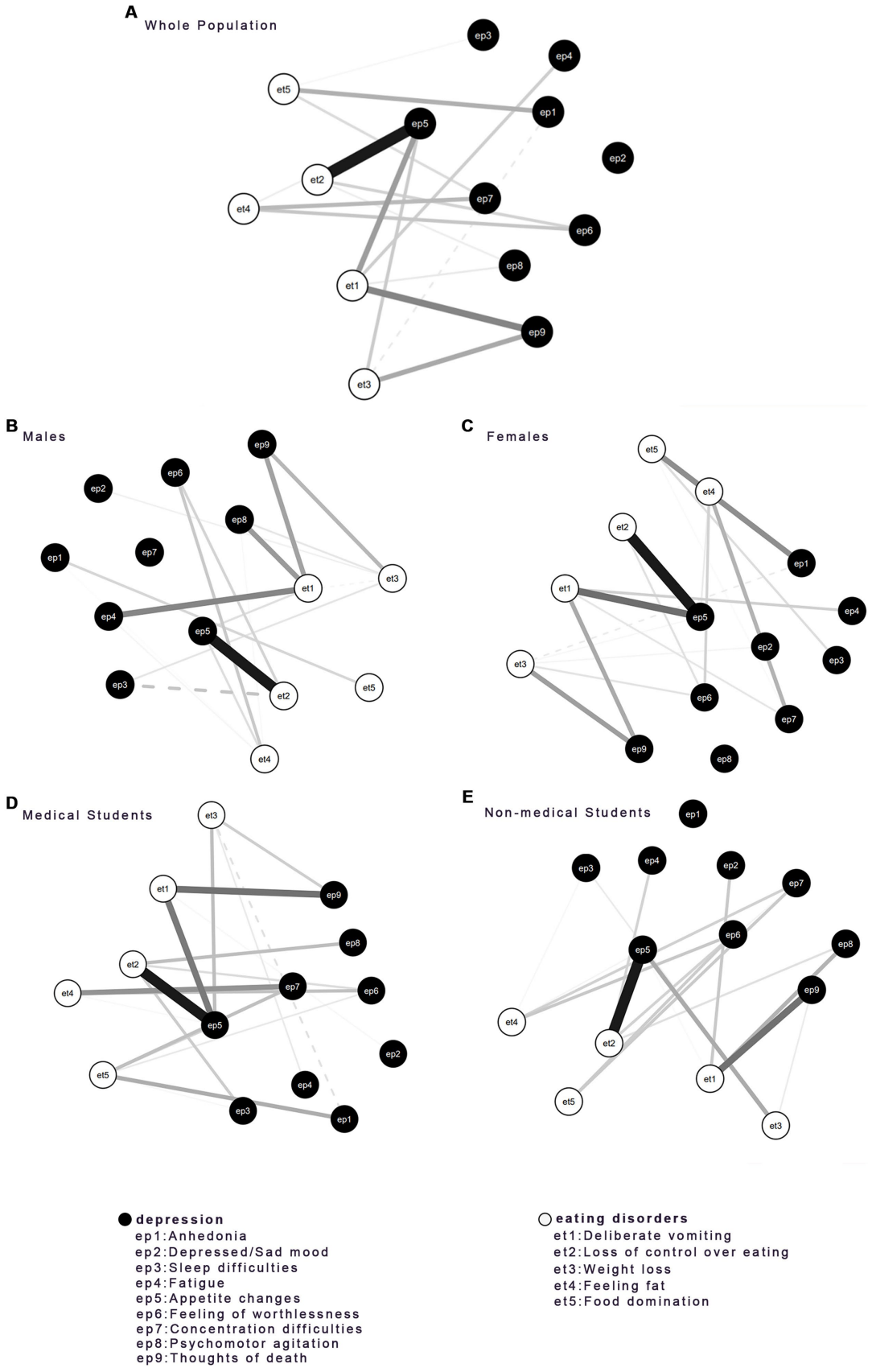

FIGURE 3
Bridge connection between EDs and depression disorder of all groups included **(A)** the whole population, **(B)** males, **(C)** females, **(D)** medical students, and **(E)** non-medical students. Solid lines represent positive connections, and dashed lines represent negative connections.

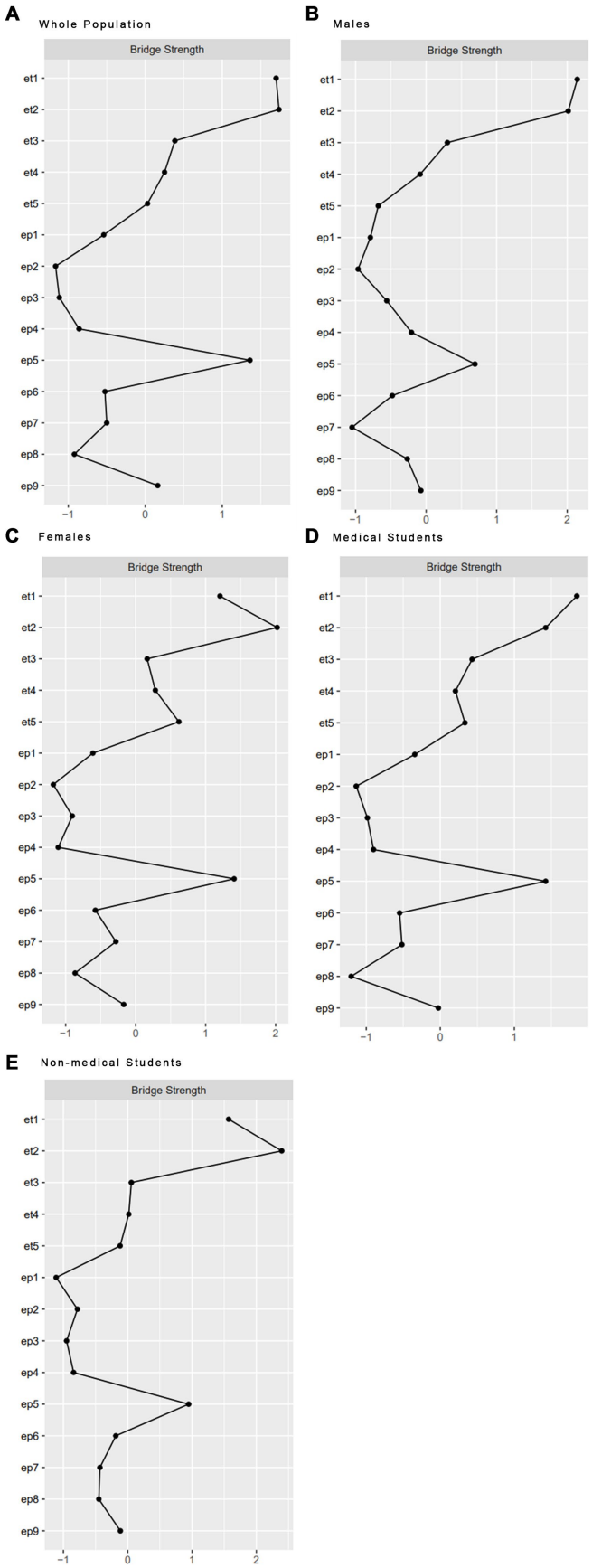

FIGURE 4
Bridge strength of all groups between EDs and Depression included **(A)** the whole population, **(B)** males, **(C)** females, **(D)** medical students, and **(E)** non-medical students.

service, worries about their own health and well-being, and that of their family. Gastrointestinal discomfort caused by staying up late learning, coupled with high levels of depression, could make medical students more prone to vomit.

EDs edges

Within the community of EDs symptoms, three positive edges were markedly higher than others, including the edge between "Loss of control over eating" and "Deliberate vomiting," the edge between "Loss of control over eating" and "Feeling fat," and the edge between "Loss of control over eating" and "Food domination."

The previous study had shown "Feeling fat" to be a significant and independent predictor of dietary restraint and eating concerns (55), suggesting that students feeling fat are more likely to lose control of overeating. Additionally, body dissatisfaction (e.g., "feeling fat"), low self-esteem, and maladaptive social comparison, which might be common in student populations, had been indicated as disruptive psychological patterns common in EDs and unipolar depression (56). These findings highlighted the need for guidance to build a healthy body image in order to prevent EDs symptoms on campus. The unhealthy cult of slimming, which is now popular on social -media, needs to be addressed, as young adults are more vulnerable to information from media sources. Our findings also drew attention to the importance of exploring whether "feeling fat" can be used as an effective target in the treatment of EDs, and the development of standardized measures of "feeling fat."

Depression edges

Within the depression community, our result of a strong positive link between "Psychomotor agitation or retardation" and "Thoughts of death or self-harm" was consistent with results from other populations such as migrant Filipino domestic workers in China (57) and depressed children and adolescents in Hungary (58). Our results emphasized the importance of timely identification and cognitive interventions that address psychomotor agitation or retardation to block negative thoughts of death or self-harm as early among Chinese university students in the COVID-19 pandemic.

EDs-depression pathways

The edge between "loss of control over eating" and "appetite changes" was a potential bridge between EDs and depression. The depression symptom "appetite changes" includes both poor appetite and overeating. The EDs symptom "loss of control over eating" measures the worry about losing control over eating. The overlap of items concerning overeating in both measures might be an important reason for the high positive correlation between the theses two symptoms. Future researchers exploring the association between depression and EDs symptoms should consider excluding overeating-related item in depression scales, or investigating overeating and poor appetite separately. The lockdown limited students' ability to exercise at gyms or outdoors during the COVID-19 pandemic. Therefore, concerns about health and body image may be a motivating factor for the development of a restrained diet (59). Other risk factors, such as increased time with social media and the objectification of the ideal of thinness, could increase the likelihood of anorexia nervosa (59). Encouraging students to exercise at home may help to address some of their concerns during this specific stage, and it may also serve as a potential pathway to alleviate disordered eating and depression. Quarantine during the COVID-19 pandemic has caused feelings of isolation and distress among many individuals (60). Eating has played a significant role in alleviating stress and improving mood (61), and as a result, many people have turned to food as a source of comfort during the lockdown period (48). Emotional eating has become more common as people stayed at home alone (62, 63). This has increased the risk of symptoms related to eating disorders, such as "Loss of control over eating." Therefore, interventions aimed at addressing symptoms of EDs among university students during the COVID-19 pandemic should target negative emotions such as anxiety, fear, and depression.

Limitations

There are several limitations to this study that should be acknowledged. Firstly, the cross-sectional design of this study limited our ability to draw conclusions about the directionality of relationships between symptoms. Secondly, the current findings might not be generalizable to students who have experienced other types of disasters (e.g., earthquakes, typhoons). It is possible that the unique restrictions on living and studying environment due to the COVID-19 pandemic only partially account for the associations within symptom networks. Thirdly, cross-cultural differences may limit the generalizability of the network models to global student populations. Additionally, the study only used self-reported data, which could result in inaccurate reports for some participants who lack self-awareness of psychological symptoms. Lastly, the lack of clinical interviews for eating disorders and depression is a limitation of this study.

Strengths

Despite the limitations, the current study also has several strengths. Firstly, the study included a large sample of university students who were known to have difficulties with EDs and depression impairments. This enabled us to provide reliable and valid evidence of the underlying relationships between these disorders, which could inform the development of interventions. To the best of our knowledge, most network analyses of EDs and depression focused on clinical samples, and the non-clinical research mainly focused on adolescents (31), with university students receiving less attention. Our study filled this gap. Furthermore, the instruments used to assess EDs and depression in our study were validated for use in Chinese students (36, 40), and the SCOFF had been proved to be a valid and reliable screening tool for EDs screening in written form (64). We asked all items in the scales, which allowed for more accurate network estimates. To minimize bias, we excluded the data from questionnaires that were completed too quickly (less than 120 s). Finally, the strength

centrality indexes of all networks were highly stable, which values above 0.50 (19).

Implications

Our study findings have important implications for future clinical practice. We found that the strongest connection in our network was between EDs symptom "Loss of control over eating" and depression symptom "Appetite changes." Therefore, interventions aimed at improving these symptoms may be practical treatment approaches for university students experiencing these disorders during the COVID-19 pandemic. Targeting bridge symptoms through interventions may have the potential to improve symptoms transdiagnostically in individuals with comorbid EDs and depression. Specifically, the examination of variables such as "Loss of control over eating," "Appetite changes," and "Feeling of worthlessness" could serve as potential targets for reducing symptoms of both EDs and depression. It would be valuable for further investigations to explore the influences of these symptoms on university students during the pandemic, particularly focusing on the specific context of Chinese university students. Experimental studies could be designed to examine the effects of educational and social cues, as well as threats related to "Loss of control over eating," "Appetite changes," and "Feeling of worthlessness" among Chinese university students, in order to gain a better understanding of these factors and their impact on individuals in this population. By targeting and addressing these symptoms, interventions may hold promise in improving the overall well-being of Chinese university students facing EDs and depression. Additionally, further research on cross-cultural symptom networks of the association between mental problems (such as EDs and depression) could provide new insights. Longitudinal studies of the comorbidity could also help to understand the directionality, variability, and interaction of symptoms within the network over time.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the ethics committee of Jinan University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

WY and DX: methodology, interpretation, writing—original draft, and writing—review and editing. YS: methodology, data analysis and interpretation, and writing—original draft. TD: methodology, data analysis and interpretation, and writing—original draft. PX: conceptualization, data collection, methodology, writing—review and editing, supervision, project administration, and funding acquisition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1176076/full#supplementary-material

References

1. Berekaa MM. Insights into the COVID-19 pandemic: origin, pathogenesis, diagnosis, and therapeutic interventions. *Front Biosci (Elite Ed)*. (2021) 13:117–39. doi: 10.2741/874

2. Clemente-Suárez VJ, Martínez-González MB, Benitez-Agudelo JC, Navarro-Jiménez E, Beltran-Velasco AI, Ruisoto P, et al. The impact of the COVID-19 pandemic on mental disorders. A critical review. *Int J Environ Res Public Health*. (2021) 18:10041. doi: 10.3390/ijerph181910041

3. Treasure J, Duarte TA, Schmidt U. Eating disorders. *Lancet*. (2020) 395:899–911. doi: 10.1016/S0140-6736(20)30059-3

4. Eisenberg D, Nicklett EJ, Roeder K, Kirz NE. Eating disorder symptoms among college students: prevalence, persistence, correlates, and treatment-seeking. *J Am Coll Heal*. (2011) 59:700–7.2010.546461. doi: 10.1080/07448481.2010.546461

5. Tavolacci MP, Grigioni S, Richard L, Meyrignac G, Déchelotte P, Ladner J. Eating disorders and associated health risks among university students. *J Nutr Educ Behav*. (2015) 47:412–420.e1. doi: 10.1016/j.jneb.2015.06.009

6. Tong J, Miao S, Wang J, Yang F, Lai H, Zhang C, et al. A two-stage epidemiologic study on prevalence of eating disorders in female university students in Wuhan,

China. *Soc Psychiatry Psychiatr Epidemiol*. (2014) 49:499–505. doi: 10.1007/s00127-013-0694-y

7. Zhang Y, Bao X, Yan J, Miao H, Guo C. Anxiety and depression in Chinese students during the COVID-19 pandemic: a Meta-analysis. *Front Public Health*. (2021) 9:697642. doi: 10.3389/fpubh.2021.697642

8. Fragkos KC, Frangos CC. Assessing eating disorder risk: the pivotal role of achievement anxiety, depression and female gender in non-clinical samples. *Nutrients*. (2013) 5:811–28. doi: 10.3390/nu5030811

9. Giovanni A-D, Carla G, Enrica M, Federico A, Maria Z, Secondo F. Eating disorders and major depression: role of anger and personality. *Depress Res Treat*. (2011) 2011:194732–2. doi: 10.1155/2011/194732

10. De Pasquale C, Sciacca F, Conti D, Pistorio ML, Hichy Z, Cardullo RL, et al. Relations between mood states and eating behavior during COVID-19 pandemic in a sample of Italian college students. *Front Psychol*. (2021) 12:684195–5. doi: 10.3389/fpsyg.2021.684195

11. Puccio F, Fuller-Tyszkiewicz M, Ong D, Krug I. A systematic review and meta-analysis on the longitudinal relationship between eating pathology and depression. *Int J Eat Disord*. (2016) 49:439–54. doi: 10.1002/eat.22506

12. Heatherton TF, Baumeister RF. Binge eating as escape from self-awareness. *Psychol Bull*. (1991) 110:86–108. doi: 10.1037/0033-2909.110.1.86

13. Rodgers RF, Paxton SJ, Chabrol H. Depression as a moderator of sociocultural influences on eating disorder symptoms in adolescent females and males. *J Youth Adolesc*. (2010) 39:393–402. doi: 10.1007/s10964-009-9431-y

14. Segura-Garcia C, Rania M, Carbone EA, de Filippis R, Aloi M, Caroleo M, et al. Naturalistic and uncontrolled pilot study on the efficacy of Vortioxetine in binge eating disorder with comorbid depression, front. *Psychiatry*. (2021) 12:635502–2. doi: 10.3389/fpsyt.2021.635502

15. Borsboom D, Cramer AOJ. Network analysis: an integrative approach to the structure of psychopathology. *Annu Rev Clin Psychol*. (2013) 9:91–121. doi: 10.1146/annurev-clinpsy-050212-185608

16. Boschloo L, van Borkulo CD, Rhemtulla M, Keyes KM, Borsboom D, Schoevers RA. The network structure of symptoms of the diagnostic and statistical manual of mental disorders. *PLoS One*. (2015) 10:e0137621. doi: 10.1371/journal.pone.0137621

17. Fried EI, Cramer AOJ. Moving forward: challenges and directions for psychopathological network theory and methodology. *Perspect Psychol Sci*. (2017) 12:999–1020. doi: 10.1177/1745691617705892

18. McNally RJ. Can network analysis transform psychopathology? *Behav Res Ther*. (2016) 86:95–104. doi: 10.1016/j.brat.2016.06.006

19. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: a tutorial paper. *Behav Res Methods*. (2018) 50:195–212. doi: 10.3758/s13428-017-0862-1

20. Forrest LN, Perkins NM, Lavender JM, Smith AR. Using network analysis to identify central eating disorder symptoms among men. *Int J Eat Disord*. (2019) 52:871–84. doi: 10.1002/eat.23123

21. Forbush KT, Siew CSQ, Vitevitch MS. Application of network analysis to identify interactive systems of eating disorder psychopathology. *Psychol Med*. (2016) 46:2667–77. doi: 10.1017/S003329171600012X

22. Wang SB, Jones PJ, Dreier M, Elliott H, Grilo CM. Core psychopathology of treatment-seeking patients with binge-eating disorder: a network analysis investigation. *Psychol Med*. (2019) 49:1923–8. doi: 10.1017/S0033291718002702

23. Forrest LN, Grilo CM. Change in eating-disorder psychopathology network structure in patients with binge-eating disorder: findings from treatment trial with 12-month follow-up. *J Consult Clin Psychol*. (2022) 90:491–502. doi: 10.1037/ccp0000732

24. Smith KE, Mason TB, Crosby RD, Cao L, Leonard RC, Wetterneck CT, et al. A comparative network analysis of eating disorder psychopathology and co-occurring depression and anxiety symptoms before and after treatment. *Psychol Med*. (2019) 49:314–24. doi: 10.1017/S0033291718000867

25. Olatunji BO, Levinson C, Calebs B. A network analysis of eating disorder symptoms and characteristics in an inpatient sample. *Psychiatry Res*. (2018) 262:270–81. doi: 10.1016/j.psychres.2018.02.027

26. Wasil AR, Venturo-Conerly KE, Shinde S, Patel V, Jones PJ. Applying network analysis to understand depression and substance use in Indian adolescents. *J Affect Disord*. (2020) 265:278–86. doi: 10.1016/j.jad.2020.01.025

27. Gijzen MWM, Rasing SPA, Creemers DHM, Smit F, Engels RCME, De Beurs D. Suicide ideation as a symptom of adolescent depression. A network analysis. *J Affect Disord*. (2021) 278:68–77. doi: 10.1016/j.jad.2020.09.029

28. Mullarkey MC, Marchetti I, Beevers CG. Using network analysis to identify central symptoms of adolescent depression. *J Clin Child Adolesc Psychol*. (2019) 48:656–68.2018.1437735. doi: 10.1080/15374416.2018.1437735

29. Zhao Y-J, Bai W, Cai H, Sha S, Zhang Q, Lei SM, et al. The backbone symptoms of depression: a network analysis after the initial wave of the COVID-19 pandemic in Macao. *Peer J*. (2022) 10:e13840. doi: 10.7717/peerj.13840

30. Sahlan RN, Williams BM, Forrest LN, Saunders JF, Fitzsimmons-Craft EE, Levinson CA. Disordered eating, self-esteem, and depression symptoms in Iranian adolescents and young adults: a network analysis. *Int J Eat Disord*. (2021) 54:132–47. doi: 10.1002/eat.23365

31. Kenny B, Orellana L, Fuller-Tyszkiewicz M, Moodie M, Brown V, Williams J. Depression and eating disorders in early adolescence: a network analysis approach. *Int J Eating Disord*. (2021) 54:2143–54. doi: 10.1002/eat.23627

32. Meda N, Pardini S, Slongo I, Bodini L, Zordan MA, Rigobello P, et al. Students' mental health problems before, during, and after COVID-19 lockdown in Italy. *J Psychiatr Res*. (2021) 134:69–77. doi: 10.1016/j.jpsychires.2020.12.045

33. Tavolacci M-P, Ladner J, Déchelotte P. Sharp increase in eating disorders among university students since the COVID-19 pandemic. *Nutrients*. (2021) 13:3415. doi: 10.3390/nu13103415

34. Spillebout A, Dechelotte P, Ladner J, Tavolacci MP. Mental health among university students with eating disorders and irritable bowel syndrome in France. *Rev Epidemiol Sante Publique*. (2019) 67:295–301. doi: 10.1016/j.respe.2019.04.056

35. Morgan JF, Reid F, Lacey JH. The SCOFF questionnaire: assessment of a new screening tool for eating disorders. *BMJ*. (1999) 319:1467–8. doi: 10.1136/bmj.319.7223.1467

36. Leung SF, Lee KL, Lee SM, Leung SC, Hung WS, Lee WL, et al. Psychometric properties of the SCOFF questionnaire (Chinese version) for screening eating disorders in Hong Kong secondary school students: a cross-sectional study. *Int J Nurs Stud*. (2009) 46:239–47. doi: 10.1016/j.ijnurstu.2008.09.004

37. Yao S, Zhang R, Thornton LM, Peat CM, Qi B, Du S, et al. Screen-detected disordered eating and related traits in a large population sample of females in mainland China: China health and nutrition survey. *Int J Eat Disord*. (2021) 54:24–35. doi: 10.1002/eat.23409

38. Kroenke K, Spitzer Robert L. The PHQ-9: a new depression diagnostic and severity measure. *Psychiatr Ann*. (2002) 32:509–15. doi: 10.3928/0048-5713-20020901-06

39. Zhang Y-L, Liang W, Chen Z-M, Zhang H-M, Zhang J-H, Weng X-Q, et al. Validity and reliability of patient health Questionnaire-9 and patient health Questionnaire-2 to screen for depression among college students in China, Asia-Pacific. *Psychiatry*. (2013) 5:268–75. doi: 10.1111/appy.12103

40. Du N, Yu K, Ye Y, Chen S. Validity study of patient health Questionnaire-9 items for internet screening in depression among Chinese university students. *Asia Pac Psychiatry*. (2017) 9:e12266. doi: 10.1111/appy.12266

41. Epskamp S, Cramer AOJ, Waldorp LJ, Schmittmann VD, Borsboom D. Qgraph: network visualizations of relationships in psychometric data. *J Stat Softw*. (2012) 48:1–18. doi: 10.18637/jss.v048.i04

42. Bringmann LA-O, Elmer T, Epskamp S, Krause RW, Schoch DA-O, Wichers MA-O, et al. What do centrality measures measure in psychological networks? *J Abnorm Psychol*. (2019) 128:892–903. doi: 10.1037/abn0000446

43. Jones PJ, Ma R, McNally RJ. Bridge centrality: a network approach to understanding comorbidity. *Multivar Behav Res*. (2021) 56:353–67. doi: 10.1080/00273171.2019.1614898

44. Murga C, Cabezas R, Mora C, Campos S, Núñez D. Examining associations between symptoms of eating disorders and symptoms of anxiety, depression, suicidal ideation, and perceived family functioning in university students: a brief report. *Int J Eat Disord*. (2023) 56:783–9. doi: 10.1002/eat.23787

45. Hazzard VM, Hahn SL, Bauer KW, Sonneville KR. Binge eating-related concerns and depressive symptoms in young adulthood: seven-year longitudinal associations and differences by race/ethnicity. *Eat Behav*. (2019) 32:90–4. doi: 10.1016/j.eatbeh.2019.01.004

46. Owen AJ, Tran T, Hammarberg K, Kirkman M, Fisher JRW. Poor appetite and overeating reported by adults in Australia during the coronavirus-19 disease pandemic: a population-based study. *Public Health Nutr*. (2021) 24:275–81. doi: 10.1017/S1368980020003833

47. Van Strien T, Ouwens MA. Effects of distress, alexithymia and impulsivity on eating. *Eat Behav*. (2007) 8:251–7. doi: 10.1016/j.eatbeh.2006.06.004

48. Di Renzo L, Gualtieri P, Cinelli G, Bigioni G, Soldati L, Attinà A, et al. Psychological aspects and eating habits during COVID-19 home confinement: results of EHLC-COVID-19 Italian online survey. *Nutrients*. (2020) 12:2152. doi: 10.3390/nu12072152

49. de Vos JA, Radstaak M, Bohlmeijer ET, Westerhof GJ. The psychometric network structure of mental health in eating disorder patients. *Eur Eat Disord Rev*. (2021) 29:559–74. doi: 10.1002/erv.2832

50. Lawson R, Waller G. Schema-focused cognitive behaviour therapy with the eating disorders: a brief overview. *N Z Clin Psychol*. (2006) 16:8–12.

51. Cooper Z, Fairburn CG. The evolution of "enhanced" cognitive behavior therapy for eating disorders: learning from treatment nonresponse. *Cogn Behav Pract*. (2011) 18:394–402. doi: 10.1016/j.cbpra.2010.07.007

52. Guo K, Zhang X, Bai S, Minhat HS, Nazan AINM, Feng J, et al. Assessing social support impact on depression, anxiety, and stress among undergraduate students in Shaanxi province during the COVID-19 pandemic of China. *PLoS One*. (2021) 16:e0253891. doi: 10.1371/journal.pone.0253891

53. Kase T, Endo S, Oishi K. Process linking social support to mental health through a sense of coherence in Japanese university students. *Ment Health Prev*. (2016) 4:124–9. doi: 10.1016/j.mhp.2016.05.001

54. Afifi M. Gender differences in mental health. *Singap Med J*. (2007) 48:385–91.

55. Linardon J, Phillipou A, Castle D, Newton R, Harrison P, Cistullo LL, et al. Feeling fat in eating disorders: testing the unique relationships between feeling fat and measures of disordered eating in anorexia nervosa and bulimia nervosa. *Body Image*. (2018) 25:163–7. doi: 10.1016/j.bodyim.2018.04.001

56. Green MA, Fau-Cross SESN, Fau-Liao KY-HCS, Fau-Hallengren JJLK, Fau-Davids CMHJ, Fau-Carter LPDC, et al. Eating disorder behaviors and depression: a minimal relationship beyond social comparison, self-esteem, and body dissatisfaction. *J Clin Psychol*. (2009) 65:989–99. doi: 10.1002/jclp.20586

57. Garabiles MR, Lao CK, Xiong Y, Hall BJ. Exploring comorbidity between anxiety and depression among migrant Filipino domestic workers: a network approach. *J Affect Disord*. (2019) 250:85–93. doi: 10.1016/j.jad.2019.02.062

58. Liu X, Gentzler AL, Tepper P, Kiss E, Kothencnè VO, Tamás Z, et al. Clinical features of depressed children and adolescents with various forms of suicidality. *J Clin Psychiatry*. (2006) 67:1442–50. doi: 10.4088/jcp.v67n0917

59. Fernández-Aranda F, Casas M, Claes L, Bryan DC, Favaro A, Granero R, et al. COVID-19 and implications for eating disorders. *Eur Eat Disord Rev*. (2020) 28:239–45. doi: 10.1002/erv.2738

60. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet*. (2020) 395:912–20. doi: 10.1016/S0140-6736(20)30460-8

61. Strahler J, Nater UM. Differential effects of eating and drinking on wellbeing—an ecological ambulatory assessment study. *Biol Psychol*. (2018) 131:72–88. doi: 10.1016/j.biopsycho.2017.01.008

62. Heatherton T, Tice DM. *Losing control: How and why people fail at self-regulation*. San Diego, CA: Academic Press, Inc (1994).

63. McAtamney K, Mantzios M, Egan H, Wallis DJ. Emotional eating during COVID-19 in the United Kingdom: exploring the roles of alexithymia and emotion dysregulation. *Appetite*. (2021) 161:105120. doi: 10.1016/j.appet.2021.105120

64. Perry L, Morgan J, Reid F, Brunton J, O'Brien A, Luck A, et al. Screening for symptoms of eating disorders: reliability of the SCOFF screening tool with written compared to oral delivery. *Int J Eat Disord*. (2002) 32:466–72. doi: 10.1002/eat.10093

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A clinically managed weight loss program evaluation and the impact of COVID-19

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Introduction: With the prevalence of obesity increasing, many weight-loss programs were created to aid in combating the trend. The Weight Loss Clinic (WLC) was created to provide personalized support for lifestyle changes using a multidisciplinary team with medical oversight. This study evaluated the clinically-managed weight loss program at the Wellness Institute.

Methods: This was a prospective evaluation of a newly established program between January 2019–August 2020. Participants who entered the weight loss program were approached to learn about the evaluation. A total of 41 participants were included. The primary outcomes included changes in body weight and achievement of more than 5% initial body weight loss. Outcome measures were collected pre-and post-program and the data was analyzed through paired t-tests on R studio.

Results: Greater body weight-loss was seen in completers pre-COVID-19 compared to those who completed during the pandemic (Mean, ±SD; 7.51 ± 6.24 kg n=13 p<0.001 vs. 1.75 ± 4.43 kg n=9, p=0.02). Completers pre-COVID-19 demonstrated improvements in waist circumference, Framingham risk score, blood pressure, hemoglobin A1C, and body fat percentage.

Conclusions and implications: Though the sample size was small to show definitve evidence, the results may suggest the program worked well prior to the pandemic but the pandemic created barriers to weight-loss for participants.

KEYWORDS

weight loss, weight loss program, obesity, clinically managed weight loss program, evaluation

1. Introduction

Almost two-thirds of Canadian adults are living with overweight or obesity (1), which can increase the stress on the health system via increased risk for chronic diseases (2) including type-2 diabetes and cardiovascular diseases. Weight reduction is well documented to improve cardiovascular disease risk factors such as the lowering of high blood pressure, low density lipoprotein (LDL)-cholesterol, and triglycerides (3). Weight reduction is also associated with reduced all-cause mortality in individuals living with overweight and obesity (4).

While the market is overwhelmed by weight loss products and services that are often non-evidence based, there is a gap in evidence-based, professionally delivered clinical weight

loss services in Canada. The 2020 Canadian Clinical Practice Guidelines (CCPG) for obesity management recommends that interventions for adults living with obesity should follow individualized care plans that address the root causes of obesity and provide support for behavioral change such as diet and lifestyle intervention, psychological intervention, pharmacotherapy, or bariatric surgery (2, 5). As summarized in the CCPG, living with obesity is multi-factorial and involves a variety of factors, including not only weight, but sleep, quality of life and mental health. The Wellness Institute (WI) is a self-supporting non-profit organization that operates as a medical fitness facility attached to the Seven Oaks General Hospital (SOGH) in Winnipeg, Manitoba. A 2015 outcome analysis conducted with WI members indicated that 51% of new members had high blood sugars and blood pressure, and/or were living with overweight or obesity (6, 7). In response to these identified risks, the WI developed a clinically managed weight loss program focused not only on body weight reduction but also improvement in cardiometabolic risk factors. This new program, known as the Weight Loss Clinic (WLC) provides personalized support for individuals to ensure the program is customized to participants' needs. The program is managed by a clinical team including a program manager, registered dietitians (RD), Canadian Society of Exercise Physiology (CSEP)-certified personal trainers (CCPTs), a clinical psychology associate (CPA) or a cognitive behavioral therapist (CBT), and a physician. With the focus on improvement in cardiometabolic risk factors, the program assesses body mass index (BMI), lipid profile, and Framingham risk scores (8). To further guide assessments by the team, general self-efficacy (9) and components of nutrition are measured, such as mindful eating, cognitive restraint, and emotional eating (10, 11).

In March 2020, Coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was declared a global pandemic, changing the lives of everyone around the globe. A number of public health measures were implemented to combat the spread of COVID-19 with varying success (12). These include lockdowns and quarantine orders which have resulted in increases in both unhealthful dietary behavior and sedentary behavior, and declines in mental health (13). Thus, COVID-19 and resulting public health orders may have increased obesogenic behaviors and the potential for weight gain (14). In Manitoba, the pandemic resulted in restrictions which impacted the delivery of the WLC. This study describes an evaluation of participating in the WLC, which was ongoing when the COVID-19 pandemic began, creating a natural experiment of the impact of a global pandemic on a clinically managed weight loss program.

2. Materials and methods

2.1. Participants and setting

This study was a prospective evaluation of a newly established weight loss program between January 2019 and August 2020. The inclusion criteria of the program were individuals over the age of 18 years old and living with overweight or obesity (BMI > 25 kg/m^2), who had been told by a physician or primary care provider to lose weight, and had tried to lose weight in the past but had been unsuccessful at maintaining weight loss. Women who were pregnant or lactating were not eligible for the program. All potential participants who entered the program were approached and asked if they would like to participate in a program evaluation. Participants gave informed consent before participating in the evaluation. The WLC is located in the WI at SOGH in Winnipeg, Manitoba, Canada. The data was collected at the Chronic Disease Innovation Centre (CDIC), a non-profit health research institute located at SOGH that provides independent research services for academic, industry, and non-profit partners including WI.

This study was conducted in accordance with the Declaration of Helsinki, and received approval from the Manitoba Research Ethics Board [Ethics # HS22267 (H2018:401)]. It was registered on Clinicaltrials.gov (ID# NCT04290910) retrospectively as it was a program evaluation and not a clinical trial. Informed consent was obtained from all participants involved in the study.

2.2. Program design

The WLC was delivered in-person by a team, including a program manager, physician, RD, CCPT and CPA/CBT. The team collaborated to prescribe a plan best suited for the participants' needs. Appointments with the RD and CCPT consisted of seven 1-h appointments and seven 30-min appointments each (details shown in Supplementary Figure 1). The weight loss program was based on sustaining behavioral changes and was also tailored to improve lifestyle, sleep, and mental health. During the initial and exit assessments, the CCPT collected self-reported health conditions, medications and cardiovascular biomarkers such as, BMI, blood pressure, lipid profile, and Framingham risk score. The Framingham Risk Score was categorized into low, intermediate or high and was used to estimate a 10-year cardiovascular disease risk (8). An oscillometric blood pressure monitor was used to collect blood pressure and heart rate. Non-fasted blood samples were collected from participants by a trained phlebotomist and analyzed for lipid profile and hemoglobin A1C at the Diagnostic Services of Manitoba in Winnipeg, Canada (15).

The program evolves in a 3-stage progression, which is explained in detail in Supplementary Figure 1. The first stage (Day 1–7) is the assessment phase, this is where participants share what they are looking to achieve and assessing their stage of readiness to change. Each discipline also has the opportunity to assess the participants based on their area of expertise. The second stage is the intensive phase (Day 18–21), this is where the participants receive a nutrition prescription based on the RD's assessment, this may include a meal plan from EatLove website/app or nutritional goals (6). The RD used information gathered from the three-factor questionnaire (11), mindful eating questionnaire (10), and 3-day food recall (these were filled out at the initial assessment) and a one-on-one appointment to further guide the intervention. In terms of exercise, the CCPT used information from the initial assessment questionnaire to guide and provide a personalized exercise prescription through the Wellness App (6). A one-hour assessment is included during the initial phase. A psychological intervention may have replaced the nutrition intervention at this stage if the participant screened for severe depression, anxiety, or disordered eating, or if they presented with any psychosocial concerns. The psychological intervention includes support for overcoming challenges and barriers, help understanding stages of change, and cognitive behavioral therapy. The third stage, the

transformation phase (Day 22–119), was the remaining 105 days in the program and includes sessions with both the RD and CCPT. The nutrition and exercise prescriptions were modified depending on lifestyle changes and/or progress that the participant made. The participants had a total of 12 h each with the RD and CCPT. After 119 days in the program, the participants were given the options to continue in the transformation phase, enter the maintenance phase, or exit the program. During the maintenance phase, participants had two meetings per month with the RD and CCPT. This phase is available to help routinize the habits participants learned in previous phases. The maintenance phase was not included in this evaluation.

The program was delivered in-person and in-center for those who completed prior to March 2020. With the impact of COVID-19, the program was delivered virtually for those who joined the program after March 2020. Given that the program was still running during COVID-19, there were a few participants that started in-person and ended virtually.

2.3. Program study design

There were no changes to the program evaluation pre-and during COVID. Program success was defined as achieving weight loss of more than 5% of initial body weight. Due to the personalized nature of the program, the number of days the participant attended and how much weight was lost was used to further guide the success of the program. To further evaluate program effectiveness, baseline and exit measures were collected, which included cardiovascular disease risk factors, clinical chemistry, and dietary behavior. They were then compared to reference values to indicate whether there was improvement in measurements. Participants who completed the program were asked to fill out an exit survey assessing acceptability of the program, participant feedback, and program experience. The exit survey was created by the WLC team and is provided under Supplementary material.

2.4. Outcome measures

The primary outcomes included changes in body weight and achievement of more than 5% initial body weight loss. The secondary outcomes include changes in BMI, waist circumference, blood pressure, heart rate, Framingham risk score, blood lipids, hemoglobin A1C, body fat percentage, sleep quality (16), quality of life (17), general self-efficacy (9), mindful eating (10), cognitive restraint (11), and emotional eating (11). These were assessed through questionnaires, including the Pittsburgh sleep quality index, SF-36 quality of life, general self-efficacy scale, three-factor eating questionnaire, and mindful eating questionnaire. Measurements were taken prior to starting the program and after completion of the transformation phase. For those who did not complete the program, all measures up until the participant exited were collected.

2.5. Data analysis

Statistical analysis was performed using R Studio (R Studio, Boston, MA, United States) (18). The effects of participation in the weight loss program on the captured outcomes were analyzed by the R generalized linear model function using a pre-post design. To evaluate the impact of COVID-19, the completed groups were separated into pre-and during COVID-19. We included age and sex as fixed factors and compared the last measurement taken for each outcome measure to baseline, pairing by participant. For all analyses, value of ps less than 0.05 were considered significant. Descriptive statistics, such as attendance and participant feedback were also measured and reported. Results were reported as mean +/− standard deviation and frequency and percentage for continuous and categorical variables, respectively.

3. Results

A total of 43 participants were enrolled in the evaluation; 2 decided not to continue, 16 did not complete, 25 completed and 22 were included at the time of analysis (the remaining three participants completed the program but were not included at the time of analysis due to no exit data collected, the participants declined to come into the facility and have their exit data collected due to concerns around COVID-19). For those that did not complete the program, reasons for incompletion pre-COVID-19 included loss to follow up ($n = 4$), medical reasons unlinked to the program ($n = 3$), family reason ($n = 1$), program hold ($n = 1$), decided not to continue ($n = 1$), not a good fit right now ($n = 1$), and moved out of the country ($n = 1$), whereas, for those that completed during COVID-19, reasons for incompletion included loss to follow up ($n = 2$), decided not to continue ($n = 1$) and encountered medical reasons requiring stoppage unlinked to the program ($n = 1$).

Participants were 46 ± 12.52 years old with majority female (Table 1). At baseline, cardiovascular disease risk markers, such as blood pressure, Framingham risk score, and lipid profile were within normal range for most participants, both male and female. As expected, weight, BMI and body fat percentage were higher than the ideal range (Table 1). There were some participants who declined to be measured or provide measurements for certain outcomes, hence the variations in sample size found in Tables 2, 3. Overall, participants who completed the program lost 5.15 ± 5.18 kg, $p < 0.001$, $n = 22$ (Table 2). Since we were unable to collect exit measurements on participants who did not complete, their last measurement taken was collected. Participants who did not complete remained in the program for an average of 80 ± 47.23 days and lost −0.91 ± 2.71 kg, $p = 0.10$, $n = 9$. There were three participants who joined the program pre-COVID-19 and completed during COVID-19.

Participants who completed pre-COVID 19 lost 7.51 kg ± 6.24 kg, $p < 0.001$, $n = 13$), this is an average of 6.34% ($p < 0.001$) initial body weight loss. There were improvements in waist circumference (−6.54 ± 4.50 cm, $p < 0.001$, $n = 13$), Framingham risk score (−2.43 ± 2.61%, $p = 0.008$, $n = 12$), systolic blood pressure (−9.33 ± 9.87 mmHg, $p = 0.005$, $n = 13$), diastolic blood pressure (−5.51 ± 5.93 mmHg, $p = 0.006$, $n = 13$), hemoglobin A1C (−0.13 ± 0.20%, $p = 0.04$, $n = 12$, body fat percentage (−2.72 ± 1.81%, $p < 0.001$, $n = 13$), and body fat mass (−6.59 ± 4.73 kg, $p < 0.001$, $n = 13$) in completers pre-COVID-19 (Table 3) compared to baseline. For participants who completed pre-COVID-19, we saw an improvement in cognitive restraint (+4.62 ± 4.88, $p = 0.007$, $n = 12$), decline in uncontrollable eating

TABLE 1 Participant characteristics at baseline.

Parameter	N	Baseline mean±SD					Ideal range for parameters
		Total	n	Female	n	Male	
Age (years)	43	46.76 ± 12.52	38	46.34 ± 12.95	5	50.00 ± 9.08	
Weight (kg)	41	114.25 ± 30.44	36	108.43 ± 26.72	5	156.16 ± 22.9	
Total BMI (kg/m^2)	41	40.72 ± 9.30	36	37.02 ± 9.01	5	47.08 ± 5.69	Underweight < 18.5
							Healthy Weight 18.5–24.9, Overweight 25–29.9
							Obesity Class I 30–34.9
							Obesity Class II 35–39.9
							Obesity Class III > 40
BMI overweight (kg/m^2)	4	28.47 + 0.65	4	28.47 + 0.65	0	-	25–29.9
BMI Obesity class I (kg/m^2)	10	32.87 ± 1.14	10	32.87 ± 1.14	0	-	30–34.9
BMI Obesity class II (kg/m^2)	8	37.35 ± 1.45	8	37.35 ± 1.45	0	-	35–39.9
BMI Obesity class III (kg/m^2)	19	48.78 ± 7.07	14	49.39 ± 7.60	5	47.08 ± 5.69	Obesity Class III > 40
Waist circumference (cm)	40	124.27 ± 21.23	35	119.02 ± 17.29	5	149.94 ± 14.04	<88 cm (F) (19)
							<102 cm (M) (19)
Systolic blood pressure (mmHg)	41	127.67 ± 15.08	36	125.37 ± 13.27	5	131.60 ± 11.06	<130 mmHg (20)
Diastolic blood pressure (mmHg)	41	81.78 ± 7.67	36	80.17 ± 6.71	5	86 ± 8.57	<85 mmHg (20)
Heart rate (beats per minute)	41	75.18 ± 11.12	36	73.11 ± 10.33	5	77.54 ± 9.48	60–80 beats per min (21)
Total blood cholesterol (TC) (mmol/L)	41	4.90 ± 1.12	36	5.06 ± 1.03	5	3.55 ± 0.47	<5.2 mmol/L (22)
HDL cholesterol (mmol/L)	41	1.30 ± 0.38	36	1.36 ± 0.40	5	3.55 ± 0.47	>1.3 mmol/L (F) (22)
							>1.0 mmol/L (M) (22)
LDL cholesterol (mmol/L)	41	2.76 ± 0.86	36	2.86 ± 0.80	5	1.89 ± 0.47	<3.5 mmol/L (22)
TC/HDL cholesterol ratio	40	3.89 ± 1.27	35	3.94 ± 1.36	5	3.48 ± 0.67	<4 (F) (23)
							<5.2 (M) (23)
Triglycerides (mmol/L)	41	1.85 ± 0.91	36	1.85 ± 0.99	5	1.50 ± 0.44	≤1.7 mmol/L (22)
Hemoglobin A1C (%)	40	5.78 ± 0.67	35	5.74 ± 0.53	5	5.72 ± 0.72	4%–6% (24)
Body fat percentage (%)	41	49.40 ± 5.21	36	49.21 ± 5.32	5	46.72 ± 3.63	18%–28% (F) (25)
							10%–20% (M) (25)
Skeletal muscle mass (kg)	41	31.90 ± 8.38	36	30.00 ± 5.50	5	47.0 ± 5.56	
Body fat mass (kg)	40	56.35 ± 18.21	35	52.06 ± 16.39	5	73.39 ± 15.81	
Total Framingham risk score (%)	35	6.85 ± 5.46	30	6.28 ± 5.46	5	10.26 ± 4.53	Low < 10%
							Intermediate 10%–19%
							High ≥ 20%
Low Framingham risk score (%)	30	5.17 ± 3.01	28	5.14 ± 3.11	2	5.6 ± 0.0	<10%
Intermediate Framingham risk score (%)	4	14.33 ± 2.63	1	17.2 ± 0.0	3	13.37 ± 2.20	10%–19%
High Framingham risk score (%)	1	27.4 ± 0.0	1	27.4 ± 0.0	0	-	>20%

(−4.42 ± 4.35, $p = 0.005$, $n = 12$) and emotional eating (−1.37 ± 1.23, $p = 0.002$, $n = 12$), and improvement in general health (+18.33 ± 17.32, $p = 0.013$, $n = 9$) based on the questionnaires (Table 4). There were no improvements in the other SF-36 components, such as, physical functioning, emotional problems, energy/fatigue, emotional well-being, social functioning and pain. There were improvements in sleep (−1.09 + 2.84, $p = 0.23$, $n = 11$) but are considered statistically insignificant.

Participants who completed during COVID-19 lost (2.05 kg ± 4.39, $p = 0.19$, $n = 9$), this is an average of 1.5% ($p = 0.07$) initial body weight loss. The remaining outcomes (waist circumference, Framingham risk score, systolic blood pressure, diastolic blood pressure, hemoglobin A1C, body fat percentage, body fat mass) remained unchanged compared to baseline. For participants who completed during COVID-19, quality of life, sleep and nutrition outcomes remained unchanged compared to baseline.

TABLE 2 The mean differences (baseline and exit) of weight, BMI and percent body weight loss for the non-completers, completers, completers pre-COVID-19 and completers during COVID-19.

Change in Parameters	Non-completers (n=9)		All completers (n=22)		Completers pre-COVID-19 (n=13)		Completers during COVID-19 (n=9)		p-value for completers pre-COVID-19 vs. completers during COVID-19
	Mean difference±SD	p-value	Mean difference±SD	p-value	Mean difference±SD	p-value	Mean difference±SD	p-value	
Weight (kg)	-0.91 ± 2.71	0.1063	−5.15 ± 5.18	0.0008	−7.51 ± 6.24	0.0009	−2.05 ± 4.39	0.1985	0.025
BMI (kg/m^2)	−0.13 ± 0.90	0.2981	−1.97 ± 2.33	0.0007	−2.68 ± 2.00	0.0004	−0.18 ± 1.26	0.495	0.002
Percent body weight loss (%)	−1.50 ± 1.95	0.0734	−4.78 ± 4.85	0.0005	−6.34 ± 4.25	0.0009	−2.52 ± 5.01	0.1985	0.0807

The changes in body weight in participants in all completers pre-COVID, during COVID and non-completers are plotted in Supplementary Figure 3. It shows that completers pre-COVID lost more weight than completers during COVID-19, where completers during COVID-19 may have actually gained weight.

For non-completers, the last body weight attained by the program was used. Completers pre-COVID-19 lost more than 5% of their initial body weight, whereas, only 11% of completers during COVID-19 achieved the same. The impact of COVID-19 on weight loss is plotted in Supplementary Figure 4. Participants who completed pre-COVID-19 lost more body weight than completers during COVID-19. The impact of program duration on weight loss as a percentage is shown in Supplementary Figure 5. Although it was available, the nutritional intervention was not replaced by psychological intervention for any of the participants in the evaluation.

3.1. Exit survey results

The results of our exit survey showed that 73% (16 out of 22) of participants used the Wellness App, 86% (19 out of 22) of participants used the EatLove software for meal planning and preparation, 72% (17 out of 22) of participants gained knowledge, skills, and confidence as the program went on, and 82% (18 out of 22) of participants reported making valuable lifestyle changes. In terms of the satisfaction of the different components of the program, 85% (17 out of 20) reported satisfaction with the nutrition portion, 100% (21 out of 21) reported satisfaction with the exercise portion, and 50% (10 out of 20) reported satisfaction with the psychology portion. As well, 100% (22 out of 22) of participants reported they would recommend the weight loss program to a friend or family member.

4. Discussion

The evaluation results suggest that participating in the program in-person resulted in health benefits, reduced adiposity and improved cardiometabolic health, however, some outcomes were not seen in some participants due to barriers created by the COVID-19 pandemic. When COVID-19 was declared a pandemic in March 2020, life around the world changed. In Manitoba, the pandemic lockdowns and restrictions made in-person delivery of the weight loss program more difficult or even impossible in some cases. Thus the delivery of the program was done virtually or through telephone with the same number of hours pre-COVID-19 allocated per WLC team member. The program was designed to be delivered in-person, not virtually, and for a virtual program to be successful there may be a need for additional support including online digital platforms.

For a four-month weight loss program, the ideal weight lost is between 7.3 to 14.5 kg (one to two pounds per week) (2, 4). The average weight lost was 7.51 kg for those who completed the program pre-COVID-19, which is clinically significant for a 4-month weight loss program. In comparison, minimal changes in body weight were observed for those that completed during COVID-19. The changes from the COVID-19 pandemic may have had a negative impact on the program. As shown on Supplementary Figures 3, 4, it showed that participants who took part pre-COVID-19 lost more weight than those who took part

TABLE 3 The mean differences (baseline and exit) for the participants who have completed the program, grouped by those who completed pre-COVID-19 and during COVID-19.

Change in Parameters	Completers pre-COVID-19 n=13			Completers during COVID-19 n=9			p-value for completers pre-COVID-19 vs. completers during COVID-19
	n	Mean difference±SD	p-value	n	Mean difference±SD	p-value	
Waist circumference (cm)	13	−6.54 ± 4.50	0.0002	9	−5.04 ± 7.31	0.072	0.5936
Framingham risk score (%)	12	−2.43 ± 2.61	0.008	7	−2.04 ± 3.11	0.1327	0.7848
Systolic blood pressure (mmHg)	13	−9.33 ± 9.87	0.005	9	−5.52 ± 8.68	0.093	0.3512
Diastolic blood pressure (mmHg)	13	−5.51 ± 5.93	0.006	9	−4.39 ± 6.30	0.070	0.6804
TC (mmol/L)	12	−0.04 ± 0.61	0.828	9	−0.02 ± 0.50	0.903	0.9416
HDL cholesterol (mmol/L)	12	0.034 ± 0.09	0.226	8	−0.04 ± 0.21	0.542	0.3201
LDL cholesterol (mmol/L)	12	−0.098 ± 0.35	0.353	8	0.12 ± 0.31	0.281	0.1497
Triglycerides (mmol/L)	12	0.004 ± 0.60	0.981	8	−0.20 ± 0.49	0.243	0.3894
Hemoglobin A1C (%)	12	−0.13 ± 0.20	0.04	8	−0.1 ± 0.28	0.3198	0.768
Body fat percentage (%)	13	−2.72 ± 1.81	0.0001	9	−0.99 ± 2.56	0.2801	0.1033
Skeletal muscle mass (lbs)	13	−1.51 ± 3.23	0.117	9	−4.9 ± 13.46	0.3068	0.4793
Body fat mass (kg)	13	−6.59 ± 4.73	0.0002	7	−1.56 ± 4.27	0.3696	0.0295

during COVID-19. This could be due to the conditions created by the COVID-19 pandemic including lockdowns and quarantines. A study by Zachary et al. identified risk factors for weight gain during self-quarantine including a lack of dietary restraint, eating in response to stress, and reduced physical activity (16). Additionally, many people have reported weight gain during the pandemic (16, 26, 27), Marchitelli et al. (28) reported weight gain during lockdown in participants with and without a psychiatric diagnosis (16, 26). Lockdown and quarantine orders have been shown to change dietary behaviors, increase sedentary behaviors, and worsen mental health, with individuals living with obesity showing greater increases to unhealthful dietary behaviors and declines in mental health (15). It is possible that participating in the weight loss program during COVID-19 may have helped in weight maintenance, given that the participants were at a high risk for weight gain. Participants who completed pre-COVID-19 showed improvements in dietary behaviors such as, mindful eating, cognitive restraint, uncontrollable eating, and emo-tional eating, whereas there were no changes shown in these measures for those who completed during COVID-19. An evaluation by the Look AHEAD Research Group (29) showed that weight loss achieved with health behavioral changes is usually 3%–5% of body weight, which can result in meaningful improvements in obesity-related comorbidities. Those that com-pleted the program pre-COVID-19 lost an average of 6.34% body weight.

There were also improvements in the secondary outcomes for those that completed the program pre-COVID-19, including waist circumference, systolic blood pressure, diastolic blood pressure, and body fat percentage. These improvements would suggest a decreased risk of obesity-related morbidities, such as type 2 diabetes (30), and hypertension (31). Conversely, those that participated during-COVID-19 saw no changes in these measures. However, it is important to note that average blood pressure, cholesterol and blood glucose values at baseline were within the ideal range, suggesting that the population in the study was not experiencing metabolic complications and/or the participants were being adequately treated for these risk factors.

A major issue that weight loss programs may face is an increased risk of drop-outs. A study done by Bauer et al. (32) found a drop-out rate of 8% for a 6-month weight loss program, though attrition rates were low this may have attributed to the fact that the cost of the program was fully covered by health insurance in the case of 80% program par-ticipation (7). A study by Ponzo et al. (33) found that a 50% attrition is common among weight loss programs, with rates up to 80% after starting treatment. They found that individuals that dropped out early reported decreased mental well-being. The WLC evaluation saw a dropout rate of 39% which is lower than rates often seen in the literature (53.6%–69.5%) (34-36). Some factors that may have contributed to the lower dropout rate include the multidisciplinary team approach, the active ongoing contact with the participants, and the personalization of the program.

The WLC is a fee for service program. A base fee was charged monthly for participants. Some services offered, including appointments with the RD or psychologist may be covered through individual participants health insurance plans.

4.1. Strengths and limitations

A strength of this study is it involves collection of data from an ongoing and existing program, not a program designed to answer a research question. Another strength is the data collection was ongoing prior to the COVID-19 pandemic, creating a unique natural experiment in which looks at the impact of the pandemic. Limitations include the pre-post design, with no control group, and that the impact of COVID-19 included both stoppages in in-person program services due to lockdowns, as well as the heightened stress of living and trying to

TABLE 4 The mean differences (baseline and exit) for questionnaire data on the participants who have completed the program, grouped by those who completed pre-COVID-19 and during COVID-19.

Change in Questionnaires	Completers pre-COVID-19			Completers during COVID-19			*p*-value
	n	Mean difference±SD	*p*-value	*n*	Mean difference±SD	*p*-value	
General self-efficacy scale	12	−0.79 ± 4.90	0.5873	7	0.86 ± 2.19	0.341	0.3297
Mindful eating	12	−0.26 ± 0.23	0.0024	7	−0.54 ± 0.79	0.1176	0.3833
Three factor eating—cognitive restraint	12	4.62 ± 4.88	0.0073	7	4.07 ± 4.15	0.041	0.7965
Three factor eating—uncontrollable eating	12	−4.42 ± 4.35	0.005	7	−3.14 ± 3.34	0.047	0.485
Three factor eating—emotional eating	12	−1.37 ± 1.23	0.0025	7	0.143 ± 3.62	0.9204	0.32
Pittsburgh sleep quality index score	11	−1.09 ± 2.84	0.2322				0.3894
SF-36 physical functioning	9	8.33 ± 11.45	0.060				0.4594
SF-36 role limitations due to physical health	9	30.55 ± 41.03	0.055				0.8853
SF-36 role limitations due to emotional problems	9	14.82 ± 42.44	0.3463				0.2534
SF-36 energy/fatigue	9	10.55 ± 22.56	0.1981				0.9072
SF-36 emotional well-being	9	6.67 ± 11.49	0.1199				0.0372
SF-36 social functioning	9	−5.83 ± 10.40	0.131				0.0947
SF-36 pain	9	−0.05 ± 23.65	0.9945				0.1927
SF-36 general health	9	18.33 ± 17.32	0.013				0.4204

lose weight during a pandemic. These two factors both could have impaired the WLC program participants success and could not be separated in this study. As well, no exit surveys were collected from participants who dropped out of the evaluation—collecting this data would have provided critical feedback for the program. Finally, the sample size was not based on a power calculation, it was simply dictated by the program capacity, the length of the evaluation period, and the number or program participants who chose to enroll in the evaluation, thus some of the outcomes may have been underpowered.

5. Implications for research and practice

Participating in the WLC program prior to the COVID-19 pandemic resulted in weight loss and improvements in waist circumference, systolic blood pressure, diastolic blood pressure, and body fat percentage. This suggests that the program works for many when it can be conducted as originally designed. The COVID-19 pandemic has created additional barriers to weight loss, including but not limited to, inconsistent in-person delivery and its negative impact on participants' mental health. Long term effects of this pandemic on weight management in adults could exacerbate the problem of obesity in adults, further increasing the prevalence of adults living with obesity (36). The demand for evidence-based weight loss programs post-pandemic will likely be high, and this evaluation suggests that a multi-disciplinary personalized program can be effective. Since most virtual programs are supported by digital platforms, future research should evaluate programs offered virtually that directly address barriers to weight loss created by the COVID-19 pandemic, this could help individuals easily access customized weight loss programs with no interruptions in delivery. As well as, future research should look into types of interventions that evaluate cost effectiveness, to determine if these programs can be covered by healthcare vs. fee based. Since the main focus of this study was weight, measuring dietary and physical changes were challenging, using an actigraphy would be a good way to measure physical activity in future evaluations and measuring dietary change with apps like Keenoa and Rx food may be beneficial (35, 36).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

KC collected and analyzed the data. KC wrote the first draft of the paper which was edited by RM, SM, and DM. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1167813/full#supplementary-material

References

1. Bancej C, Jayabalasingham B, Wall RW, Rao DP, Do MT, de Groh M, et al. Evidence brief—trends and projections of obesity among Canadians. *Chron Dis Injur Can*. (2015) 35, 109–112. doi: 10.24095/hpcdp.35.7.02

2. Lau DCW, Douketis JD, Morrison KM, Hramiak IM, Sharma AM, Ur E, et al. 2006 Canadian clinical practice guidelines on the management and prevention of obesity in adults and children [summary]. *Can Med Assoc J*. (2007) 176:S1–S13. doi: 10.1503/cmaj.061409

3. Zomer E, Gurusamy K, Leach R, Trimmer C, Lobstein T, Morris S, et al. Interventions that cause weight loss and the impact on cardiovascular risk factors: a systematic review and meta-analysis. *Obes Rev*. (2016) 17:1001–11. doi: 10.1111/obr.12433

4. Ma C, Avenell A, Bolland M, Hudson J, Stewart F, Robertson C, et al. Effects of weight loss interventions for adults who are obese on mortality, cardiovascular disease, and cancer: systematic review and meta-analysis. *BMJ*. (2017) 359:j4849. doi: 10.1136/bmj.j4849

5. Wharton S, Lau DCW, Vallis M, Sharma AM, Biertho L, Campbell-Scherer D, et al. Obesity in adults: a clinical practice guideline. *CMAJ*. (2020) 192:E875–91. doi: 10.1503/cmaj.191707

6. The Wellness Institute. Weight Loss Clinic. (2018) Available at: https://wellnessinstitute.ca/weight-loss-clinic/ (Accessed 26 January 2021).

7. Genest J, McPherson R, Frohlich J, Anderson T, Campbell N, Carpentier A, et al. Canadian cardiovascular society/Canadian guidelines for the diagnosis and treatment of dyslipidemia and prevention of cardiovascular disease in the adult—2009 recommendations. *Can J Cardiol*. (2009) 25:567–79. doi: 10.1016/S0828-282X(09)70715-9

8. Framingham Risk Score (FRS)(2017), Estimation of 10-year Cardiovascular Disease (CVD) Risk. Available at: https://www.ccs.ca

9. Luszczynska A, Scholz U, Schwarzer R. The general self-efficacy scale: multicultural validation studies. *J Psychol*. (2005) 139:439–57. doi: 10.3200/JRLP.139.5.439-457

10. Framson C, Kristal AR, Schenk J, Littman AJ, Zeliadt S, Benitez D. Development and validation of the mindful eating questionnaire. *J Am Diet Assoc*. (2009) 109:1439–44. doi: 10.1016/j.jada.2009.05.006

11. James BL, Loken E, Roe LS, Rolls BJ. The weight-related eating questionnaire offers a concise alternative to the three-factor eating questionnaire for measuring eating behaviors related to weight loss. *Appetite*. (2017) 116:108–14. doi: 10.1016/j.appet.2017.04.023

12. Flaxman S, Mishra S, Gandy A, Unwin HJT, Mellan TA, Coupland H, et al. Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature*. (2020) 584:257–61. doi: 10.1038/s41586-020-2405-7

13. Flanagan EW, Beyl RA, Fearnbach SN, Altazan AD, Martin CK, Redman LM. The impact of COVID-19 stay-at-home orders on health behaviors in adults. *Obesity*. (2020) 29. doi: 10.1002/oby.23066

14. Zachary Z, Brianna F, Brianna L, Garrett P, Jade W, Alyssa D, et al. Self-quarantine and weight gain related risk factors during the COVID-19 pandemic. *Obes Res Clin Pract*. (2020) 14:210–6. doi: 10.1016/j.orcp.2020.05.004

15. Diagnostic Services. Shared health (2021) Available at: https://sharedhealthmb.ca/services/diagnostic/ (Accessed 26 May 2021).

16. Thomson CA, Morrow KL, Flatt SW, Wertheim BC, Perfect MM, Ravia JJ, et al. Relationship between sleep quality and quantity and weight loss in women participating in a weight-loss intervention trial. *Obesity*. (2012) 20:1419–25. doi: 10.1038/oby.2012.62

17. Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): I. conceptual framework and item selection. *Med Care*. (1992) 30:473–83. doi: 10.1097/00005650-199206000-00002

18. RStudio. RStudio (2019) Available at: https://www.rstudio.com/products/rstudio/ (Accessed 10 September 2019).

19. Hypertension Canada. Canadian guidelines for body weight classification in adults—quick reference tool for professionals. Aem (2003). Available at: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/healthy-weights/canadian-guidelines-body-weight-classification-adults/quick-reference-tool-professionals.html (Accessed 14 October 2020).

20. Hypertension Canada. I. Accurate measurement of blood pressure. (2020) Available at: https://guidelines.hypertension.ca/diagnosis-assessment/measuring-blood-pressure/ (Accessed 14 October 2020).

21. Heart and Stroke Foundation of Canada. Arrhythmia. (2020) Available at: https://www.heartandstroke.ca/en/heart-disease/conditions/arrhythmia/ (Accessed 14 October 2020).

22. Medical Council of Canada. Normal values. (2020) Available at: https://mcc.ca/objectives/normal-values/ (Accessed 14 October 2020).

23. University of Rochester Medical Center. Lipid panel with Total cholesterol: HDL ratio—health Encyclopedia. (2020) Available at: https://www.urmc.rochester.edu/encyclopedia/content.aspx?contenttypeid=167&contentid=lipid_panel_hdl_ratio (Accessed 14 October 2020).

24. A1C-derived average glucose study group. Diabetes Care (2008), 31:1473–1478. doi: 10.2337/dc08-0545

25. InBody. 570 (2020). The InBody Result Sheet eBook. Available at: https://inbodycanada.ca

26. Marchitelli S, Mazza C, Lenzi A, Ricci E, Gnessi L, Roma P. Weight Gain in a Sample of Patients Affected by Overweight/Obesity with and without a Psychiatric Diagnosis during the Covid-19 Lockdown. *Nutrients*. (2020):12. doi: 10.3390/nu12113525

27. Pellegrini M, Ponzo V, Rosato R, Scumaci E, Goitre I, Benso A, et al. Changes in Weight and Nutritional Habits in Adults with Obesity during the "Lockdown" Period Caused by the COVID-19 Virus Emergency. *Nutrients*. (2020):12. doi: 10.3390/nu12072016

28. Eight-Year Weight Losses with an Intensive Lifestyle Intervention. *The Look AHEAD Study. Obesity (Silver Spring)*. (2014) 22:5–13. doi: 10.1002/oby.20662

29. Gagnon C, Brown C, Couture C, Kamga-Ngande CN, Hivert MF, Baillargeon JP, et al. A cost-effective moderate-intensity interdisciplinary weight-management

programme for individuals with prediabetes. *Diabetes & Metabolism*. (2011) 37:410–8. doi: 10.1016/j.diabet.2011.01.003

30. Di Angelantonio E, Bhupathiraju SN, Wormser D, Gao P, Kaptoge S, de Gonzalez AB, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *The Lancet*. (2016) 388:776–86. doi: 10.1016/S0140-6736(16)30175-1

31. Ponzo V, Scumaci E, Goitre I, Beccuti G, Benso A, Belcastro S, et al. Predictors of attrition from a weight loss program. A study of adult patients with obesity in a community setting. *Eat Weight Disord*. (2020). doi: 10.1007/s40519-020-00990-9

32. Predictors of dropout in weight loss interventions: a systematic review of the literature - Moroshko - 2011 - Obesity Reviews - Wiley Online Library n.d. (https://onlinelibrary-wiley-com.uml.idm.oclc.org/doi/full/10.1111/j.1467-789X.2011.00915.x).

33. Perna S, Spadaccini D, Riva A, Allegrini P, Edera C, Faliva MA, et al. A path model analysis on predictors of dropout (at 6 and 12 months) during the weight loss interventions in endocrinology outpatient division. *Endocrine*. (2018) 61:447–61. doi: 10.1007/s12020-018-1563-y

34. Bhutani S, Cooper JA. COVID-19 related home confinement in adults: weight gain risks and opportunities. *Obesity*. (2020). doi: 10.1002/oby.22904

35. Keenoa. A must for dietitians (2023). Available at: https://keenoa.com/ (Accessed 12 May 2023).

36. RxFood. RxFood (2023). Available at: https://rxfood.co (Accessed 12 May 2023).

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Refueling the post COVID-19 brain: potential role of ketogenic medium chain triglyceride supplementation: an hypothesis

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COVID-19 infection causes cognitive changes in the acute phase, but also after apparent recovery. Over fifty post (long)-COVID symptoms are described, including cognitive dysfunction ("brain fog") precluding return to pre-COVID level of function, with rates twice as high in females. Additionally, the predominant demographic affected by these symptoms is younger and still in the workforce. Lack of ability to work, even for six months, has significant socio-economic consequences. This cognitive dysfunction is associated with impaired cerebral glucose metabolism, assessed using ^{18}F-fluorodeoxyglucose-positron emission tomography (FDG-PET), showing brain regions that are abnormal compared to age and sex matched controls. In other cognitive conditions such as Alzheimer's disease (AD), typical patterns of cerebral glucose hypometabolism, frontal hypometabolism and cerebellar hypermetabolism are common. Similar FDG-PET changes have also been observed in post-COVID-19, raising the possibility of a similar etiology. Ketone bodies (B-hydroxybutyrate, acetoacetate and acetone) are produced *endogenously* with very low carbohydrate intake or fasting. They improve brain energy metabolism in the face of cerebral glucose hypometabolism in other conditions [mild cognitive impairment (MCI) and AD]. Long-term low carbohydrate intake or prolonged fasting is not usually feasible. Medium chain triglyceride (MCT) is an *exogenous* route to nutritional ketosis. Research has supported their efficacy in managing intractable seizures, and cognitive impairment in MCI and AD. We hypothesize that cerebral glucose hypometabolism associated with post COVID-19 infection can be mitigated with MCT supplementation, with the prediction that cognitive function would also improve. Although there is some suggestion that post COVID-19 cognitive symptoms may diminish over time, in many individuals this may take more than six months. If MCT supplementation is able to speed the cognitive recovery, this will impact importantly on quality of life. MCT is readily available and, compared to pharmaceutical interventions, is cost-effective. Research shows general tolerability with dose titration. MCT is a component of enteral and parenteral nutrition supplements, including in pediatrics, so has a long record of safety in vulnerable populations. It is not associated with weight gain or adverse changes in lipid profiles. This hypothesis serves to encourage the development of clinical trials evaluating the impact of MCT supplementation on the duration and severity of post COVID-19 cognitive symptoms.

KEYWORDS

post (long) COVID-19, subjective cognitive decline, beta-hydroxybutyrate, medium chain triglyceride, brain fog

Introduction/background

Current statistics[1] report that the SARS-CoV-2 pandemic (COVID-19) has exceeded 650 million cases worldwide, with over 6 million reported deaths. This likely underestimates the numbers as it does not capture cases from countries where diagnostic testing is not readily available, or untested cases with more mild disease. Worldwide new variants keep emerging, and there is persistent infection and re-infection.

Following apparent recovery from COVID-19 infection, several persistent post-COVID-19 symptoms have been documented in a cohort of patients. These post COVID-19 symptoms were first reported in the media (1, 2), and data now suggest one in three people are not fully recovered after several weeks (3), with as many as fifty symptoms being described (4). They include persistent exercise intolerance, breathlessness, cough, anxiety, palpitations, poor concentration, intense fatigue, mood swings, muscle/joint pains, headaches, attention disorder and memory loss or 'brain fog' (5). Because of the increasing number of cases of acute and long COVID worldwide, in October 2021 the World Health Organization clearly defined long COVID as a condition that "occurs in individuals with a history of probable or biologically confirmed SARS-COV-2 infection initially symptomatic at the acute phase, with numerous symptoms lasting for at least two months, usually three months, from the onset of COVID-19 that cannot be explained by an alternative diagnosis" (6).

People affected with post COVID-19 sequalae are often more physically fit and younger at baseline. In addition, women are disproportionately affected by these "long haul" symptoms, with a prevalence of 64% versus 35% in men (7). The impact of long COVID on socioeconomic status is therefore significant [Chen et al. (5)]. Symptoms of possible brain origin include: loss of smell and taste; complaints of brain fog; impaired attention and memory function; sleep disturbances; pain; emotional disorders; and symptoms related to dysautonomia (breathlessness, tachycardia, orthostatic intolerance and orthostatic hypotension) (7–9).

The most debilitating symptoms include fatigue (reported in 73%) and brain fog (28%), which was self-defined as "dementia" in at least one study of 30–40-year-olds (7). Additionally, because of the varied and non-specific nature of these symptoms, many are dismissed by health care providers (10), or are simply not reported. Rehabilitation of COVID-19 survivors remains widely neglected (11) not only because of this under-recognition, but because most health care systems are still overwhelmed with acute cases. Fatigue in long-COVID is multifactorial, including ongoing hypoxia, disordered lung function, depression and chronic fatigue syndrome (11). Fatigue may improve, but this will likely depend on the etiology in each case.

The specific etiology of the cognitive symptoms remains unclear. Clinicians are increasingly aware that cognitive symptoms are not necessarily related to poor pulmonary function and dyspnoea, making their potential treatment challenging. There is evidence of direct viral spread to the central nervous system (CNS) for COVID-19 and other coronaviruses (12, 13), as well as adverse effects on the CNS from other systemic symptoms, such as hypoxia. Animal studies have shown a specific vulnerability of the hippocampus (14). If this is the case with COVID-19 infection in humans, it raises the concern of the infection having an impact on memory and possible accelerated onset of hippocampus-related neurodegenerative diseases such as Alzheimer's dementia (AD). In addition, COVID-19 infection worsens cognitive function in those with pre-existing AD, through both direct infection effects as well as the pandemic-related social and environmental restrictions (15). The mechanism for direct infection was investigated in a post-mortem study (16). It suggests concomitant COVID-19 infection could amplify pre-existing dementia in at least two ways: (1) by modulating the expression of proteins that may worsen AD; (2) stressing the already dysfunctional neurons especially in areas with abundant hyperphosphorylated tau protein and/or β-amyloid-42; (3) potentially increasing neuroinflammation (16).

Most of the research focuses on patients requiring admission to hospital for COVID-19 infection. However, cognitive symptoms especially, can also occur in people who had a seemingly mild infection (not requiring hospitalization) from which they apparently fully recovered, i.e., their acute viral symptoms resolved (11, 13). In one study where 80% of participants had a mild COVID-19 infection, 28.6% reported new "dementia" symptoms (7).

Importantly, metabolic brain studies (17–21) have shown cerebral hypometabolism using ^{18}F-fluorodeoxyglucose-positron emission tomography (FDG-PET) imaging. This research shows a consistent pattern of frontal hypometabolism and cerebellar hypermetabolism in post COVID-19 patients complaining of cognitive deterioration. FDG-PET imaging also shows cerebral glucose hypometabolism in other conditions associated with cognitive decline such as mild cognitive impairment (MCI) and AD (22). This glucose hypometabolism can potentially be countered by providing a dietary source of substrate to increase serum ketone bodies (23, 24) with, in the case of MCI, a direct and significant benefit in several cognitive domains (25).

As a therapeutic strategy, *endogenous* ketosis to correct brain glucose hypometabolism requires a significant and prolonged reduction in insulin, which is typically achieved by fasting and/or very significant reduction in carbohydrate intake. However, both ketone bodies and medium-chain fatty acids (MCFA) can also be supplied from an *exogenous* dietary source, such as medium chain triglyceride (MCT, C8, caprylic acid), without needing to change energy or macronutrient intake. Such a daily MCT supplement partially overcomes the cerebral glucose hypometabolism in MCI (25, 26) and AD (27, 28) with concomitant improvement in cognitive symptoms in the domains of memory, executive function, language, and processing speed. Some studies suggest ketone bodies selectively target neuronal mitochondrial function (29, 30). Other than the direct effect of ketone provision, MCT can also directly inhibit AMPA receptors (glutamate receptors), and change cell energetics through mitochondrial biogenesis (31).

Hypothesis

Ketosis induced by MCT oil supplementation will improve brain energy metabolism post-COVID-19 because ketone bodies will correct/bypass persistent brain glucose hypometabolism, resulting in better cognitive function and less brain fog. See Figure 1.

1 www.worldometers.info/coronavirus/

Evaluation of the hypothesis

Generation of ketone bodies

Endogenous

The brain metabolizes 120–130 g/day of glucose (32). It consumes 16% of the body's total O_2 consumption, despite representing only 2.0–2.3% of adult body weight. In numerous physiological states, including the neonatal period, fasting, calorie restriction, starvation, post exercise, and very low carbohydrate diets, the body is able to generate ketone bodies (acetoacetate and beta hydroxybutyrate) as an alternative brain energy source to glucose (33). *Endogenous* ketone bodies are normally generated by beta-oxidation of long chain fatty acids released from adipose tissue. This process is dependent on low insulin levels, which enhances lipolysis in white adipose tissue due to the suppressed insulin-induced inhibition of hormone sensitive lipase (34). In long-term fasting, ketone bodies can supply >60% of the brain's energy requirements (32, 35), and are actually preferentially taken up by the brain over glucose when adequate amounts of both energy substrates are available (36–39), although glucose will always be used in conjunction with ketone bodies. *Endogenous* ketosis can also be induced with a very low carbohydrate high fat (VLCHF) diet (40) or a ketogenic diet (41).

Whether ketogenesis or catabolism is normal in COVID-19 acute illness or post-COVID is unknown. Indeed, if treatment includes intravenous dextrose, insulin will undoubtedly suppress endogenous ketone production.

Nutritional (exogenous)

Long term compliance with fasting or VLCHF, LCHF and ketogenic diet (KD) regimes is challenging (40). Although the cardiometabolic safety of the KD is becoming less of a concern, it is still best applied under close medical or dietetic supervision (40, 41).

MCT consumption, on the other hand, has the potential advantage of inducing nutritional ketosis without the need for a drastic change in dietary habits, especially during a time when a person is perhaps the least able to adjust (24–28, 30, 39, 42–46). Medium chain fatty acids (6-12C) from MCT are rapidly absorbed from the gastrointestinal tract, and unlike long chain fatty acids (13-22C), move directly into the liver *via* the portal vein and do not promote triglyceride synthesis (23). See Figure 2 (23). Once absorbed some are metabolized into ketone bodies, which enter the citric acid cycle to provide energy *via* adenosine triphosphate (ATP). The remainder of the absorbed MCFA enter the circulation and cross the blood brain barrier as MCFAs (24, 31, 47, 48). Unlike long-chain fatty acids, MCFAs are able to directly enter mitochondria without the need for carnitine-dependent transport. This allows for rapid Beta-oxidation and ATP generation (24, 49), which is particularly important in the role of MCT for epilepsy management (50–52). *Exogenous* ketosis from MCT is independent of the fasting state, plasma insulin or carbohydrate intake.

There is a direct dose–response relationship between MCT consumption, plasma ketone [B-hydroxybutyrate (BHB)] response (46) and brain ketone uptake (30). MCT can be consumed *per se* or emulsified into a drink, and is generally well tolerated provided the dose is slowly increased (28). Research interest is growing in the use of lipid nanoparticles as another potential mode of delivery, perhaps allowing for increased doses and better MCT tolerability (53). Reducing simple sugar intake while providing MCT may improve insulin sensitivity and potentially help endogenous ketosis (54). Ketone response can also be easily assessed with finger-prick BHB testing (46).

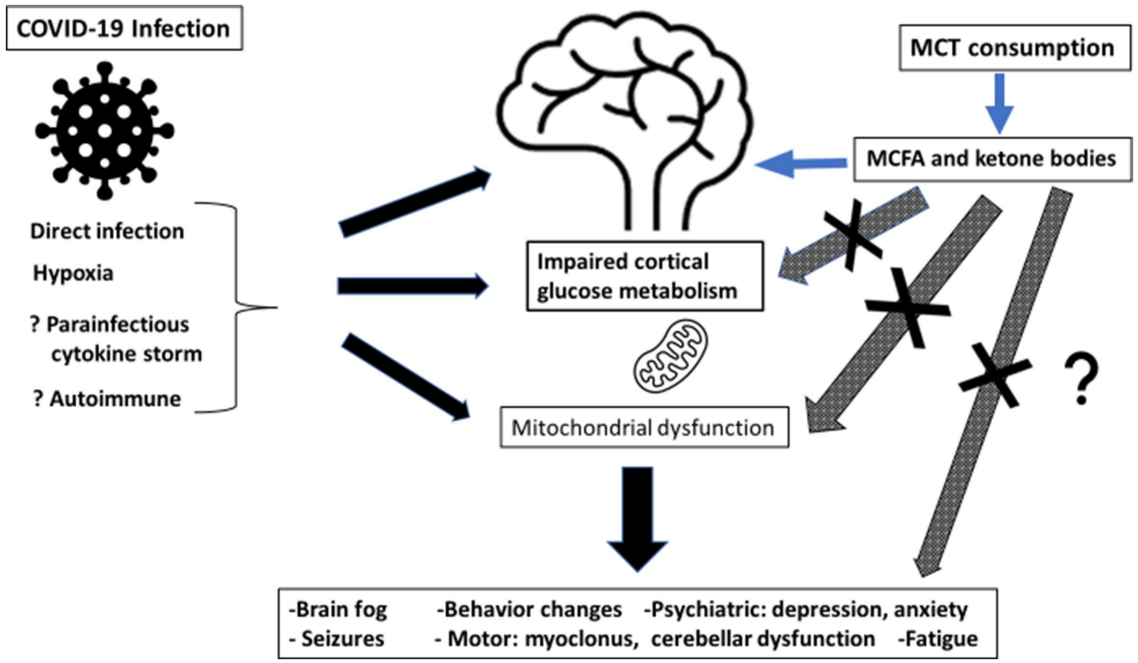

FIGURE 1
Summary of potential mechanism of action of medium chain triglyceride (MCT) consumption for post-COVID-19 cognitive symptoms. MCT, medium chain triglyceride; MCFA, medium chain fatty acids.

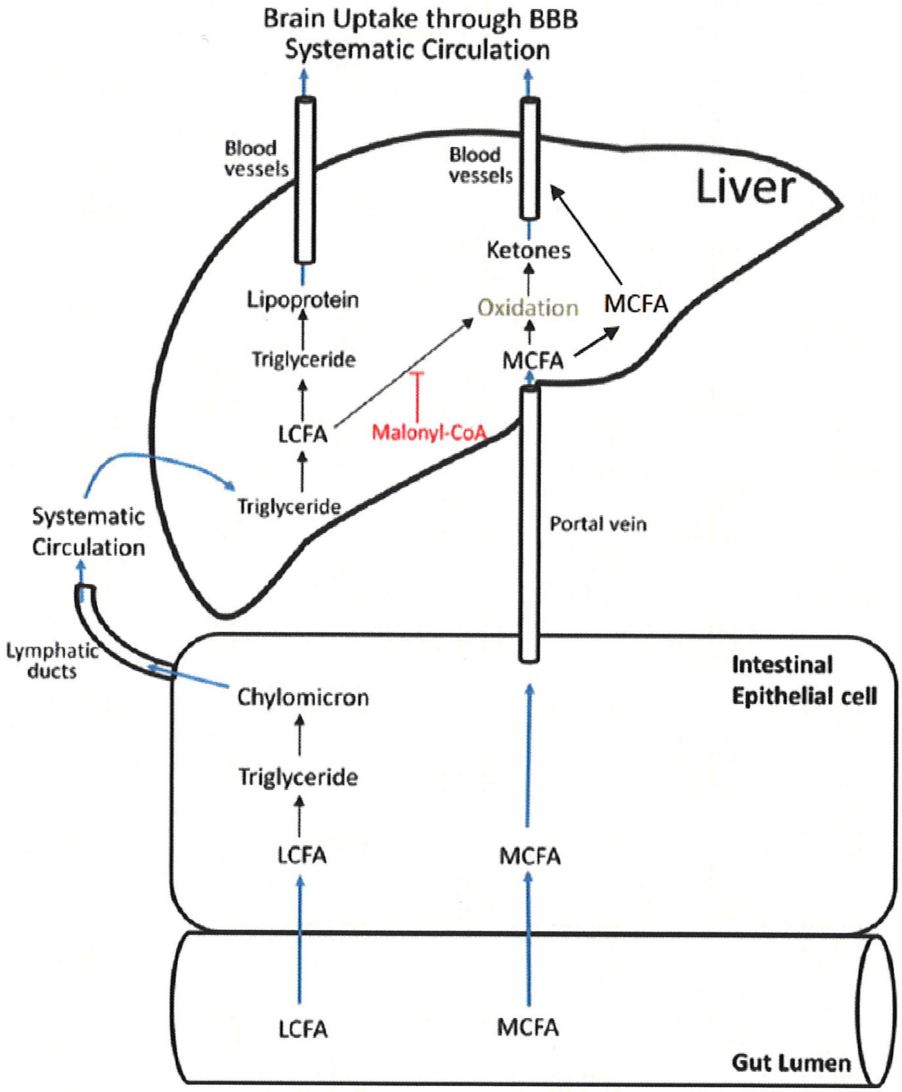

FIGURE 2
MCT absorption and metabolism. LCFA, long chain fatty acids; MCFA, medium chain fatty acids (22) (Figure adapted) (Reproduced with permission by the publisher).

Long term safety with MCT consumption has been established in pediatric populations over the years with the use of MCT in pediatric supplements (55). Safety in adults with AD and MCI participants has also been shown (28, 56). MCT supplementation requires input from knowledgeable physicians, dietitians, or other health professionals, to optimize potential beneficial effects and minimize side effects.

As previously noted, some of the MCT consumed is converted into ketone bodies in the liver, but some also remains as MCFAs in the blood, the relative amount of which depends on the MCT consumed. For example, C8 MCT produces more ketone bodies than C10 MCT (47).

Ketone bodies (such as BHB) and MCFAs have been shown to be supplementary cognitive fuels in different cellular compartments in the brain (57). BHB and MCFAs enter the brain via different mechanisms: BHB depends on monocarboxylate transporters; while MCFAs appear to diffuse passively across cell membranes (50, 58). Studies in animal models suggest that MCFAs are metabolized by astrocytes, although they may also support neuronal metabolism (49). In contrast, neurons appear to be the primary cellular compartment of ketone body metabolism (58). This appears to be a non-competitive process (57). It is currently unknown whether, apart from ketone body production, MCFAs *per se* have value as auxiliary fuels to the brain (57). However, this data suggests that using MCT *per se*, rather than ketone esters or a ketogenic diet alone, may well provide auxiliary fuel to both major cell types in the central nervous system, and may be preferred in conditions where there are defects in glucose metabolism in astrocytes and neurons (57).

In epilepsy treated with MCT there is no clear correlation between serum ketone body levels and seizure reduction, suggesting that in this circumstance, at least, there is a role of the MCFA *per se* (particularly C10 MCFA) for seizure reduction (52). To date, MCT supplementation

has not be assessed for cognitive effects in post COVID-19 cognitive complaints.

Possible causes of cognitive impairment post COVID-19

The etiology of post COVID-19 cognitive symptoms continues to be investigated with both direct and indirect causes possible. See Figure 3 (59). Vascular disease appears to be disproportionately common in COVID-19 than in comparable infections, whereas immunologically mediated neurological conditions are similar in frequency (59). The evidence supporting direct central nervous system by SARS-CoV-2 as a cause of neurological disease is conflicting (59).

Direct

Direct invasion

Although direct invasion of the central nervous system (CNS) by COVID-19 has been reported it is still debated (59) One hypothesis of CNS infection through a nasopharyngeal route is supported by clinical observations of frequent and persistent anosmia/dysgeusia (12, 60, 61).

However, of note, no descriptions of viral inclusions or reactive cellular changes typical of true infection have been reported (62, 63), and there is no evidence COVID-19 can cross the blood brain barrier (59). Contradictory reports from different groups highlight the technical challenges involved, and the possibility of viral contaminants from the blood or endothelium (59).

Indirect

Immunological

Acute inflammation

The hyperinflammatory state secondary to COVID-19 infection, causes a massive release of cytokines and chemokines that could alter the permeability of the blood–brain barrier. This phenomenon can activate a neuroinflammation cascade (64). A COVID-19 patient presented with only mild respiratory symptoms but with encephalitis (60), and responded to steroid therapy, suggesting the neurological symptoms could have involved a cytokine-mediated hyperinflammatory response. Although there was no evidence of SARS-CoV-2 in the CSF by RT-PCR, a direct CNS infection could not be excluded (50). Since that initial report, several studies have reported delirium and encephalitis post-COVID (65, 66).

Increased IL-6 levels in the blood and CSF in some COVID patients may support a para-infectious cytokine release, postinfectious antibody-or cell-mediated immune mechanism. Cytokines can pass the blood–brain barrier, induce central inflammatory responses and influence neurotransmitter metabolism and neural plasticity (67, 68). They induce dysfunction in brain areas implicated in emotional and

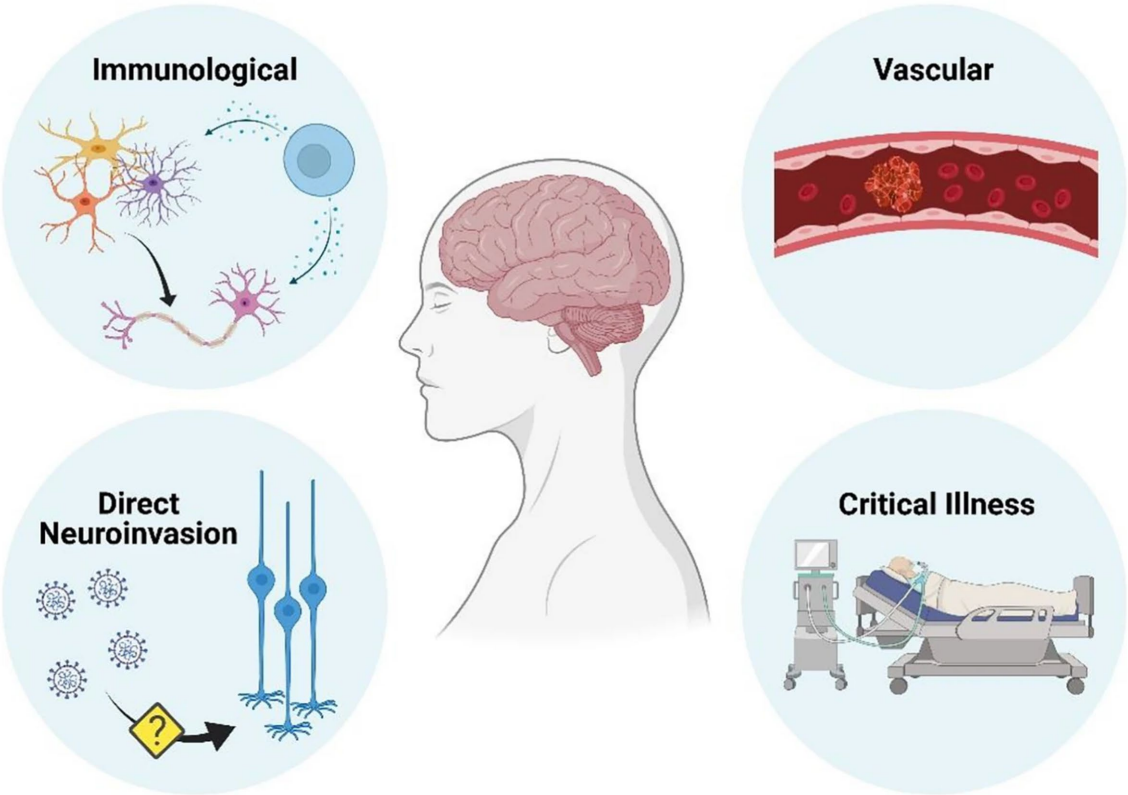

FIGURE 3
Mechanisms by which neurological disease can occur as a result of COVID-19 infection (59) (Reproduced with permission from the publisher). Figure created with BioRender.com.

behavioral regulation and cognition (such as the prefrontal cortex, basal ganglia) and fear and anxiety-related regions (such as the amygdala, insula and anterior cingulate cortex) (67).

e Silva and colleagues (68) propose that tumor necrosis factor-α (TNF-α) and IL-6 are the two major cytokines upregulated in COVID-19 that directly affect brain physiology. These cytokines are also upregulated in AD and depression (67), and therefore may be responsible for the mood and cognitive changes identified in long-COVID.

Chronic inflammation

Chronic inflammation occurs in several neurological disorders (69). The proinflammatory response to COVID-19 may contribute to the neurological sequelae. In addition, its effect on the immune system further promotes viral propagation. The CNS effects such as brain fog may impair individual judgment, affecting behavior and compliance with COVID prevention recommendations/protocols, thereby further promoting viral propagation (29).

So far, anti-inflammatory therapy has not been shown to be useful in affecting long COVID cognitive function, including dexamethasone, and tocilizumab (70, 71).

Autoimmune

Female preponderance has led to speculation of a possible autoimmune basis for persistent symptoms in long-COVID patients (72, 73) with some groups showing elevated anti-nuclear antibody (ANA) titers. Hypothetically, COVID-19 could also induce, by molecular mimicry-related mechanisms, the production of antibodies against neural or glial cells, as demonstrated for HSV-1, Epstein–Barr virus, and Japanese encephalitis (62).

Mitochondrial damage

CNS neuronal mitochondrial function requires high oxygen levels. SARS-CoV-2 genomic and subgenomic RNA (sgRNA) transcripts hijack the host cell's machinery (74). This viral "hijacking" of the mitochondrial genome (74, 75) results in mitochondrial dysfunction which compromises the high oxygen demands of the neurons causing cerebral hypoxia (29, 76). This selective neuronal mitochondrial targeting by SARS-CoV-2 may be an evolutionary advantage, as it causes "brain fog" and behavioral changes that favor viral propagation (29, 76).

Vascular

A D-dimer is a degradation product of crosslinked fibrin, and reflects ongoing activation of the hemostatic system. With COVID-19 infection D-dimer levels are known to be elevated, with or without venous thromboembolism (65) suggesting *microvascular* coagulation factor activation. Fibrin amyloid microclots have recently been identified in patients with long COVID symptoms using fluorescence microscopy (77). Failed fibrinolysis of these microclots could contribute to micro-capillary blockage and tissue hypoxia, and the diversity of symptoms of long COVID (77).

Macrovascular disease is well documented with an increased risk for acute cerebrovascular accidents, over and above the risks associated with immobility and dehydration (21, 78). Immunologically mediated thrombosis may also play a role, with reports of the presence of anticardiolipin and antiphospholipid antibodies, as well as lupus anticoagulant (73, 79). These are prothrombotic resulting in recurrent arterial and venous thromboembolic events (73). Endotheliitis is also a likely contributing factor to pathological clotting and cerebral vascular events, as well as effects on other organs such as lung, heart, kidney and intestine (80).

Brainstem dysfunction

Compared to other brain regions, the brainstem has a relatively high expression of angiotensin-converting enzyme 2 (ACE2) receptors. Brainstem involvement has been shown in post-mortem studies with detection of SARS CoV-2 RNA or proteins in 53% of patients. Indeed, a recent hypothesis paper (81) discusses persistent brainstem dysfunction in long-COVID. This may be related to direct SARS-CoV-2 invasion, or a pathological immune response, or vascular activation (81).

Glucose and insulin metabolism in COVID-19

The severity, morbidity and mortality due to COVID-19 have been shown to be increased in those with pre-existing diabetes and obesity (82, 83), and hyperglycemia promotes severity and disease progression (84, 85). In addition, COVID-19 has accelerated the global pandemic of hyperglycemia (86). Elevated blood glucose acts synergistically with COVID-19 to inactivate angiotensin converting enzyme-2 which dysregulates glycaemic control in all those cell types that are infected by the virus (87). Obesity has been reported to be associated with a greater number of long COVID symptoms (88).

Elevated serum ketones *per se* have only been reported with acute COVID-19 infection, but not in long COVID patients. Patients, both diabetic and non-diabetic, with acute COVID-19 infection have presented with ketosis or ketoacidosis (89). Another group reported an initial increase in the ketone body 3-hydroxybutyrate on the first day of acute COVID-19 infection, suggesting a ketotic-like state. Although this was reduced over a week, it still persisted to a small extent beyond 7 days (90).

One of the consequences of inflammation is insulin and glucocorticoid receptor resistance (87). These changes result in a reduction of glucose availability to peripheral tissues and the brain (91), and are particularly relevant following recovery from the acute stage while the inflammation remains. In addition, brain glucose metabolism might be a factor in the spread of the SARS-CoV-2 virus in the brain (92).

Cerebral glucose hypometabolism has also been reported in many other viral diseases including SARS, HIV, Hepatitis C, and tick-borne encephalitis. Essentially in any viral infection associated with encephalopathy (93, 94).

Cerebral glucose hypometabolism in COVID-19 (as assessed by FDG-PET neuroimaging)

Research groups from around the globe have investigated cerebral glucose metabolism in COVID-19, both in the acute stage and over time. Initial reports were related to hospitalized patients. From France, Helms and colleagues (21) reported on 58 hospitalized COVID-19 patients. Using magnetic resonance imaging (MRI), they demonstrated

bilateral frontal hypoperfusion in 11 patients. Cani and colleagues (17) reported a case study from Italy of a 77-year-old female hospitalized and ventilated for COVID-19 infection with impaired consciousness. Her respiratory symptoms subsequently improved, but her cognitive issues did not, and an FDG-PET scan showed frontal lobe hypometabolism, with bilateral frontotemporal hypoperfusion and anterior slowing on the EEG. Subsequently, Guedj and colleagues (20) reported on two male COVID-19 patients from France. After recovery (requiring admission to intensive care), persistent cognitive complaints prompted FDG-PET imaging and showed hypometabolism in the pre/post central gyrus, thalamus/hypothalamus, cerebellum and brainstem, with brain abnormalities persisting after the remission of the infectious phase. Delorme et al. (18), also from France, reported on four patients presenting with cognitive symptoms, predominantly affecting the frontal lobe, presenting 0–12 days after their COVID-19 symptoms. All had normal MRI and CSF findings, but consistent FDG-PET frontal hypometabolism and cerebellar hypermetabolism. All improved clinically with intravenous polyvalent immunoglobulin (IVIg) or pulse corticosteroid immunotherapy.

A larger study of 29 post hospitalized subjects from Germany (95) also looked at neurological sequelae. At approximately 1-month after the acute infection, they showed pathological changes on FDG-PET in 10/15 subjects with predominantly frontoparietal hypometabolism. These changes were confirmed objectively with impaired frontoparietal scores on the Montreal Cognitive assessment (MoCA) tool.

Because many cases of post COVID-19 cognitive decline are not associated with severe infection or even hospitalization, this raises speculation that there may be other mechanisms of neurological damage in addition to viral load and infection severity, as discussed previously. Symptoms of brain fog occur more commonly in those people who do not require hospitalization given the "mildness" of their COVID-19 symptoms. It is postulated, that the FDG-PET abnormalities identified may be an indicator of astrocyte dysfunction (96–99), leading to persistent synaptic dysfunction as a potential etiology for the identified symptoms and FDG-PET hypometabolism (100).

Despite their different clinical presentations, all the patients in these trials presented with similar altered FDG-PET pattern: bilateral frontotemporal hypoperfusion and cerebellar hypermetabolism. It is important to note that this *FDG-PET pattern is very distinct*, and different from that typically seen in patients with delirium, who exhibit global cortical hypometabolism (101). FDG-PET findings are more strongly associated with clinical symptoms, disease course and status than is MRI (except for cerebrovascular events) so some authors suggest *it should be considered for the initial workup, as well as for monitoring treatment in COVID-related encephalopathy* (102, 103). A recent consensus paper from the European Association of Nuclear Medicine (EANM) neuroimaging committee not only confirms the hypometabolic profile in patients with long COVID symptoms, but they go on to recommend FDG-PET neuroimaging as a way to objectively assess brain involvement in long COVID (104). They add a caveat that the testing should be done three to six months following the initial infection, or with worsening symptoms. They also reiterate the importance of a multi-disciplinary approach to also address the non-neurological symptoms (104).

Whether brain ketone metabolism is also affected remains to be determined.

Natural history of cognitive symptoms

Hospitalized patients

There are still limited data on the natural history of post COVID-19 cognitive symptoms. One recent publication (105) re-evaluated eight previously hospitalized post COVID-19 patients from Freiburg, Germany, six months after initial infection. Although there was some improvement in their MoCA score from their initial score, it was still below normal cut-offs, and in the range of MCI, with persistent deficits in visuo-constructive, executive and memory function (105). Their FDG-PET images showed some improvement, but compared to normal controls, they still had significantly more frontoparietal and temporal hypometabolism. The authors felt this slow reversal was due to ongoing subcortical peri-inflammatory processes (105).

Kas and colleagues (102) looked at FDG-PET images at baseline, 1-and 6-months post COVID-19 in seven patients. All had a consistent pattern of hypometabolism in many brain areas including the frontal cortex, anterior cingulate, insula and caudate nucleus. After six months, the majority had improved clinically, but cognitive and emotional disorders of varying severity remained, with attention/executive disabilities and anxio-depressive symptoms. In addition, there were lasting prefrontal, insular and subcortical FDG-PET abnormalities. Interestingly, while some of their patients almost returned to normal cerebral metabolism (even those with initial widespread decrease), others only partially improved or, indeed, worsened. After having first improved, one patient subsequently worsened, with clinical symptoms and a new pattern of brain hypometabolism (102). This again raises the question of an associated neurodegenerative disorder. None of these patients had SARS-CoV-2 in the CSF and/or meningitis, nor had FDG-PET anomalies limited to the olfactory gyrus that could corroborate a direct viral neuro-invasion (102).

Retrospectively evaluating their long COVID patients, Guedj and colleagues reported a larger case series of 35, showing similar abnormal FDG-PET imaging changes as reported in the acute stage, when compared to their database of healthy subjects (106). In a prospective case–control study from Italy, Sollini and colleagues (107) enrolled 13 long COVID patients, and again showed FDG-PET cerebral hypometabolism in the right parahippocampal gyrus and right thalamus compared to melanoma patients matched for age and sex (107). In their study, brain hypometabolism was correlated with current symptoms, rather than the severity of the acute infection.

Larger studies of hospitalized patients included one study of 165 subjects, without baseline cognitive symptoms. They found 40% still had ongoing neurological symptoms at the 6-month follow up (108). Older age, baseline comorbidities, and infection severity were considered to be major risk factors for ongoing neurological symptoms. Neuroimaging was however not included in this study.

Adding to the imperative to explore strategies to address these brain changes, is the concerning report that similar patterns of FDG PET brain hypometabolism are also seen in pediatric COVID-19 patients (109). It is possible that some patients may have received MCTs *via* parenteral or enteral nutrition, but currently there are no publications specifically discussing this, and whether there was any cognitive impact.

Non-hospitalized patients

There is a paucity of data on non-hospitalized COVID-19 patients with neurological symptoms. One report (72) reviewed 100 patients attending a Neuro-COVID-19 clinic. Their average age was 43-years, and 70% were female. The main neurological complaint (81%) was brain fog. This was associated with impaired quality of life, and worse attention and working memory cognitive scores compared to non-COVID controls. MRI and EEG studies were normal. None of their participants had FDG-PET imaging.

Recent reviews have summarized the knowledge to date of FDG-PET findings in acute and long COVID-19 (110, 111).

Possible exacerbation of neurodegenerative diseases

Given the ongoing nature of the pandemic, long term neurological sequelae of COVID-19 are still relatively unknown, including possible acceleration of pre-existing neurological diseases. It has been reported that FDG brain hypometabolism in the pre-frontal cortex is also present in multiple neurodegenerative disorders (such as Parkinson's disease and AD) (24, 112, 113) and neuropsychiatric conditions (114). These changes can pre-date clinical symptoms, sometimes by years. In fact, new onset Parkinsonism has already been reported post COVID-19 infection (115). COVID-19 infection can impact pre-existing mild cognitive impairment and Alzheimer's dementia worsening the progression of both (116).

This has generated concern about a "delayed pandemic" of neurodegenerative and neuropsychiatric disease (117, 118).

Role of ketone bodies in cognitive function

Although glucose is the main fuel for brain function, under certain circumstances, such as prolonged fasting, ketone bodies can replace glucose as the main fuel, and provide 50–60% of the brain energy needs (119). Even if glucose availability is acutely reduced, by experimental hypoglycemia, ketone infusion or medium chain fatty acid (MCFA) ingestion preserves cognitive function, and symptoms of acute glucopenia are not observed (120, 121).

Ketone bodies are not only for brain energy metabolism; they serve as lipogenic and steroid biosynthetic substrates in many tissues including the developing brain, lactating mammary gland and liver (33). They are avidly oxidized in the heart and muscle, as an alternative and glucose-sparing fuel source, and the myocardium is the highest ketone body consumer per unit mass (33). Ketone bodies are also signaling molecules for cell-surface and intracellular receptors (33), and therefore regulate mitochondrial metabolism, energetics, and reactive oxygen species (ROS) production (33). This increases seizure threshold and is felt to be one of the mechanisms of the beneficial effects of ketone bodies in epilepsy (122). They also drive protein posttranslational modification and are modulators of inflammation and oxidative stress (123). Not surprisingly, therefore, they are being investigated for their role in cell metabolism, homeostasis, and signaling under a wide variety of physiological and pathological states (124).

Ketone bodies generated from MCT consumption not only spare glucose, but also support brain metabolism during energy crises, without prior adaptations from fasting (125). They have neuroprotective effects through two main mechanisms: improved mitochondrial function, and regulation of gene expression (126).

Cerebral insulin resistance is known to be a contributing factor in AD (127, 128). This brain insulin resistance aggravates toxic Aβ production and tau-hyperphosphorylation (129–132). The metabolism of ketone bodies mitigates some of the negative CNS effects of hyperglycemia (133), thereby improving insulin sensitivity and attenuating insulin resistance (134, 135).

Evidence for ketone bodies in other cognitive disorders

Neuroinflammation is a common feature in neurodegenerative disease and may promote a brain energy crisis (136), and this can be mitigated by ketone bodies. MCT use in this hypothesis is not being suggested as an anti-inflammatory agent, but for its direct effect on cerebral metabolism.

In other neurocognitive disorders associated with documented FDG-PET brain hypometabolism, such as MCI and AD, patients present with a decline in their cognitive abilities ranging from subjective complaints to more objectively and clinically defined cognitive deficits. These FDG-PET identified metabolic changes can pre-date the clinical neurological deficits (39, 113). In Parkinson's disease, amyotrophic lateral sclerosis, and Huntington disease, glucose hypometabolism in selected brain regions is prominent, and correlates with disease severity (24, 34). In addition, AD and MCI patients have changes in mood often presenting with features of depression and apathy, both of which are also seen in the post COVID-19 state.

Unlike for COVID-19 infection, there is data in AD and MCI that shows, despite impaired cerebral glucose metabolism, cerebral ketone uptake is preserved (25, 26).

Exogenous ketone bodies, supplied by MCT consumption, may have beneficial effects on cognitive outcomes in both established AD and MCI (25, 27, 28, 43–45, 137, 138). Results are sometimes conflicting, likely related to different MCT formulations, outcome measures, dose, duration, and participant inclusion criteria. A recent meta-analysis of the trials of MCT supplementation in AD by Avgerinos and colleagues, concluded that MCTs can induce mild ketosis and may improve cognition in patients with MCI and AD (139). MCT supplement doses used in clinical trials varies depending on the study design, MCT composition and formulation. There is no clear dosing regime, but data so far suggests a minimum of 28 g of MCT is needed daily to have a measurable clinical impact (25–28). Dividing the doses (ideally 3–4/day) not only improves tolerability, but also facilitates higher levels of ketone bodies and MCFA throughout the day.

Other than being a source of brain energy, in mouse models of AD, ketone bodies were reported to show cognition-sparing, and reduction of amyloid-beta and tau pathology (140, 141). This raises the intriguing possibility that MCT consumption could also potentially affect the recently described fibrin amyloid microclots felt to be contributing to symptoms in long COVID patients (77).

The effect of ketone bodies on feeding behavior, energy expenditure, mood and behavior, and neuroprotection have been reported, and are summarized in a recent review (123).

Discussion

The consequences of COVID-19 infection on cognitive function in both the acute and long COVID phases, in previously cognitively normal patients, has now been well documented. As more patients are followed long-term, increased data will become available as to the duration, social and psychological consequences of these cognitive deficits. What remains to be seen is whether this will translate into the development of other neurodegenerative diseases such as Alzheimer's dementia and Parkinson's disease, and whether this will occur at an earlier age of onset than is currently seen. A "delayed pandemic" of neurodegenerative and neuropsychiatric disease is predicted (117, 118). The societal and health systems consequences of this could be catastrophic.

In addition, it is now well recognized that COVID-19 infection can impact pre-existing mild cognitive impairment and Alzheimer's dementia, worsening the progression of both (116). It can cause delirium which may not resolve, or may unmask undiagnosed MCI.

MCT is a component of coconut oil, and readily available worldwide. Given the cerebral glucose hypometabolism documented post COVID-19, as summarized in Figure 1, we hypothesize that treatment of neurological symptoms in post COVID-19 patients using MCT supplementation will provide clinical benefit in the short term, and perhaps aid functional recovery of the brain in the long term. The fact that cerebral glucose hypometabolism has also now been documented in the pediatric COVID-19 population is particularly concerning, but it is reassuring that there has already been experience and an established safety profile with MCT supplementation in the pediatric population.

If there is improvement in symptoms with MCT supplementation, further research will need to be done to evaluate whether this is a direct effect on the cerebral glucose hypometabolism, or whether it is an indirect effect through improvement of mitochondrial function; an effect on post COVID fatigue; and/or, its anti-amyloid activity reducing the number of fibrin amyloid microclots.

To date over 500 million people have had a documented COVID-19 infection. Conservatively estimating 30% will experience long COVID symptoms, of which 30% will have cognitive complaints, leaves at least 45 million people with cognitive decline from their baseline. Any strategies to aid in cognitive recovery, or mitigate the cognitive effects of the disease will have significant consequences at personal, population and health system levels.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

SC has consulted for or received travel honoraria or test products from Nestlé Health Science, Abbott, and Cargill.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Vastag B, Mazur B. (2020). Researchers warn covid-19 could cause debilitating long-term illness in some patients. The Washington Post. Available at: washingtonpost.com/health/could-covid-19-cause-long-term-chronic-fatigue-and-illness-in-some-patients/2020/05/29/bcd5edb2-a02c-11ea-b5c9-570a91917d8d_story.html (Accessed May 30, 2020).

2. Kleinman Z. (2020). Coronavirus: thousands say debilitating symptoms last 'for weeks'. BBC News. Available at: bbc.com/news/health-53269391 (Accessed May 30, 2020).

3. Carfi A, Bernabei R, Landi F, Gemelli Against COVID-19 Post-Acute Care Study Group. Persistent Symptoms in Patients After Acute COVID-19. *JAMA* (2020) 324:603–5.

4. Lopez-Leon S, Wegman-Ostrosky T, Perelman C, Sepulveda R, Rebolledo P, Cuapio A, et al. More than 50 long-term effects of COVID-19: A systematic review and Meta-analysis. *Res Sq*. (2021). doi: 10.21203/rs.3.rs-266574/v1

5. Chen C, Haupert SR, Zimmermann L, Shi X, Fritsche LG, Mukherjee B. Global prevalence of post COVID-19 condition or long COVID: a meta-analysis and systematic review. *J Infect Dis*. (2022) 226:1593–607. doi: 10.1093/infdis/jiac136

6. WHO. A clinical case definition of post COVID-19 condition by a Delphi consensus, 6 October 2021. Available at: https://www.who.int/publications/i/item/WHO-2019-nCoV-Post_COVID-19_condition-Clinical_case_definition-2021.1

7. Kamal M, Abo Omirah M, Hussein A, Saeed H. Assessment and characterisation of post-COVID-19 manifestations. *Infect Dis*. (2020) 75:e13746. doi: 10.1111/ijcp.13746

8. Saleki K, Banazadeh M, Saghazadeh A, Rezaei N. The involvement of the central nervous system in patients with COVID-19. *Rev Neurosci*. (2020) 31:453–6. doi: 10.1515/revneuro-2020-0026

9. The Management Group of the EAN Dementia and Cognitive Disorders Scientific PanelToniolo S, Scarioni M, Di Lorenzo F, Hort J, Georges J, et al. Dementia and COVID-19, a bidirectional liaison: Risk factors, biomarkers, and optimal health care. *J Alzheimers Dis*. (2021) 82:883–98.

10. Godlee F. Living with covid-19. *BMJ*. (2020) 370:m3392. doi: 10.1136/bmj.m3703

11. Iqbal A, Iqbal K, Arshard Ali SA, Azim D, Farid E, et al. The COVID-19 sequelae: a cross-sectional evaluation of post-recovery symptoms and the need for rehabilitation of COVID-19 survivors. *Cureus*. (2021) 13:e13080. doi: 10.7759/cureus.13080

12. Desforges M, Le Coupanec A, Dubeau P, Bourgouin A, Lajoie L, Dubé M, et al. Human corona viruses and other respiratory viruses: underestimated opportunistic pathogens of the central nervous system? *Viruses*. (2019) 12:14. doi: 10.3390/v12010014

13. Filatov A, Sharma P, Hindi F. Neurological complications of coronavirus disease (COVID-19): encephalopathy. *Cureus*. (2020) 70:311–22. doi: 10.7759/cureus.7352

14. Hosseini S, Wilk E, Michaelsen-Preusse K, Gerhauser I, Baumgartner W, Geffers R, et al. Long-term Neuroinflammation induced by influenza A virus infection and the impact on hippocampal neuron morphology and function. *J Neurosci*. (2018) 38:3060–80. doi: 10.1523/JNEUROSCI.1740-17.2018

15. Hardan L, Filtchev D, Kassem R, Bourgi R, Lukomska-Szymanska M, Tarhini H, et al. COVID-19 and Alzheimer's disease: A literature review. *Medicina*. (2021) 57:1159. doi: 10.3390/medicina57111159

16. Nuovo GJ, Suster D, Sawant D, Mishra A, Michaille JJ, Tili E. The amplification of CNS damage in Alzheimer's disease due to SARS-CoV2 infection. *Ann Diagn Pathol*. (2022) 61:152057. doi: 10.1016/j.anndiagpath.2022.152057

17. Cani I, Barone V, D'Angelo R, Pisani L, Allegri V, et al. Frontal encephalopathy related to hyperinflammation in COVI-19. *J Neurol*. (2020) 268:16–9. doi: 10.1007/s00415-020-10057-5

18. Delorme C, Paccoud O, Kas A, Hesters A, Bombois S, Shambrook P, et al. COVID-19 related encephalopathy: A case series with brain FDG-PET/CT findings. *Eur J Neurol*. (2020) 27:2651–7. doi: 10.1111/ene.14478

19. Daulatzai MA. Cerebral hypoperfusion and glucose hypometabolism: key pathological modulators promote neurodegeneration, cognitive impairment, and Alzheimer's disease. *J Neurosci Res*. (2017) 95:943–72. doi: 10.1002/jnr.23777

20. Guedj E, Million M, Dudouet P, Tissot-Dupont H, Bregeon F, Cammilleri S, et al. 18F-FDG brain PET hypometabolism in postSARS-CoV-2 infection: substrate for persistent/delayed disorders? *Eur J Nucl Med Mol Imaging*. (2020) 48:592–5. doi: 10.1007/s00259-020-04973-x

21. Helms J, Kremer S, Merdji H, Clere-Jehl R, Schenck M, Kummerlen C, et al. Neurologic features in severe SARS-CoV-2 infection. *N Engl J Med*. (2020) 382:2268–70. doi: 10.1056/NEJMc2008597

22. An Y, Varma VR, Varma S, et al. Evidence for brain glucose dysregulation in Alzheimer's disease. *Alzheimers Dement*. (2018) 14:318–29. doi: 10.1016/j.jalz.2017.09.011

23. Lei E, Vacy K, Boon WC. Fatty acids and their therapeutic potential in neurological disorders. *Neurochem Int*. (2016) 95:75–84. doi: 10.1016/j.neuint.2016.02.014

24. Cunnane SC, Trushina E, Morland C, Prigione A, Casadesus G, Andrews ZB, et al. Brain energy rescue: an emerging therapeutic concept for neurodegenerative disorders of ageing. *Nat Rev Drug Discov*. (2020) 19:609–33. doi: 10.1038/s41573-020-0072-x

25. Fortier M, Castellano CA, St-Pierre V, Myette-Côté É, Langlois F, Roy M, et al. A ketogenic drink improves cognition in mild cognitive impairment: results of a 6-month RCT. *Alz Demen*. (2020) 15:625–34. doi: 10.1002/alz.12206

26. Croteau E, Castellano CA, Richard MA, Fortier M, Nugent S, Lepage M, et al. Ketogenic medium chain triglycerides increase brain energy metabolism in Alzheimer's disease. *J Alzheimers Dis*. (2018) 64:551–61. doi: 10.3233/JAD-180202

27. Hendersen ST, Vogel JL, Barr LJ, Garvin F, Jones JJ, Constantini LC. Study of the ketogenic agent AC-1202 in mild to moderate Alzheimer's disease: a randomized, double-blind, placebo-controlled, multicenter trial. *Nutr Metab*. (2009) 9:6–31. doi: 10.1186/1743-7075-6-31

28. Juby AG, Blackburn TE, Mager DR. Use of medium chain triglyceride (MCT) oil in subjects with Alzheimer's disease: A randomized, double-blind, placebo-controlled, crossover study, with an open-label extension. *Alzheimer's Dementia*. (2022) 8:e12259. doi: 10.1002/trc2.12259

29. Stefano GB, Ptacek R, Ptackova H, Martin A, Kream RM. Selective neuronal mitochondrial targeting in SARS-CoV-2 infection affects cognitive processes to induce 'Brain Fog' and results in behavioral changes that favor viral survival. *Med Sci Monit*. (2021) 27:e930886. doi: 10.12659/MSM.930886

30. Cunnane SC, Courchesne-Loyer A, Vandenberghe C, St-Pierre V, Fortier M, Hennebelle M, et al. Can ketones help rescue brain fuel supply in later life? Implications for cognitive health during aging and the treatment of Alzheimer's disease. *Front Mol Neurosci*. (2016) 9:53. doi: 10.3389/fnmol.2016.00053

31. Augustin K, Khabbush A, Williams S, Eaton S, Orford M, Cross JH, et al. Mechanisms of action for the medium-chain triglyceride ketogenic diet in neurological and metabolic disorders. *Lancet Neurol*. (2018) 17:84–93. doi: 10.1016/S1474-4422(17)30408-8

32. Owen OE, Morgan AP, Kemp HG, Sullivan JM, Herrera MG, Cahill GF. Brain metabolism during fasting. *J Clin Invest*. (1967) 46:1589–95. doi: 10.1172/JCI105650

33. Cotter DG, Schugar RC, Crawford PA. Ketone body metabolism and cardiovascular disease. *Am J Physiol Heart Circ Physiol*. (2013) 304:H1060–76. doi: 10.1152/ajpheart.00646.2012

34. Jensen NJ, Wodschow HZ, Nilsson M, Rungby J. Effects of ketone bodies on brain metabolism and function in neurodegenerative diseases. *Int J Mol Sci*. (2020) 21:8767. doi: 10.3390/ijms21228767

35. Drenick EJ, Alvarez LC, Tamasi GC, Brickman AS. Resistance to symptomatic insulin reactions after fasting. *J Clin Invest*. (1972) 51:2757–62. doi: 10.1172/JCI107095

36. Hasselbach SG, Madsen PL, Hageman LP, Olsen KS, Justesen N, Holm S, et al. Changes in cerebral blood flow and carbohydrate metabolism during acute hyperketonemia. *Am J Phys*. (1996) 270:E746–51. doi: 10.1152/ajpendo.1996.270.5.E746

37. Corchesne Loyer A, Croteau E, Castellano CA, St Pierre V, Hennebelle M, Cunnane SC. Inverse relationship between brain ketone metabolism in adults during short-term moderate dietary ketosis: A dual tracer quantitative positron emission tomography study. *JCBFM*. (2017) 37:2485–93. doi: 10.1177/0271678X16669366

38. Nugent S, Croteau E, Pifferi F, Fortier M, Tremblay S, Turcotte E, et al. Brain and systemic glucose metabolism in the healthy elderly following fish oil supplementation. *PLEFA*. (2011) 85:287–91. doi: 10.1016/j.plefa.2011.04.008

39. Croteau E, Castellano CA, Fortier M, Bocti C, Fulop T, Plaquet N, et al. A cross-sectional comparison of brain glucose and ketone metabolism in cognitively healthy older adults, mild cognitive impairment and early Alzheimer's disease. *Exp Gerontol*. (2018) 107:18–26. doi: 10.1016/j.exger.2017.07.004

40. Caprio M, Infante M, Moriconi E, Armani A, Fabbri A, Mantovani G, et al. Very-low-calorie ketogenic diet (VLCKD) in the management of metabolic diseases: systematic review and consensus statement from the Italian society of endocrinology (SIE). *J Endocrinol Inv*. (2019) 42:1365–86. doi: 10.1007/s40618-019-01061-2

41. Taylor MK, Sullivan DK, Mahnken JD, Burns JM, Swerdlow RH. Feasibility and efficacy data from a ketogenic diet intervention in Alzheimer's disease. *Alz Dem Transl Res Clin Interven*. (2018) 4:28–36. doi: 10.1016/j.trci.2017.11.002

42. Newport MT, Van Itallie TB, Kashiwaya Y, King MT, Veech RL. A new way to produce hyperketonemia: use of ketone monoester in a case of Alzheimer's disease. *Alz Demen*. (2015) 11:99–103. doi: 10.1016/j.jalz.2014.01.006

43. Rebello CJ, Keller JN, Liu AG, Johnson WD, Greenway FL. Pilot feasibility and safety examining the effect of medium chain triglyceride supplementation in subjects with mild cognitive impairment: a randomized controlled trial. *BBA Clin*. (2015) 3:123–5. doi: 10.1016/j.bbacli.2015.01.001

44. Xu Q, Zhang Y, Zhang X, Liu L, Zhou B, Mo R, et al. Medium-chain triglycerides improved cognition and lipid metabolomics in mild to moderate Alzheimer's disease patients with APOE4−/−: a double-blind, randomized, placebo-controlled crossover trial. *Clin Nutr*. (2020) 39:2092–105. doi: 10.1016/j.clnu.2019.10.017

45. Reger MA, Henderson ST, Hale C, Cholerton B, Baker LD, Watson GS, et al. Effect of B-hydroxybutyrate on cognition in memory-impaired adults. *Neurobiol Aging*. (2004) 25:311–4. doi: 10.1016/S0197-4580(03)00087-3

46. Juby AG, Brocks DR, Jay DA, Davis CMJ, Mager DR. Assessing the impact of factors that influence the ketogenic response to varying doses of medium chain triglyceride (MCT) oil. *J Prev Alz Dis*. (2021) 1:19–28. doi: 10.14283/jpad.2020.53

47. St-Pierre V, Vandenberghe C, Lowry CM, Fortier M, Castellano CA, Wagner R, et al. Plasma ketone and medium chain fatty acid response in humans consuming different medium chain triglycerides during a metabolic study day. *Front Nutr*. (2019) 6:46. doi: 10.3389/fnut.2019.00046

48. Hughes SD, Kanabus M, Anderson G, Hargreaves IP, Rutherford T, Donnell MO, et al. The ketogenic diet component decanoic acid increases mitochondrial citrate synthase and complex I activity in neuronal cells. *J Neurochem*. (2014) 129:426–33. doi: 10.1111/jnc.12646

49. Ebert D, Haller RG, Walton ME. Energy contribution of octanoate to intact rat brain metabolism measured by 13C nuclear magnetic resonance spectroscopy. *J Neurosci*. (2003) 23:5928–35. doi: 10.1523/JNEUROSCI.23-13-05928.2003

50. Han FY, Conboy-Schmidt L, Rybachuk G, Volk HA, Zanghi B, Pan Y, et al. Dietary medium chain triglycerides for management of epilepsy: new data from human, dog, and rodent studies. *Epilepsia*. (2021) 62:1790–806. doi: 10.1111/epi.16972

51. Wlaź P, Socała K, Nieoczym D, Łuszczki JJ, Żarnowska I, Żarnowski T, et al. Anticonvulsant profile of caprylic acid, a main constituent of the medium-chain triglyceride (MCT) ketogenic diet, in mice. *Neuropharmacology*. (2012) 62:1882–9. doi: 10.1016/j.neuropharm.2011.12.015

52. Schoeler NE, Orford M, Vivekananda U, Simpson Z, Van de Bor B, Smith H, et al. Vita: a feasibility study of a blend of medium chain triglycerides to manage drug-resistant epilepsy. *Brain Communications*. (2021) 3:fcab160. doi: 10.1093/braincomms/fcab160

53. Tan JY, Yoon BK, Cho NJ, Lovrić J, Jug M, Jackman JA. Lipid nanoparticle technology for delivering biologically active fatty acids and monoglycerides. *Int J Mol Sci*. (2021) 22:9664. doi: 10.3390/ijms22189664

54. Vandenberghe C, St-Pierre V, Fortier M, Castellano CA, Cuenoud B, Cunnane SC. Medium chain triglycerides modulate the ketogenic effect of a metabolic switch. *Front Nutr*. (2020) 7:3. doi: 10.3389/fnut.2020.00003

55. Cober MP, Gura KM, Mirtallo JM, Ayers P, Boullata J, Anderson CR, et al. ASPEN lipid injectable emulsion safety recommendations part 2: neonate and pediatric considerations. *Nutr Clin Pract*. (2021) 36:1106–25. doi: 10.1002/ncp.10778

56. Myette-Côté É, St-Pierre V, Beaulieu S, Castellano CA, Fortier M, Plourde M, et al. The effect of a 6-month ketogenic medium-chain triglyceride supplement on plasma cardiometabolic and inflammatory markers in mild cognitive impairment. *Prostaglandins Leukot Essent Fat Acids*. (2021) 169:102236. doi: 10.1016/j.plefa.2020.102236

57. Andersen JV, Westi EW, Neal ES, Aldana BI, Borges K. β-Hydroxybutyrate and medium-chain fatty acids are metabolized by different cell types in mouse cerebral cortex slices. *Neurochem Res*. (2023) 48:54–61. doi: 10.1007/s11064-022-03726-6

58. Achanta LB, Rae CD. β-Hydroxybutyrate in the brain: one molecule, multiple mechanisms. *Neurochem Res*. (2017) 42:35–49. doi: 10.1007/s11064-016-2099-2

59. Ren AL, Digby RJ, Needham EJ. Neurological update: COVID-19. *J Neurol*. (2021) 268:4379–87. doi: 10.1007/s00415-021-10581-y

60. Pilotto A, Odoloni S, Masciocchi S, Cornelli A. Steroid-responsive encephalitis in coronavirus disease 2019. *Ann Neurol*. (2020) 88:423–7. doi: 10.1002/ana.25783

61. Baig AM, Khaleeq A, Ali U, Syeda H. Evidence of the COVID-19 virus targeting the CNS: tissue distribution, host-virus interaction, and proposed neurotropic mechanisms. *ACS Chem Neurosci*. (2020) 11:995–8. doi: 10.1021/acschemneuro.0c00122

62. Li YC, Bai WZ, Hashikawa T. The neuroinvasive potential of SARSCoV2 may play a role in the respiratory failure of COVID-19 patients. *J Med Virol*. (2020) 92:707–9. doi: 10.1002/jmv.25728

63. Lou JJ, Movassaghi M, Gordy D, Olson MG, Zhang T, Khurana MS, et al. Neuropathology of COVID-19 (neuro-COVID): clinicopathological update. *Free Neuropathol*. (2021) 2:2. doi: 10.17879/freeneuropathology-2021-2993

64. Dorcet G, Benaiteau M, Bost C, Mengelle C, Bonneville F, Martin-Blondel G, et al. Two cases of late-onset antiNMDAr auto-immune encephalitis after herpes simplex virus 1 encephalitis. *Front Neurol*. (2020) 11:38. doi: 10.3389/fneur.2020.00038

65. Helms J, Kremer S, Merdji H, Schenck M, Severac F, Clere-Jehl R, et al. Delirium and encephalopathy in severe COVID-19: a cohort analysis of ICU patients. *Crit Care*. (2020) 24:491. doi: 10.1186/s13054-020-03200-1

66. Chou SH-Y, Beghi E, Helbok R, Moro E, Sampson J, Altamirano V, et al. Global incidence of neurological manifestations among patients hospitalized with COVID-19-A report for the GCS-neuro COVID consortium and the ENERGY consortium. *JAMA Neurol*. (2021):4. doi: 10.1001/jamanetworkopen.2021.12131

67. Felger JC. Imaging the role of inflammation in mood and anxiety related disorders. *Curr Neuropharmacol*. (2018) 16:533–58. doi: 10.2174/1570159X15666171123201142

68. E Silva NM, Barros-Aragão FG, De Felice FG, Ferreira ST. Inflammation at the crossroads of COVID-19, cognitive deficits and depression. *Neuropharmacology*. (2022) 209:109023. doi: 10.1016/j.neuropharm.2022.109023

69. Esch T, Stefano GB. Proinflammation: A common denominator or initiator of different pathophysiological disease processes. *Med Sci Monit*. (2002) 8:HY1–9.

70. Duindam HB, Kessels RPC, van den Borst B, Pickkers P, Abdo WF. Long-term cognitive performance and its relation to anti-inflammatory therapy in a cohort of survivors of severe COVID-19. *Brain Behav Immun Health*. (2022) 25:100513. doi: 10.1016/j.bbih.2022.100513

71. Putilina MV, Grishin DV. SARS-CoV-2 (COVID-19) as a predictor of Neuroinflammation and neurodegeneration: potential treatment strategies. *Neurosci Behav Physiol*. (2021) 51:577–82. doi: 10.1007/s11055-021-01108-z

72. Graham EL, Clark JR, Orban ZS, Lim PH, Szymanski AL, Taylor C, et al. Persistent neurological symptoms and cognitive dysfunction in non-hospitalized Covid-19 "long haulers". *Ann Clin Transl Neurol*. (2021) 10:1073:1085. doi: 10.1002/acn3.51350

73. Tung ML, Tan B, Cherian R, Chandra B. Anti-phospholipid syndrome and COVID-19 thrombosis: connecting the dots. *Rheumatol Adv Pract*. (2021) 5:rkaa081. doi: 10.1093/rap/rkaa081

74. Wu KE, Fazal FM, Parker KR, Zou J, Chang HY. RNA-GPS predicts SARS-CoV-2 RNA residency to host mitochondria and nucleolus. *Cell Syst*. (2020) 11:102–108.e3. doi: 10.1016/j.cels.2020.06.008

75. Singh KK, Chaubey G, Chen JY, Suravajhala P. Decoding SARS-CoV-2 hi¬jacking of host mitochondria in COVID-19 pathogenesis. *Am J Physiol Cell Physiol*. (2020) 319:C258–67. doi: 10.1152/ajpcell.00224.2020

76. Stefano GB, Esch T, Kream RM. Potential Immunoregulatory and antiviral/SARS-CoV-2 activities of nitric oxide. *Med Sci Monit*. (2020) 26:e925679. doi: 10.12659/MSM.925679

77. Kell DB, Laubscher GJ, Pretorius E. A central role for amyloid fibrin microclots in long COVID/PASC: origins and therapeutic implications. *Biochem J*. (2022) 479:537–59. doi: 10.1042/BCJ20220016

78. Tsivgoulis G, Palaiodimou L, Zand R, Lioutas VA, Krogias C, Katsanos AH, et al. COVID-19 and cerebrovascular diseases: a comprehensive overview. *Ther Adv Neurol Disord*. (2020) 13:1756286420978004. doi: 10.1177/1756286420978004

79. Helms J, Tacquard C, Severac F, Leonard-Lorant I, Ohana M, Delabranche X, et al. High risk of thrombosis in patients in severe SARS-CoV-2 infection: a multicenter prospective cohort study. *Intensive Care Med*. (2020) 46:1089–98. doi: 10.1007/s00134-020-06062-x

80. Calabretta E, Moraleda JM, Iacobelli M, Jara R, Vlodavsky I, O'Gorman P, et al. COVID-19-induced endotheliitis: emerging evidence and possible therapeutic strategies. *Br J Haematol*. (2021) 193:43–51. doi: 10.1111/bjh.17240

81. Yong SJ. Persistent brainstem dysfunction in long-COVID: a hypothesis. *ACS Chem Neurosci*. (2021) 12:573–80. doi: 10.1021/acschemneuro.0c00793

82. Holly JMP, Biernacka K, Maskell N, Perks CM. Obesity, diabetes and COVID-19: An infectious disease spreading from the east collides with the consequences of an unhealthy Western lifestyle. *Front Endocrinol (Lausanne)*. (2020) 11:582870. doi: 10.3389/fendo.2020.582870

83. Holly JM. Commentary: A machine-generated view of the role of blood glucose levels in the severity of COVID-19. A metabolic endocrinology perspective. *Front Endocrinol*. (2022) 13:13. doi: 10.3389/fendo.2022.877973

84. Holman N, Knighton P, Kar P, O'Keefe J, Curley M, Weaver A, et al. Risk factors for COVID-19-related mortality in people with type 1 and type 2 diabetes in England: A population-based cohort study. *Lancet Diabetes Endocrinol*. (2020) 8:823–33. doi: 10.1016/S2213-8587(20)30271-0

85. Codo AC, Davanzo GG, de Brito ML, de Souza GF, Muraro SP, Virgilio-da-Silva JV, et al. Elevated glucose levels favor SARS-CoV-2 infection and monocyte response through a HIF-1α/glycolysis-dependent axis. *Cell Metab*. (2020) 32:437–46. doi: 10.1016/j.cmet.2020.07.007

86. Al Mahmeed W, Al-Rasadi K, Banerjee Y, Ceriello A, Cosentino F, Galia M, et al. Promoting a Syndemic approach for Cardiometabolic disease management during COVID-19: the CAPISCO international expert panel. *Front Cardiovasc Med*. (2021) 8:787761. doi: 10.3389/fcvm.2021.787761

87. Miller GE, Chen E, Sze J, Marin T, Arevalo JM, Doll R, et al. A functional genomic fingerprint of chronic stress in humans: blunted glucocorticoid and increased NF-κB signaling. *Biol Psychiatry*. (2008) 64:266–72. doi: 10.1016/j.biopsych.2008.03.017

88. Fernández-de-Las-Peñas C, Torres-Macho J, Elvira-Martínez CM, Molina-Trigueros LJ, Sebastián-Viana T, Hernández-Barrera V. Obesity is associated with a greater number of long-term post-COVID symptoms and poor sleep quality: A multicentre case-control study. *Int J Clin Pract*. (2021) 75:e14917. doi: 10.1111/ijcp.14917

89. Li J, Wang X, Chen J, Zuo X, Zhang H, Deng A. COVID-19 infection may cause ketosis and ketoacidosis. *Diabetes Obes Metab*. (2020) 22:1935–41. doi: 10.1111/dom.14057

90. Liptak P, Baranovicova E, Rosolanka R, Simekova K, Bobcakova A, Vysehradsky R, et al. Persistence of metabolomic changes in patients during post-COVID phase: A prospective, observational study. *Meta*. (2022) 12:641. doi: 10.3390/metabo12070641

91. Weinstein SP, Paquin T, Pritsker A, Haber RS. Glucocorticoid-induced insulin resistance: dexamethasone inhibits the activation of glucose transport in rat skeletal muscle by both insulin-and non-insulin-related stimuli. *Diabetes*. (1995) 44:441–5. doi: 10.2337/diab.44.4.441

92. Martini AL, Carli G, Kiferle L, Piersanti P, Palumbo P, Morbelli S, et al. Time-dependent recovery of brain hypometabolism in neuro-COVID-19 patients. *Eur J Nucl Med Mol Imaging*. (2022) 50:90–102. doi: 10.1007/s00259-022-05942-2

93. Dietmann A, Putzer D, Beer R, Helbok R, Pfausler B, Nordin AJ, et al. Cerebral glucose hypometabolism in tick-borne encephalitis, a pilot study in 10 patients. *Int J Infect Dis*. (2016) 51:73–7. doi: 10.1016/j.ijid.2016.06.022

94. Yarlott L, Heald E, Forton D. Hepatitis C virus infection, and neurological and psychiatric disorders–A review. *J Adv Res*. (2017) 8:139–48. doi: 10.1016/j.jare.2016.09.005

95. Hosp JA, Dressing A, Blazhanets G, Bormann T, Rau A, Schwabenland M, et al. Cognitive impairment and altered cerebral glucose metabolism in the subacute stage of COVID-19. *Brain*. (2021) 144:1–14. doi: 10.1093/brain/awab009

96. Magistretti PJ, Pellerin L. The contribution of astrocytes to the 18F-2-deoxyglucose signal in PET activation studies. *Mol Psychiatry*. (1996) 1:445–52.

97. Zimmer ER, Parent MJ, Souza DG, Leuzy A, Lecrux C, Kim HI, et al. [(18)F] FDG PET signal is driven by astroglial glutamate transport. *Nat Neurosci*. (2017) 20:393–5. doi: 10.1038/nn.4492

98. Carter SF, Herholz K, Rosa-Neto P, Pellerin L, Nordberg A, Zimmer ER. Astrocyte biomarkers in Alzheimer's disease. *Trends Mol Med*. (2019) 25:77–95. doi: 10.1016/j.molmed.2018.11.006

99. Stoessl AJ. Glucose utilization: still in the synapse. *Nat Neurosci*. (2017) 20:382–4. doi: 10.1038/nn.4513

100. Fontana IC, Souza DG, Pellerin L, Souza DO, Zimmer ER. About the source and consequences of 18F-FDG brain PET hypometabolism in short and long COVID-19. *Eur J Nucl Med Mol Imaging*. (2021) 48:2674–5. doi: 10.1007/s00259-021-05342-y

101. Haggstrom LR, Nelson JA, Wegner EA, Caplan GA. 2-18F-fluoro-2-deoxyglucose positron emission tomography in delirium. *J Cereb Blood Flow Metab*. (2017) 37:3556–67. doi: 10.1177/0271678X17701764

102. Kas A, Soret M, Pyatigoskaya N, Habert MO, Hesters A, le Guennec L, et al. The cerebral network of COVID-19-related encephalopathy: a longitudinal voxel-based 18F-FDG-PET study. *Eur J Nucl Med Mol Imaging*. (2021) 48:2543–57. doi: 10.1007/s00259-020-05178-y

103. Morbelli S, Ekmekcioglu O, Barthel H, Albert NL, Boellaard R, Cecchin D, et al. COVID-19 and the brain: impact on nuclear medicine in neurology. *Eur J Nucl Med Mol Imaging*. (2020). doi: 10.1007/s00259-020-04965-x

104. Verger A, Barthel H, Tolboom N, Fraioli F, Cecchin D, Albert NL, et al. 2-[18F]-FDG PET for imaging brain involvement in patients with long COVID: perspective of the EANM neuroimaging committee. *Eur J Nucl Med Mol Imaging*. (2022) 49:3599–606. doi: 10.1007/s00259-022-05913-7

105. Blazhenets G, Schroeter N, Bormann T, Thurow J, Wagner D, Frings L, et al. Slow but evident recovery from neocortical dysfunction and cognitive impairment in a series of chronic COVID-19 patients. *J Nucl Med*. (2021) 62:910–5. doi: 10.2967/jnumed.121.262128

106. Guedj E, Campion JY, Dudouet P, Kaphan E, Bregeon F, Tissot-Dupont H, et al. 18F-FDG brain PET hypometabolism in patients with long COVID. *Eur J Nucl Med Mol Imaging*. (2021) 48:2823–33. doi: 10.1007/s00259-021-05215-4

107. Sollini M, Morbelli S, Ciccarelli M, Cecconi M, Aghemo A, Morelli P, et al. Long COVID hallmarks on [18F]FDGPET/CT: a case-control study. *Eur J Nucl Med Mol Imaging*. (2021) 48:3187–97. doi: 10.1007/s00259-021-05294-3

108. Pilotto A, Cristillo V, Cotti Piccinelli S, Zoppi N, Bonzi G, Sattin D, et al. Long-term neurological manifestations of COVID-19: prevalence and predictive factors. *Neurol Sci*. (2021) 42:4903–7. doi: 10.1007/s10072-021-05586-4

109. Morand A, Campion JY, Lepine A, Bosdure E, Luciani L, Cammilleri S, et al. Similar patterns of [18F]-FDG brain PET hypometabolism in paediatric and adult patients with long COVID: a paediatric case series. *Eur J Nucl Med Mol Imaging*. (2022) 49:913–20. doi: 10.1007/s00259-021-05528-4

110. Meyer PT, Hellwig S, Blazhenets G, Hosp JA. Molecular imaging findings on acute and long-term effects of COVID-19 on the brain: a systematic review. *J Nucl Med*. (2022) 63:971–80. doi: 10.2967/jnumed.121.263085

111. Dressing A, Bormann T, Blazhenets G, Schroeter N, Walter LI, Thurow J, et al. Neuropsychological profiles and cerebral glucose metabolism in neurocognitive long COVID-syndrome. *J Nucl Med*. (2021) 63:1058–63. doi: 10.2967/jnumed.121.262677

112. Meyer PT, Frings L, Rücker G, Hellwig S. 18F-FDG PET in parkinsonism: differential diagnosis and evaluation of cognitive impairment. *J Nucl Med*. (2017) 58:1888–98. doi: 10.2967/jnumed.116.186403

113. Mosconi L. Brain glucose metabolism in the early and specific diagnosis of Alzheimer's disease. FDG-PET studies in MCI and AD. *Eur J Nucl Med Mol Imaging*. (2005) 32:486–510. doi: 10.1007/s00259-005-1762-7

114. Lehrer DS, Christian BT, Mantil J, Murray AC, Buchsbaum BR, Oakes TR, et al. Thalamic and prefrontal FDG uptake in never medicated patients with schizophrenia. *Am J Psychiatry*. (2005) 162:931–8. doi: 10.1176/appi.ajp.162.5.931

115. Morassi M, Palmerini F, Nici S, Magni E, Savelli G, Guerra UP, et al. SARS-CoV-2-related encephalitis with prominent parkinsonism: clinical and FDG-PET correlates in two patients. *J Neurol*. (2021) 268:3980–7. doi: 10.1007/s00415-021-10560-3

116. Gordon MN, Heneka MT, Le Page LM, Limberger C, Morgan D, Tenner AJ, et al. Impact of COVID-19 on the onset and progression of Alzheimer's disease and related dementias: A roadmap for future research. *Alzheimers Dement*. (2022) 18:1038–46. doi: 10.1002/alz.12488

117. Wang F, Kream RM, Stefano GB. Long term respiratory and neurological sequelae of COVID-19. *Med Sci Monit*. (2020) 26:996. doi: 10.12659/MSM.928996

118. Serrano-Castro PJ, Estivill-Torrús G, Cabezudo-García P, Reyes-Bueno JA, Ciano Petersen N, Aguilar-Castillo MJ, et al. Impact of SARS-CoV-2 infection on neurodegenerative and neuropsychiatric diseases: a delayed pandemic? *Neurologia*. (2020) 35:245–51. doi: 10.1016/j.nrl.2020.04.002

119. Cahill GF Jr. Fuel metabolism in starvation. *Annu Rev Nutr*. (2006) 26:1–22. doi: 10.1146/annurev.nutr.26.061505.111258

120. Veneman T, Mitrakou A, Mokan M, Cryer P, Gerich J. Effect of hyperketonemia and hyperlacticacidemia on symptoms, cognitive dysfunction, and counterregulatory hormone responses during hypoglycemia in normal humans. *Diabetes*. (1994) 43:1311–7. doi: 10.2337/diab.43.11.1311

121. Page KA, Williamson A, Yu N, McNay EC, Dzuira J, McCrimmon RJ, et al. Medium-chain fatty acids improve cognitive function in intensively treated type 1 diabetic patients and support in vitro synaptic transmission during acute hypoglycemia. *Diabetes*. (2009) 58:1237–44. doi: 10.2337/db08-1557

122. Bough KJ, Rho JM. Anticonvulsant mechanisms of the ketogenic diet. *Epilepsia*. (2007) 48:43–58. doi: 10.1111/j.1528-1167.2007.00915.x

123. Puchalska P, Crawford PA. Metabolic and signaling roles of ketone bodies in health and disease. *Ann Rev Nutri*. (2021) 41:49–77. doi: 10.1146/annurev-nutr-111120-111518

124. de Cabo R, Mattson MP. Effects of intermittent fasting on health, aging, and disease. *N Engl J Med*. (2019) 381:2541–51. doi: 10.1056/NEJMra1905136

125. Xin L, Ipek Ö, Beaumont M, Shevlyakova M, Christinat N, Masoodi M, et al. Nutritional ketosis increases NAD+/NADH ratio in healthy human brain: an in vivo study by 31P-MRS. *Front Nutr*. (2018):62. doi: 10.3389/fnut.2018.00062

126. Maalouf M, Rho JM, Mattson MP. The neuroprotective properties of calorie restriction, the ketogenic diet, and ketone bodies. *Brain Res Rev*. (2009) 59:293–315. doi: 10.1016/j.brainresrev.2008.09.002

127. Griffith CM, Eid T, Rose GM, Patrylo PR. Evidence for altered insulin receptor signaling in Alzheimer's disease. *Neuropharmacology*. (2018) 136:202–15. doi: 10.1016/j.neuropharm.2018.01.008

128. Arnold SE, Arvanitakis Z, Macauley-Rambach SL, Koenig AM, Wang HY, Ahima RS, et al. Brain insulin resistance in type 2 diabetes and Alzheimer disease: concepts and conundrums. *Nat Rev Neurol*. (2018) 14:168–81. doi: 10.1038/nrneurol.2017.185

129. Son SM, Song H, Byun J, Park KS, Jang HC, Park YJ, et al. Accumulation of autophagosomes contributes to enhanced amyloidogenic APP processing under insulin-resistant conditions. *Autophagy*. (2012) 8:1842–4. doi: 10.4161/auto.21861

130. Devi L, Alldred MJ, Ginsberg SD, Ohno M. Mechanisms underlying insulin deficiency-induced acceleration of β-amyloidosis in a mouse model of Alzheimer's disease. *PLoS One*. (2012) 7:e32792. doi: 10.1371/journal.pone.0032792

131. Kim B, Backus C, Oh S, Hayes JM, Feldman EL. Increased tau phosphorylation and cleavage in mouse models of type 1 and type 2 diabetes. *Endocrinology*. (2009) 150:5294–301. doi: 10.1210/en.2009-0695

132. Puig KL, Floden AM, Adhikari R, Golovko MY, Combs CK. Amyloid precursor protein and proinflammatory changes are regulated in brain and adipose tissue in a murine model of high fat diet-induced obesity. *PLoS One*. (2012) 7:e30378. doi: 10.1371/journal.pone.0030378

133. Sato K, Kashiwaya Y, Keon CA, Tsuchiya N, King MT, Radda GK, et al. Insulin, ketone bodies, and mitochondrial energy transduction. *FASEB J*. (1995) 9:651–8. doi: 10.1096/fasebj.9.8.7768357

134. Tardif A, Julien N, Pelletier A, Thibault G, Srivastava AK, Chiasson JL, et al. Chronic exposure to β-hydroxybutyrate impairs insulin action in primary cultures of adult cardiomyocytes. *Am J Physiol Endocrinol Metabolism*. (2001) 281:E1205–12. doi: 10.1152/ajpendo.2001.281.6.E1205

135. Würtz P, Mäkinen VP, Soininen P, Kangas AJ, Tukiainen T, Kettunen J, et al. Metabolic signatures of insulin resistance in 7,098 young adults. *Diabetes*. (2012) 61:1372–80. doi: 10.2337/db11-1355

136. Lacourt TE, Vichaya EG, Chiu GS, Dantzer R, Heijnen CJ. The high costs of low-grade inflammation: persistent fatigue as a consequence of reduced cellular-energy availability and non-adaptive energy expenditure. *Front Behav Neurosci*. (2018):78. doi: 10.3389/fnbeh.2018.00078

137. Ohnuma T, Toda A, Kimoto A, Takebayashi Y, Higashiyama R, Tagata Y, et al. Benefits of use, and tolerance of, medium-chain triglyceride medical food in the management of Japanese patients with Alzheimer's disease: a prospective, open-label pilot study. *Clin Interv Aging*. (2016) 11:29. doi: 10.2147/CIA.S95362

138. Ota M, Matsuo J, Ishida I, Takano H, Yokoi Y, Hori H, et al. Effects of a medium-chain triglyceride-based ketogenic formula on cognitive function in patients with mild-to-moderate Alzheimer's disease. *Neurosci Lett*. (2019) 690:232–6. doi: 10.1016/j.neulet.2018.10.048

139. Avgerinos KI, Egan JM, Mattson MP, Kapogiannis D. Medium chain triglycerides induce mild ketosis and may improve cognition in Alzheimer's disease. A systematic review and meta-analysis of human studies. *Ageing Res Rev*. (2020) 58:101001. doi: 10.1016/j.arr.2019.101001

140. Van der Auwera I, Wera S, Van Leuven F, Henderson ST. A ketogenic diet reduces amyloid beta 40 and 42 in a mouse model of Alzheimer's disease. *Nutrit Metabol*. (2005) 2:1–8. doi: 10.1186/1743-7075-2-28

141. Kashiwaya Y, Bergman C, Lee JH, Wan R, King MT, Mughal MR, et al. A ketone ester diet exhibits anxiolytic and cognition-sparing properties, and lessens amyloid and tau pathologies in a mouse model of Alzheimer's disease. *Neurobiol Aging*. (2013) 34:1530–9. doi: 10.1016/j.neurobiolaging.2012.11.023

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The effects of body dissatisfaction and depression levels on the dietary habits of university students in southern China during COVID-19

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Introduction: The novel coronavirus disease of 2019 has impacted people's lives greatly. The spread of the pandemic has restricted many everyday social lives. Some studies have shown that strict risk control during the pandemic threatens people's mental health and eating habits. University students vulnerable to mental health problems may have more prominent mental health and eating disorders during the pandemic. This study aims to elucidate the relationship between body dissatisfaction, depression, body mass index, and emotional eating among university students in the context of the pandemic in southern China. It provides a theoretical basis for developing future approaches to improve depression and emotional eating among university students.

Methods: A total of 1,135 university students were recruited for the study. All participants completed anthropometric, body dissatisfaction, eating behavior, and depression level surveys.

Results: The study finds that female students have higher levels of body dissatisfaction, depression, and emotional eating than male students. University students in the high body dissatisfaction group had higher levels of depression. Depression level (β = 0.33, p < 0.01), body dissatisfaction (β = 0.22, p < 0.01), sex (β = 0.16, p < 0.01), and income (β = 0.06, p < 0.01) were significant predictors of emotional eating. Fundamentally, this study highlights the impact of body dissatisfaction on depression and emotional eating.

Discussion: The potential to improve depression and emotional eating among university students by improving their levels of body dissatisfaction was demonstrated.

KEYWORDS

body dissatisfaction, depression, dietary habits, emotional eating behavior, university students, China

1. Introduction

Since 2019, people's lives have been affected to some extent by coronavirus disease of 2019 (COVID-19) in various countries (1). Many countries have adopted stricter quarantine policies to slow the spread of the pandemic (2). Some studies have shown that under strict quarantine, people's

eating behaviors have changed, and binge eating has increased (2, 3). A study with 1,097 adults in Poland revealed that more than half of the adult Poles snacked significantly more during the pandemic windfall than during the pre-pandemic period (4). The results of another study that included 1,047 people from Asia, Europe, and Africa as respondents showed that people's food consumption patterns changed during the pandemic, with more snacking between main meals (5).

1.1. Mental health

Mental health issues, such as anxiety and depression, are thought to be important in changing people's food consumption patterns during the pandemic (3). Studies have shown that emotional eaters believe that eating relieves negative emotions due to stress (6, 7). New crown pneumonia is spreading rapidly worldwide, causing mental health problems in many people (3). In addition to the fear of COVID-19 infection, forced reduction of social and isolation policies can lead to psychological problems such as depression (8). According to a systematic study of mental health findings in the general populations of eight countries, the prevalence of severe anxiety increased from 6.3% before the pandemic to 50.9%. The incidence of depression increased from 14.6% before the pandemic to 48.3% (9). A study conducted among Italian adults showed that nearly a quarter of people changed their eating habits because of higher anxiety levels (3).

1.2. Factors influencing dietary habits

Body image is the perception of one's own body (10). It is closely related to many aspects of human functioning, including emotions, thoughts, behaviors, and relationships (11). Body dissatisfaction occurs when there is a discrepancy between the ideal and actual body shapes (12). It results in poor eating habits such as overeating (12, 13), and high levels of body image dissatisfaction may lead to depression (13, 14). High body mass index (BMI) may bring high risk of body dissatisfaction and dietary habits (12). Furthermore, body dissatisfaction is common among young people (13, 14), and under the pressure of the COVID-19 pandemic, body dissatisfaction may have a more serious negative impact on young people's health (12).

1.3. The specificity of the university student population

University students experience changes in their social environments and face the challenge of moving from adolescence to adulthood (12). Because their parents do not supervise them, university students may find it difficult to maintain a healthy diet (15–17). They grow up, become independent adults as compared to children who were dependent on their parents while overcoming the pressures of academics, which makes them a vulnerable group for mental health problems (16–18). However, little research has been conducted on body dissatisfaction, depression, or emotional eating. Especially in the context of COVID-19, the physical and mental burden of university students may increase. Accordingly, this could further increase the likelihood of depression and emotional eating among university students.

1.4. Purpose

This study aims to explore the relationship between body dissatisfaction, depression levels, BMI and emotional eating behavior among university students in the context of the pandemic.

2. Materials and methods

2.1. Study participants

This study was conducted at a selected comprehensive university in Ganzhou City, Jiangxi Province, China. Participant recruitment information was disseminated on campus through posters put up in front of the dormitory building and leaflets distributed in study rooms. A total of 1,200 under graduate students were recruited and physically measured, and questionnaires were administered across the university between September and December 2021. As there were very few students older than 24 years, those who was older than 24 years were excluded from the study. Of these, 1,135 students (male: 555; female: 580) provided complete and valid data to be included in this study.

2.2. Body measurements

Height was measured using a height ruler with an accuracy (Seca 213, Germany) of 0.1 cm, and weight, body fat percentage, and muscle mass (0.1 kg precision) were measured using a body composition analyzer (Tanita BC-610, Japan). Body mass index (BMI; kg/m^2) was calculated using height and weight; the BMI categories were underweight (BMI < 18.5), normal (18.5 ≤ BMI < 25), and overweight (BMI ≥ 25) (19).

2.3. Body type discontent

Sex-adapted silhouettes were used to assess body dissatisfaction among university students (20). The body type progression chart scores indicate a progression from the lowest obesity score to the highest muscular score. The lowest score was-7, and the highest score was 7. In this study, participants were asked to select their actual body silhouette (Current Silhouettes, CS) and their ideal body silhouette (Ideal Silhouettes, IS). The difference between the ideal body silhouette score and the actual body silhouette score is the level of body dissatisfaction. Allowing the definition of three categorized levels based on quartiles analyses: low dissatisfaction ($|IS - CS| \leq 1$), medium dissatisfaction ($2 \leq |IS - CS| \leq 4$), high dissatisfaction ($|IS - CS| \geq 5$) (20).

2.4. Emotional eating levels

The Chinese version of the Dutch Eating Behavior Questionnaire (21) was used to assess the level of emotional eating among university

students. Emotional eating refers to the extent to which emotional factors influence college students. Here, emotion mainly refers to negative emotions and whether individuals will relieve their emotions by eating under the influence of negative emotions. For example, when individuals are depressed, they crave food. There were 13 questions, each with five options, corresponding to a score of 1–5. Higher scores indicated higher levels of emotional eating. This questionnaire is suitable for young Chinese adults and widely used in southern China (12).

2.5. Depression

The Chinese version of the Self-rating Depression Scale (SDS), widely used in China for young people, was used to assess the depression levels of university students (22). The scale contains 20 items divided into four scoring levels. The scores of each item are summed to obtain a total crude score, which is multiplied by 1.25 according to the Chinese norm to obtain a standard score; the higher the standard score, the more severe the symptoms. The standard score for evaluating depression is 53, with scores below 53 indicating no depression, 53–62 indicating mild depression, 63–72 indicating moderate depression, and 72 or more indicating severe depression. This scale has been verified to be suitable for young Chinese adults and widely used in southern China (12).

2.6. Data analysis methods

All items were tested for normality and skewness, and the data were within acceptable limits. We used a t-test to compare differences due to sex in BMI, body fat percentage, muscle mass, level of body dissatisfaction, level of depression, and score of emotional eating among university students. One-way ANOVA was used to compare differences in depression levels and emotional eating scores across body type groups, and the Tukey–Kramer test was used to compare two-by-two differences between groups. College students' emotional eating scores were used as dependent variables in the multiple regression analyses, and BMI, depression level scores, body type dissatisfaction level scores, and monthly living expenses were used as predictor variables. A stepwise incremental approach with a threshold p value of 0.20 was chosen. All statistical analyses were performed using JMP version 16.0 J (SAS Institute Inc., Cary, NC, United States). Statistical significance was set at $p < 0.05$.

2.7. Sociodemographic characteristics

Data on the age, sex, and monthly living cost of the university students were collected through a questionnaire.

2.8. Sample size estimation

The sample size for the study was determined using the G*Power calculator 3.1.9.7 (Franz Faul et al., Universität Kiel, Germany, http://www.gpower.hhu.de/). Considering an $\alpha = 0.05$, $1-\beta = 0.90$, the number of tested predictors = 3 (SDS score, body dissatisfaction, and BMI), the number of covariates = 3 (age, sex, and monthly living cost), we calculated the sample size to be 33, 73, 528, respectively if the effect size f^2 equaled to 0.35 (large), 0.15 (medium) and 0.02 (small). Furtherly, a 20% dropout rate was assumed, and the total number was estimated as 42–660. To make sure the power, we increased the sample size to 1,200, and the actual valid sample size was 1,135, which was much larger than the estimated size even if given a small effect size f^2.

3. Results

3.1. Participant characteristics

The age of the participants ranged from 18 to 23 years (mean age: 18.8 ± 1.0 years; Table 1). Regarding BMI, 19% of the participants were overweight or obese (Table 1). Further, BMI, muscle mass, and obesity rates were higher in male students than in female students ($p < 0.05$). And body fat percentage, SDS, and emotional eating score were higher in female students than in male students ($p < 0.05$). Body dissatisfaction was present in both sexes (Table 1).

The mean emotional eating score for girls was 26.3, significantly higher than for boys (22.5; Table 1). There were no differences in depression levels or emotional eating scores between the body type groups ($p > 0.05$; Figures 1, 2). The emotional eating scores were significantly higher in the high body dissatisfaction group than in the moderate and low body dissatisfaction groups (Figure 3).

3.2. Factors influencing emotional eating

Table 2 shows the factors that influence emotional eating among university students. Levels of depression ($\beta = 0.33$, $p < 0.01$), body

TABLE 1 Sample characteristics (n = 1,135).

	Mean ± SD or n (%)			p
	Man (n = 555)	Woman (n = 580)	Total	
Age (years)	18.8 ± 1.1	18.8 ± 1.0	18.8 ± 1.0	
BMI (kg/m^2)	22.0 ± 3.6	21.3 ± 3.1	21.6 ± 3.4	<0.01
BMI category				
Underweight	80 (14)	96 (17)	176 (15)	
Normal	337 (61)	409 (71)	746 (66)	<0.01
Overweight/obesity	138 (25)	75 (13)	213 (19)	
Body fat percentage	16.1 ± 6.7	27.6 ± 5.9	22.0 ± 6.4	<0.01
Muscle mass (g)	50.5 ± 7.6	35.9 ± 4.0	43.0 ± 5.8	<0.01
SDS	44.9 ± 9.6	46.8 ± 8.8	45.8 ± 9.2	<0.01
Emotional eating score	22.5 ± 9.4	26.3 ± 9.8	24.4 ± 9.6	<0.01
Body dissatisfaction	2.8 ± 1.4	2.7 ± 1.3	2.7 ± 1.3	0.46
Low	164 (30)	184 (32)	348 (31)	0.51
Medium	273 (49)	286 (49)	559 (49)	
High	118 (21)	110 (19)	228 (20)	

BMI, body mass index. SDS, Self-rating Depression Scale. The significance of the differences between male and female students was determined by t-test (for quantitative variables) or by Pearson's analyses (qualitative variables).

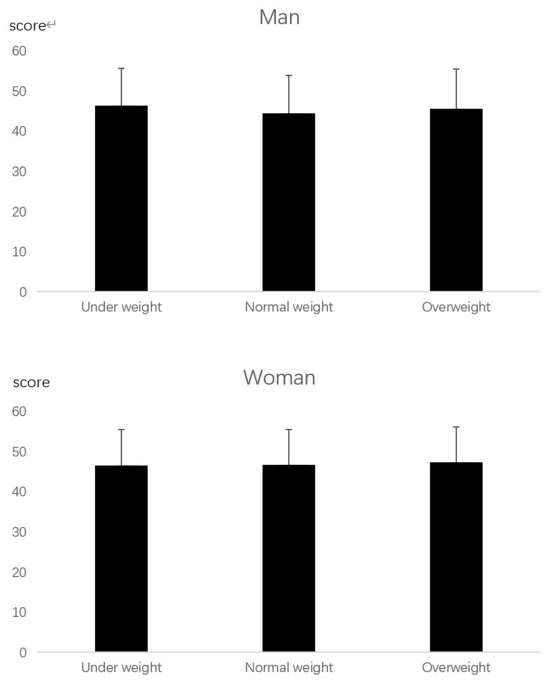

FIGURE 1
SDS scores of university students with different BMI categories.

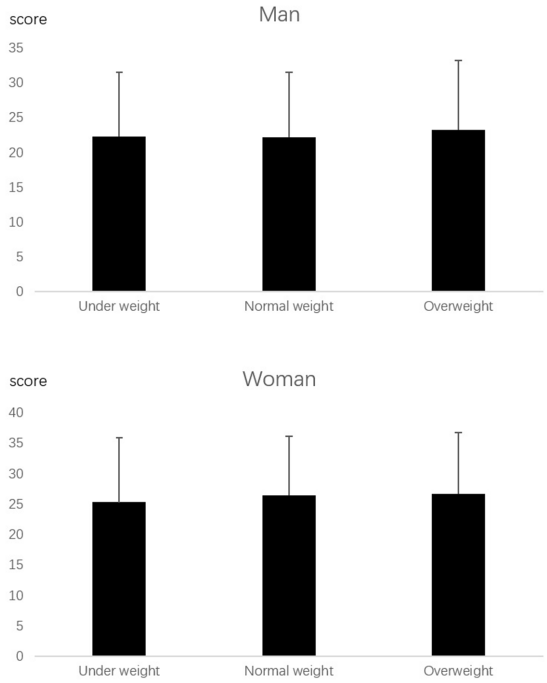

FIGURE 2
Emotional eating scores of university students with different BMI categories.

dissatisfaction ($\beta = 0.22$, $p < 0.01$), sex ($\beta = 0.16$, $p < 0.01$), and income ($\beta = 0.06$, $p < 0.05$) were significant predictors of emotional eating.

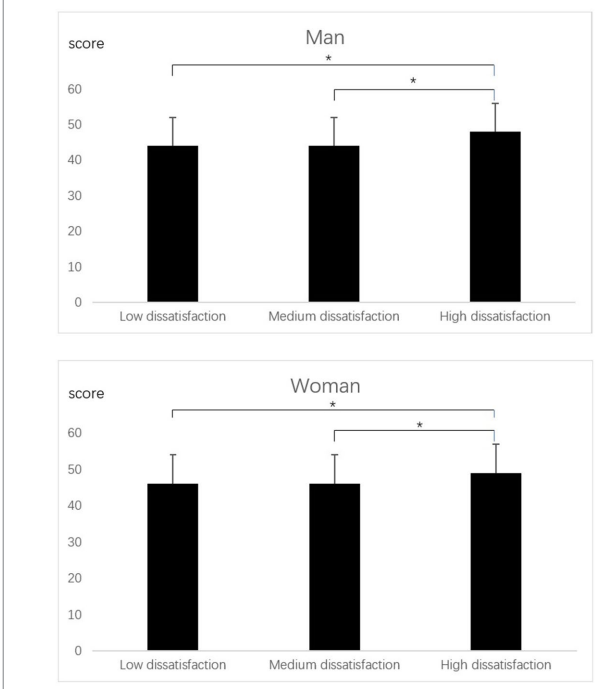

FIGURE 3
Depression scores of university students with different levels of body dissatisfaction. *Tukey, $p < 0.05$.

TABLE 2 Factors that contribute to emotional eating scores among university students.

	β	t	VIF	p
SDS	0.33	12.32	1.02	< 0.01
Body dissatisfaction	0.22	7.63	1.17	< 0.01
Sex	0.16	5.97	1.03	< 0.01
Income (/month)	0.06	2.13	1.01	< 0.05
BMI	−0.04	−1.37	1.18	NS

$R^2 = 0.21$; $p < 0.01$; RMES = 8.8; $n = 1,135$.

4. Discussion

4.1. Emotional eating and depression levels among university students

4.1.1. Emotional eating levels

Women were at a higher risk of developing health problems related to eating disorders. A study of Norwegian adults showed that emotional eating is more common in women (23). The results of the present study showed that among university students in southern China, women had higher levels of emotional eating than men (Table 1), supporting the findings of the prior study. This may be related to the physiological differences between men and women. Research suggests that the physiological differences between females and males may be reflected in emotions and behaviors, with girls likely to have increased negative emotions when faced with challenging and uncertain situations (24). Notably, emotional eating is considered an

important way of reducing negative emotions, and eating disorders may be triggered or exacerbated by pandemics (25). Thus, sex differences in emotional eating levels may continue to be magnified by the influence of the pandemic.

4.1.2. Interaction between depression and emotional eating

Emotional eating can lead to psychological distress and have negative health effects (26). A study of 1,865 Italian adults found that when considering multivariable models, women and individuals with emotional eating were more likely to report depression (26). These results support the findings of a previous study (Table 2); they demonstrated that higher levels of depression are related to higher emotional eating scores. At the same time, this effect was not unidirectional; results from a study of 24,968 inhabitants in Norway showed that people with psychological distress are four times more likely to experience emotional eating than the general population (23). A study of 365 Italian adults showed that increased emotional eating could lead to psychological problems such as depression and anxiety (27). Studies have shown that binge eaters and healthy people may regulate negative emotions through their diet (6, 7). Studies found that people who adopt emotional eating behaviors in the face of negative emotions do not reduce negative emotions during or after eating but instead increase their current negative emotions and are likely to adopt more aggressive eating behaviors in the face of negative emotions (28, 29). The interplay between depression and emotional eating may be a significant barrier to college students' heart health during the pandemic.

4.2. Factors influencing emotional eating

4.2.1. Depression levels

Women are more likely to suffer from depression than men (6). A survey of 286 university students from different ethnic groups in the United Kingdom found that women suffered from depression at twice the rate of men (30). Another survey of nearly 6,000 students in China showed that the prevalence of depression was 14% higher among female students than among male students (10%) (31). The results of this study showed that women scored higher levels of depression than men, supporting the findings of a previous study (Table 1). During COVID-19, women were more susceptible to the contagion of tension than men, as the normal range and duration of social activities were restricted, which had a more significant impact on the emotional problems of university students (32). A study of 385 Italian students aged 18–30 found that amidst the COVID-19 lockdown, 6% of the students develop more severe depressive symptoms (33). For the goal of "Zero COVID," China witnessed the longest and strictest lockdowns, and have no targeted measures for improving mental health of university students. As the COVID-19 pandemic continues, with the increase of depression level, the difference in depression levels between men and women will likely continue to increase.

4.2.2. Body mass index

BMI is considered a significant predictor of emotional eating (34, 35). Studies have highlighted the association between body size and eating habits (36, 37). However, in the present study, we did not find a relationship between body size and emotional eating or SDS score (Figures 1, 2). This suggests that, for present-day university students in southern China, emotional eating similarly affects food consumption in normal-weight and obese individuals. The intense pressure from the pandemic may be an important factor that distinguishes this study from previous research. The blockade brought about by the pandemic can impact emotional eating and change people's eating habits (27). The results of this study reveal that emotional eating levels under the influence of the pandemic may not be related to body size.

4.2.3. Body type discontent

Body image dissatisfaction is thought to be associated with poor eating habits such as dieting. A study of American high school students showed that students with higher levels of body dissatisfaction were more likely to have disordered eating behaviors than those with lower levels of body dissatisfaction (38). Similarly, a study of Dutch adolescents aged 12–16 showed that body image dissatisfaction might lead to disordered eating behaviors (39). The results of this study showed that higher levels of body dissatisfaction were associated with higher scores on emotional eating at university, supporting the findings of a previous study (Table 2).

It is important to note that because the weight loss effect of extreme eating behaviors may be short-lived, it usually results in weight regain and further increases body dissatisfaction (12, 40). Body image dissatisfaction may exacerbate depression in university students (Figure 3). Results from a study of 13,046 current university students in southern China showed that self-body awareness in early adulthood was associated with the onset of depression (13). A study with 160 Hispanic university students showed a positive correlation between levels of depression and levels of body dissatisfaction among university students (14). Therefore, improving the level of emotional eating among college students by improving their body image dissatisfaction should be considered.

4.3. Limitations

This study had several limitations. First, this study was conducted with only over 1,000 people and included only university students aged 18–23 years. In addition, because this was a cross-sectional study, no causal inferences could be drawn. Additionally, this study only examined university students living in southern China and is not representative of the national picture in general. The survey was carried out during the COVID-19 pandemic, with the strict policies "zero COVID" policy in China, and therefore, its results may not reflect the general relationship between body dissatisfaction, diet, and depression among university students. China witnessed the longest and strictest lockdowns of all, which might have skewed the results. Although a study has shown that these effects will disappear rapidly after the lifting of lockdown (33). Considering that the COVID-19 pandemic is still ongoing, the results of this study can provide a theoretical basis for formulating strategies to improve university students' eating behavior and depression levels from the present to the near future. This study did not investigate which kind of food they ate/avoided during emotional eating, we wish to solve this problem in future research.

4.4. Conclusion

Depression and emotional eating were problems among university students in southern China in the context of the pandemic. Female students had higher depression levels and emotional eating scores than male students. This study highlighted the impact of body dissatisfaction on depression and emotional eating. The potential to improve depression and emotional eating among university students by improving their levels of body dissatisfaction has been demonstrated.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethical approval for the study was granted by the Gannan Medical University, China. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CW and MH: data collection, data analysis, manuscript writing, and funding acquisition. QW and XL: study design and data analysis. WY and DY: study design, data collection, data analysis, and manuscript writing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Papandreou C, Arija V, Aretouli E, Tsilidis KK, Bulló M. Comparing eating behaviours, and symptoms of depression and anxiety between Spain and Greece during the COVID-19 outbreak: cross-sectional analysis of two different confinement strategies. *Eur Eat Disord Rev*. (2020) 28:836–46. doi: 10.1002/erv.2772

2. Johnson AN, Clockston RLM, Fremling L, Clark E, Lundeberg P, Mueller M, et al. Changes in adults' eating behaviors during the initial months of the COVID-19 pandemic: a narrative review. *J Acad Nutr Diet*. (2023):123, 144–194.e30. doi: 10.1016/j.jand.2022.08.132

3. Scarmozzino F, Visioli F. Covid-19 and the subsequent lockdown modified dietary habits of almost half the population in an Italian sample. *Foods*. (2020) 9:675. doi: 10.3390/foods9050675

4. Sidor A, Rzymski P. Dietary choices and habits during COVID-19 lockdown: experience from Poland. *Nutrients*. (2020) 12:1657. doi: 10.3390/nu12061657

5. Ammar A, Brach M, Trabelsi K, Chtourou H, Boukhris O, Masmoudi L, et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: results of the ECLB-COVID19 international online survey. *Nutrients*. (2020) 12:1583. doi: 10.3390/nu12061583

6. Macht M. How emotions affect eating: a five-way model. *Appetite*. (2008) 50:1–11. doi: 10.1016/j.appet.2007.07.002

7. Clum GA, Rice JC, Broussard M, Johnson CC, Webber LS. Associations between depressive symptoms, self-efficacy, eating styles, exercise and body mass index in women. *J Behav Med*. (2014) 37:577–86. doi: 10.1007/s10865-013-9526-5

8. Moreno C, Wykes T, Galderisi S, Nordentoft M, Crossley N, Jones N. How mental health care should change as a consequence of the COVID-19 pandemic. *Lancet Psychiatry*. (2020) 7:813–24. doi: 10.1016/S2215-0366(20)30307-2

9. Xiong J, Lipsitz O, Nasri F, Lui LM, Gill H, Phan L. Impact of COVID-19 pandemic on mental health in the general population: a systematic review. *J Affect Disord*. (2020) 277:55–64. doi: 10.1016/j.jad.2020.08.001

10. Schilder PM. *The image and appearance of the human body: studies in the constructive energies of the psyche*. New York: International Universities Press (1978).

11. Pallan MJ, Hiam LC, Duda JL, Adab P. Body image, body dissatisfaction and weight status in south Asian children: a cross-sectional study. *BMC Public Health*. (2011) 11:1–8. doi: 10.1186/1471-2458-11-21

12. Hao M, Fang Y, Yan W, Gu J, Hao Y, Wu C. Relationship between body dissatisfaction, insufficient physical activity, and disordered eating behaviors among university students in southern China. *BMC Public Health*. (2022) 22:1–7. doi: 10.1186/s12889-022-14515-9

13. Zhang Y, Liu B. Body weight perception and depressive symptoms in Chinese college students. *Child Youth Serv Rev*. (2021) 124:105969. doi: 10.1016/j.childyouth.2021.105969

14. Blow J, Cooper TV. Predictors of body dissatisfaction in a Hispanic college student sample. *Eat Behav*. (2014) 15:1–4. doi: 10.1016/j.eatbeh.2013.10.010

15. Forestell CA, Spaeth AM, Kane SA. To eat or not to eat red meat. A closer look at the relationship between restrained eating and vegetarianism in college females. *Appetite*. (2012) 58:319–25. doi: 10.1016/j.appet.2011.10.015

16. Sandoz EK, Boullion GQ, Mallik D, Hebert ER. Relative associations of body image avoidance constructs with eating disorder pathology in a large college student sample. *Body Image*. (2020) 34:242–8. doi: 10.1016/j.bodyim.2020.07.002

17. Muñoz-Rodríguez JR, Luna-Castro J, Ballesteros-Yáñez I, Pérez-Ortiz JM, Gómez-Romero FJ, Redondo-Calvo FJ, et al. Influence of biomedical education on health and eating habits of university students in Spain. *Nutrition*. (2021) 86:111181. doi: 10.1016/j.nut.2021.111181

18. Uri RC, Wu YK, Baker JH, Munn-Chernoff MA. Eating disorder symptoms in Asian American college students. *Eat Behav*. (2021) 40:101458. doi: 10.1016/j.eatbeh.2020.101458

19. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization – technical report series. (2000) 894.

20. Damasceno VO, Vianna JM, Novaes JS, de Lima JP, Fernandes HM, Reis VM. Relationship between anthropometric variables and body image dissatisfaction among

fitness center users. *Rev Psicol Deporte*. (2011) 20:367–82. doi: 10.1108/00483481111133345

21. Wang YF, Ha S, Zauszniewski JA, Ross R. Psychometric properties of the Chinese version of the Dutch eating behavior questionnaire in a sample of Taiwanese parents. *Obes Res Clin Pract*. (2018) 12:129–32. doi: 10.1016/j.orcp.2017.11.005

22. Zung WWK. A self-rating depression scale. *Arch Gen Psychiatry*. (1965) 12:63–70. doi: 10.1001/archpsyc.1965.01720310065008

23. Bemanian M, Mæland S, Blomhoff R, Rabben ÅK, Arnesen EK, Skogen JC. Emotional eating in relation to worries and psychological distress amid the COVID-19 pandemic: a population-based survey on adults in Norway. *Int J Env Res Pub Health*. (2021) 18:130. doi: 10.3390/ijerph18010130

24. Hankin BL, Abramson LY. Development of gender differences in depression: description and possible explanations. *Ann Med*. (1999) 31:372–9. doi: 10.3109/07853899908998794

25. Güner Ö, Aydın A. Determining the relationship between anxiety levels, stress coping styles, and emotional eating of women in the COVID-19 pandemic. *Arch Psychiatr Nurs*. (2022) 41:241–7. doi: 10.1016/j.apnu.2022.08.002

26. Moro GL, Bert F, Catozzi D, Scacchi A, Siliquini R. Emotional eating and depression during the pandemic: quarant eat, an Italian nationwide survey. *Nutrition*. (2022) 103–104:111825. doi: 10.1016/j.nut.2022.111825

27. Cecchetto C, Aiello M, Gentili C, Ionta S, Osimo SA. Increased emotional eating during COVID-19 associated with lockdown, psychological and social distress. *Appetite*. (2021) 160:105122. doi: 10.1016/j.appet.2021.105122

28. Heatherton TF, Baumeister RF. Binge eating as escape from self-awareness. *Psychol Bull*. (1991) 110:86. doi: 10.1037/0033-2909.110.1.86

29. Wallis DJ, Hetherington MM. Emotions and eating. Self-reported and experimentally induced changes in food intake under stress. *Appetite*. (2009) 52:355–62. doi: 10.1016/j.appet.2008.11.007

30. Jenkins PE, Ducker I, Gooding R, James M, Rutter-Eley E. Anxiety and depression in a sample of UK college students: a study of prevalence, comorbidity, and quality of life. *J Am Coll Heal*. (2021) 69:813–9. doi: 10.1080/07448481.2019.1709474

31. Sun XJ, Niu GF, You ZQ, Zhou ZK, Tang Y. Gender, negative life events and coping on different stages of depression severity: a cross-sectional study among Chinese university students. *J Affect Disord*. (2017) 209:177–81. doi: 10.1016/j.jad.2016.11.025

32. Chang J, Yuan Y, Wang D. Mental health status and its influencing factors among college students during the epidemic of COVID-19. *Nan Fang Yi Ke Da Xue Xue Bao*. (2020) 2020:171–6. doi: 10.12122/j.issn.1673-4254.2020.02.02

33. Meda N, Pardini S, Slongo I, Bodini L, Zordan MA, Rigobello P, et al. Students' mental health problems before, during, and after COVID-19 lockdown in Italy. *J Psychiatr Res*. (2021) 134:69–77. doi: 10.1016/j.jpsychires.2020.12.045

34. Nyklíček I, Vingerhoets AD, Zeelenberg M. Emotion regulation and well-being: a view from different angles In: I Nyklíček, A Vingerhoets and M Zeelenberg, editors. *Emotion regulation and well-being*. New York: Springer (2011). 1–9.

35. Konttinen H, Männistö S, Sarlio-Lähteenkorva S, Silventoinen K, Haukkala A. Emotional eating, depressive symptoms, and self-reported food consumption. A population-based study. *Appetite*. (2010) 54:473–9. doi: 10.1016/j.appet.2010.01.014

36. Ozier AD, Kendrick OW, Leeper JD, Knol LL, Perko M, Burnham J. Overweight and obesity are associated with emotion-and stress-related eating as measured by the eating and appraisal due to emotions and stress questionnaire. *J Am Diet Assoc*. (2008) 108:49–56. doi: 10.1016/j.jada.2007.10.011

37. Sevinçer GM, Konuk N. Emosyonel yeme. *J Mood Disor*. (2013) 3:171–8. doi: 10.5455/jmood.20130926052526

38. Valerie FH. High prevalence of abnormal eating and weight control practices among U.S. high-school students. *Eat Behav*. (2004) 5:325–36. doi: 10.1016/j.eatbeh.2004.04.003

39. Muris P, Meesters C, van de Blom W, Mayer B. Biological, psychological, and sociocultural correlates of body change strategies and eating problems in adolescent boys and girls. *Eat Behav*. (2005) 6:11–22. doi: 10.1016/j.eatbeh.2004.03.002

40. Hao M, Han W, Yamauchi T. Short-term and long-term effects of a combined intervention of rope skipping and nutrition education for overweight children in Northeast China. *Asia Pac J Public Health*. (2019) 31:348–58. doi: 10.1177/1010539519848275

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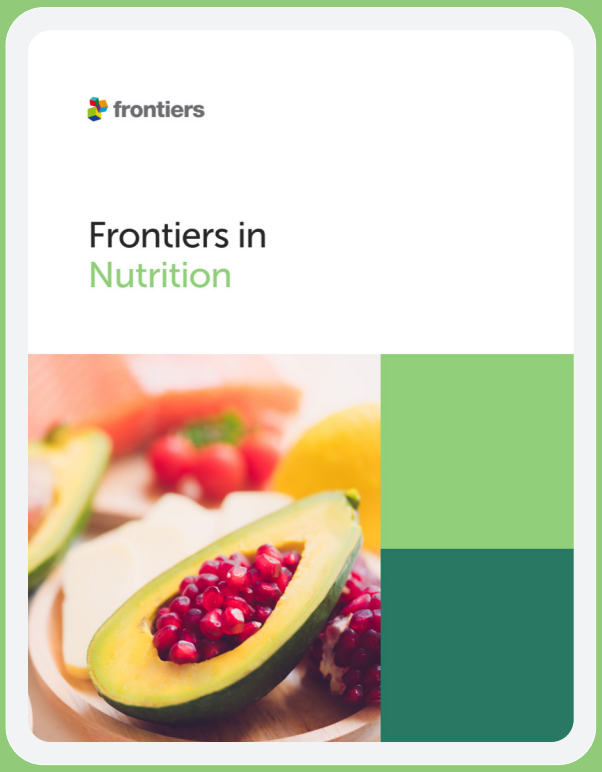

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