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EDITORIAL

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# Global challenges and opportunities for dietitians

This issue of *Nutrition & Dietetics* presents a potpourri of research from across the world that highlights the complexity of nutrition as a science and the role of dietitian-nutritionists in transforming this science into everyday practicalities.

## NUTRITION AS A COMPLEX SCIENCE

Nutrition is a complex science, encompassing not only the biochemistry, physiology, immunology, microbiology and genetics of post-swallowing nutrition but also the myriad of sciences implicated in pre-swallowing events.[1] This complexity has been captured in the eco-nutrition approach to nutrition science. Eco-nutrition encompasses an ecological approach to food and nutrition where optimal nutrition emerges from the balance between human and environmental health and the food supply mediated by social and economic systems and practices.[2] Disruption in any of the systems, be they biological, environmental, economic or social, leads—via direct (biological) and indirect pathways—to eco-health disorders, affecting every bodily system.

Describing chronic conditions or non-communicable diseases as eco-health disorders makes explicit the overlapping and interdependency of systems across the lifecourse.[3] The manifestation of obesity, for example, is no longer regarded as a simple energy in-energy out equation. The influences of the in utero environment on the epigenetic response; changes to the food supply that are rendered by high-level agricultural, economic and trade policy; improvements in transport and technology that reduce the impetus for physical activity; increases in environmental pollutants potentially influencing cortico-hypothalamic responses; and, finally, in a world that never seems to darken, disrupting circadian rhythms all contribute to the aetiology of obesity.[4,5] One example of these effects is highlighted by the article of Paz-Krumdiek et al, who investigated sedentary behaviour in Peru.[6] Adults spent, on average, nearly 6 hours sitting per day, with nearly one-quarter of the sample sitting for 8 hours or longer per day. Longer sitting times were associated with increased obesity. The other example in this issue of the journal is the analysis by Wu et al on NHANES data, looking at the associations between unprocessed red meat consumption and the inflammatory response in never, current and past smokers.[7] This article highlights that pollutants could have a profound effect on the body's physiology and biochemistry, resulting in varying responses to the consumption of the same food.

This systems approach highlights that the narrow review of chronic conditions as the sole responsibility of the individual or his or her failure to comply to guidelines is misdirected. Yet, the language that blames the individual pervades our practice. For example, we talk about individuals managing or changing their “lifestyle” as if it is a simple matter of choosing a different way to live. A more socially informed approach argues that structural and social processes actively impinge on the capacity to adopt what might be considered an almost elusive ‘healthy lifestyle’.[8] Using ‘personal behaviours’ rather than the politically loaded ‘lifestyle’ in recognition of this is one way to acknowledge these structural and social barriers.

In this issue, the challenges associated with changing personal behaviours are highlighted in four articles. Eykelenboom et al investigated weight loss patterns among Dutch adults who were overweight and obese to investigate psychological and behavioural determinants. The study used two predominant constructs: the ‘Power of Food Scale’ that assesses the psychological impact of the food environment and the second that measured the use of portion control strategies.[9] Jospe et al have acknowledged that satisfaction with a diet is an important factor to consider for dietary adherence. The short scale they have developed covers not only biological factors but also social (eating at home and away from home), time (meal preparation) and economic factors (diet is affordable).[10] Adherence is also the focus of the paper by Forslund et al, who explored the experiences of men receiving a nutrition intervention while undergoing radiotherapy for prostate cancer in Sweden. Their results speak to the social dimensions of eating and the importance of involving significant others, of sharing experiences and of tailoring dietary advice to social circumstances.[11] Finally, an article from Sri Lanka explores the availability and composition of weight loss supplements. This highlights the continual search by those seeking weight loss for a ‘magic bullet’ that will resolve the problem with minimal changes to other facets of their lives. The article is a timely reminder that dietitian-nutritionists need to understand the types of supplements on the market, the claims they are making and the potential for adverse effects.[12] Claims were not monitored, and given their broad availability, strengthening the global regulatory framework around their distribution and marketing needs to be prioritised in order to protect the public.

## DIETITIAN-NUTRITIONISTS: PRACTISING THE ART AND SCIENCE OF NUTRITION

It seems you cannot use social media, read a magazine or browse the bestseller list without seeing some reference to what food or diet should be consumed for health. There is a cacophony of nutrition noise, and everybody is an expert. Dietitian-nutritionists, however, are those professionals with training in the science of nutrition, food and the human condition and are best placed to be the translators of science into everyday practice. Nutrition is also a young science that is constantly evolving. As such, the unravelling of the mysteries of food and its components, as well as the human body and its reactions to food and the environment, across generations means that new discoveries are being made. These findings have a profound impact on the best available advice that should be delivered to the public. Dietitian-nutritionists therefore need a range of skills and attributes that encompass interpreting and critiquing the science through to those that fall under the umbrella of emotional intelligence. A combination of these embrace the art and science of nutrition, which are relevant internationally.

Essential tools are required to gather the most appropriate and accurate data to apply the science and make recommendations for everyday practice. Several papers in this issue highlight the need for tools that enable practitioners to make the best possible estimates of dietary intake with the least burden to individuals. These tools need to be tailored to the food supply that is available to individuals at any given time and to different characteristics of target populations. Beck et al, in New Zealand, describe the development and validation of a food frequency questionnaire (FFQ) that takes into consideration changes to the food supply and the applicability of the tool to women from Maori, Pasifika and European backgrounds.[13] Glabska et al respond to the growing prevalence of a double burden of malnutrition (overweight/obesity and micronutrient deficiencies) in more industrialised nations, using an FFQ to ascertain consumption of magnesium among Polish women.[14] With the rise in the consumption of plant-based diets, Waterplus et al use a plant-based diet index that discerns between healthy and unhealthy sources to monitor changes over a 10-year period and the impact on blood lipids.[15] Finally, Godois et al look at a particularly time-poor population—athletes—and describe the use of multi-pass 24-hour food recalls to develop a list of foods for an FFQ to explain nutrient variability in Brazilian athletes.[16]

At the centre of dietetic practice is person- or community-centred care. The term denotes the building of partnerships with individuals, their families and communities, where health professionals share the power to empower.[17] Person-centred care is used in lieu of patient-centred care as many individuals with chronic conditions manage these conditions more often outside of the health system than within it. Using ‘patient’ also continues to perpetuate a power imbalance and a subjectivity and identity that may not be welcomed. One of the core skills in enacting person-centred care is empathy. Yang et al highlight the levels of empathy among dietetic interns in Malaysia, which were self-reported, and from the assessment of the dietetic care recipient.[18] This article also highlights the importance of professionals' self-care in practice; empathy decreases as burn-out increases, so practitioners need to be mindful of their own physical and emotional health. Empathy is also involved when reflecting on the costs of adhering to specific diets prescribed by dietitians. Zinn et al in New Zealand identified the costs associated with following a low-carbohydrate, healthy fat diet compared to adhering to the national nutrition guidelines.[19] The cost of following a prescribed diet is a very real consideration for the significant number of people who are anxious about where their next meal is coming from. Different dietary approaches could be equally effective in improving outcomes, and the role of the dietitian-nutritionist is to marry the science with the needs and responses of individuals to optimise outcomes. For example, the article by Hashemi et al comparing the Dietary Approaches to Stop Hypertension (DASH) diet with the American Diabetes Association nutrition guidelines (both tailored to Iranian food habits) demonstrated that both diets had similar effects on lipid profiles of Iranian patients with type 2 diabetes.[20]

The remaining articles in this issue emphasise the critical role dietitian-nutritionists play in managing malnutrition in the acute care and rehabilitation settings. A team of researchers in Romania has investigated the complex relationship between acute myocardial infarction, inflammation and nutritional status.[21] Their article reports on high rates of malnutrition despite body weights that could be considered overweight or obese.

Dietitian-nutritionists have unique capabilities that mean they are best positioned to be the trusted voice of nutrition. We just need to unlock the potential of the profession as the beacons of evidence-based, pragmatic nutrition practice amidst the growing complexity of an ecologically unstable world. Increasingly, we need to ensure the profession's mobility across national borders as we optimise the consumption of sustainable, biodiverse diets in the shadow of climate change.

## CONFLICT OF INTEREST

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**ORIGINAL RESEARCH**

# Association between sitting time and obesity: A population-based study in Peru

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**Abstract**

**Aim:** To assess if there is an association between sitting time and obesity among adult Peruvian population, using three different anthropometric measurements.

**Methods:** A secondary analysis using data from a population-based study, the National Household Survey (ENAHO, in Spanish), was conducted enrolling adults aged ≥18 years from the 25 regions of Peru using a multistage random sampling technique. The outcome of interest was obesity, determined by body mass index (BMI > 30 kg/m$^2$), waist circumference (WC > 80 and >90 cm in women and men, respectively) and waist to height ratio (WHR > 0.5); while the exposure was sitting time, measured using the last domain of the International Physical Activity Questionnaire and then categorised in <4 hours/day, 4 to <8 hours/day and 8+ hours/day. Associations were estimated using Poisson regression models, reporting prevalence ratios (PRs) and their respective 95% CI.

**Results:** Data from 8587 subjects were analysed; mean age was 38.4 (SD: 13.5) and 53.6% were females. The prevalence of obesity was 16.3% (95% CI: 15.2–17.5%) by BMI, 58.5% (95% CI: 56.9–60.0%) by WC, and 78.0% (95% CI: 76.5–79.3%) by WHR. In the multivariable model, subjects reporting a sitting time of 8+ hours/day were more likely to be obese than those reporting <4 hours/day according to BMI (PR: 1.38; 95% CI: 1.15–1.65), WC (PR: 1.20; 95% CI: 1.12–1.28) and WHR (PR: 1.05; 95% CI: 1.01–1.10).

**Conclusions:** Subjects with greater sitting time were more likely to be obese, and this association was evident with three different anthropometric indicators. Findings suggest the need of generating public health actions to reduce sedentary behaviour.

**Key words:** obesity, Peru, prevalence, sedentary, sitting time.

## Introduction

Obesity is the excessive accumulation of fat and is associated, in the long term, with non-communicable conditions, including type 2 diabetes mellitus, cardiovascular disease, and some type of cancers,[1] and with a subsequent great impact on health systems and increased associated care costs, as well as the risk of disability and premature deaths.[2] In 2014, the global prevalence of obesity was 13% among adults, 10.8% in males and 14.9% in females.[3] Moreover, by 2025, the prevalence of obesity will reach 18% in men and 21% in women.[1] Peru, a middle income country, is seriously affected, as prevalence of obesity in 2014 was 17.5% in people older than 15 years; 14.4% among males and 26.2% in females.[4] Therefore, the prevention and control of obesity and its determinants are a priority issue in the Peruvian population as well as in the global health agenda.[5,6]

There are several ways to evaluate obesity, such as body mass index (BMI), waist circumference (WC) and waist to height ratio (WHR), among others. The BMI indicates general obesity, depending only on weight and height, and ignoring variations in the physical characteristics of the person or difference between lean mass and fat mass.[7,8] On the other hand, WC and WHR indicate central obesity and fat mass. In addition, WHR has been considered as a more appropriate indicator in low-size populations, such as the Peruvian population.[9] Although the use of BMI can classify persons as overweight or obese, the other indicators (i.e. WC and WHR) only can identify obese individuals.

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According to a recent consensus, the term sedentary behaviour is defined as 'any waking behaviour characterised by an energy expenditure of ≤1.5 metabolic equivalents (METs) per day, while in a sitting, reclining or lying position'.[10] As a result, sitting time is considered part of the sedentary behaviour. Recent studies indicate that the time in sitting position is a risk factor for obesity and other chronic conditions, regardless the level of physical activity.[11–13] In addition, a paper has reported that mortality rate is higher in individuals who remain seated for more than 6 hours/day compared to those who are sitting for less than 3 hours/day.[14]

As a result, the present study aimed at evaluating the association between sitting time and obesity in the adult Peruvian population, using three different anthropometric markers and a population-based study in Peru.

## Methods

This is a secondary analysis using data from a population-based study, the National Household Survey (ENAHO in Spanish). Data were retrieved from the Health Questionnaire and the Anthropometric Measurements Module (Food and Nutrition Centre—CENAN 2011) conducted in the urban and rural areas, in the 25 regions of Peru.

The original survey included residents of all regions of Peru who were selected through a multistage probabilistic sampling technique. The primary sampling unit was a city with 2000 or more inhabitants in the urban area or 500–2000 inhabitants in the rural area. The secondary sample unit was a cluster consisting of one or more blocks containing, on average, 120 houses. The tertiary sampling unit was the household. All the habitual residents in the household were potential participants of the survey; however, domestic workers, and people living in the household but who were not family members were excluded. In total, the ENAHO 2011 surveyed 21 875 individuals. For the present study, information of only 8587 subjects, men and women aged 18–64 years were used. Reasons for exclusion were: age <18 years (n = 7053) or ≥65 years (n = 1942), pregnant women or in breastfeeding period (n = 478), and those that did not have the variables of interest (i.e. sitting time or anthropometric markers, n = 3815), shown in Figure 1.

The outcome of interest was obesity assessed by using three different anthropometric indicators: BMI, WC and WHR. Anthropometric measures (weight, height and WC) were assessed from all participants by trained staff following standardised techniques based on the World Health Organisation and the National Guidelines implemented by the CENAN and the National Institute of Health in Peru.[15,16] Obesity was defined separately as a BMI ≥30 kg/m$^2$, WC ≥90 cm in men and ≥80 cm in women,[17] and WHR ≥0.5.[9]

The exposure of interest was sitting time (in hours), assessed as the self-report of the time in a sitting position, evaluated according to the last domain of the International Physical Activity Questionnaire (IPAQ), a tool validated in Spanish to measure levels of physical activity.[18] The IPAQ evaluates five domains of daily life (work, transportation, home, recreation and sitting time) and thereby classifies levels of physical activity as vigorous, moderate or low. As the questions used for this analysis assessed the sitting time on a day of the week and the sitting time on a day on the weekend, we added all the information to estimate the time spent sitting for a week and the sum was divided by 7.[19,20] Finally, this value was categorised into <4, from 4 to <8 and from 8+ hours/day. We considered these cut-off points, as <4 hours were close to the lower tertile of our sample, and 8 hours is the usual office workday.

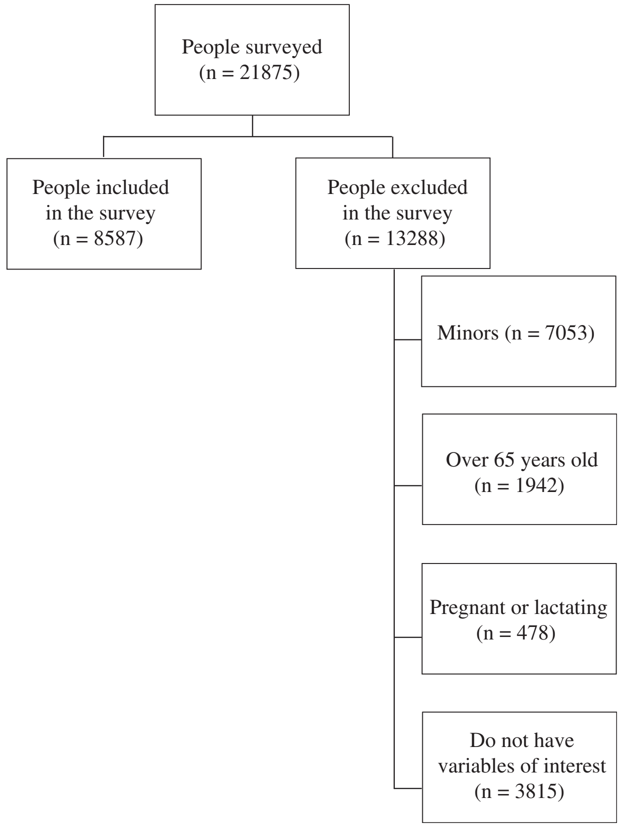


**Figure 1** Populations included and excluded.

Other variables included in the study were gender (male or female); age (in years), divided into three categories (18–29, 30–44 and 45–65 years); educational level in years (<6, 6–11 and ≥12 years); socioeconomic level, based on the presence of housing facilities (predominantly material of walls, floors and ceilings, access to water, sewage, electricity and fuel used for cooking), assigning a point when presenting the best type of facility (e.g. if gas/electricity = 1, if not = 0, or if there is a sewage service connected to the public system = 1, if not = 0). Then each facility was weighted by its frequency in the study population, and added, creating a crude indicator of socioeconomic level, based on the recommendations of the DHS Wealth Index.[21] Finally, this indicator was split into tertiles. In addition, region of origin (Coastal, Highlands and Jungle), place of residence (urban and rural), and leisure-time physical activity, as the self-report of at least 10 minutes of physical activity during leisure time (yes *vs* no) were also included.

Data analyses were conducted using STATA 13 for Windows (STATA Corp, College Station, TX, USA). Estimations were calculated taking into account the multistage design of the study,[22] adjusting the models by sampling units and selection probabilities.

Initially, we evaluated the characteristics of the study population by time in sitting position. Then, the characteristics of the individuals were compared by obesity assessed as BMI, WC and WHR. All comparisons were performed using the chi-squared test. The prevalence of obesity was estimated by each of the anthropometric indicators and reported with their respective 95% CIs. The associations of interest were evaluated using Generalised Linear Models, assuming Poisson distribution, link log and robust standard errors.[23] Adjusted models included variables such as gender, age, educational level, socioeconomic level, region of origin, place of residence and leisure-time physical activity. Prevalence ratios (PRs) and 95% CI were reported.

The present study was approved by the Ethical Committee of the Universidad Peruana de Ciencias Aplicadas (UPC), Lima, Peru. All procedures were performed according to the Declaration of Helsinki. Informed consent was waived by the Ethical Committee as this was a secondary analysis of a de-identified (anonymised), publicly available database.

## Results

Data from 8587 participants were analysed (Figure 1). The population included was mostly females (53.6%), and the overall mean age was 38.4 years (SD: 13.5). In general, 21.2% had <6 years of education, 41.3% were from the Coastal region and 70.4% were from urban areas (Table 1). When those included in the analysis were compared to those who were not included, there was a significant difference in all socio-demographic variables evaluated (Table S1). Data without considering the multistage design in the analysis is shown in Tables S2-S4.

Participants reported spending, on average, 5.9 (95% CI: 5.8–6.1) hours/day on sitting position. In addition, 21.6% (95% CI: 19.8–23.6%) of subjects reported spending less than 4 hours/day, while 22.2% (95% CI: 20.5–24.1%) spent ≥8 hours/day. In bivariable model, time in sitting position was associated with age, educational level, socioeconomic level, region of origin and place of residence (Table 1).

According to BMI, the prevalence of obesity was 16.3% (95% CI: 15.2–17.5%), whereas it was 58.5% (95% CI: 56.9–60.0%) according to WC, and 78.0% (95% CI: 76.5–79.3%) according to WHR. The bivariable analysis showed that obesity, assessed by the three anthropometric indicators was more frequent among females, among oldest individuals, among those with low educational level, higher socioeconomic level, those from coastal region, and from urban areas (Table 2).

Greater sitting time was associated with greater probability of obesity in multivariable models: those individuals who reported spending ≥8 hours/day in sitting position were more likely to be obese compared to those with <4 hours/day. This finding was valid for the three anthropometric indicators evaluated: PR: 1.38 (95% CI: 1.15–1.65) in the case of BMI; PR: 1.20 (95% CI: 1.12–1.28) according to WC and PR: 1.05 (95% CI: 1.01–1.10) according to WHR (Table 3).

## Discussion

Our results suggest strong evidence that a longer sitting time is associated with greater prevalence of obesity assessed by three different anthropometric indicators. The association had great variation according to each anthropometric marker as they do not measure obesity in the same way. In addition, more than one-fifth of the population spends more than 8 hours a day in a sitting position.

The role of sitting time on obesity is not completely clear. Some longitudinal studies have reported results similar to our findings: a positive association between sitting time and obesity, hypertension and other cardiovascular outcomes, including mortality.[14,19,24] A study in Mexican population reported that sitting time was prospectively associated with obesity, and obesity was a mediator of the relationship between sitting time and hypertension and type 2 diabetes.[24] However, there are also reports that support the reverse association.[20,25] For example, Pedisic *et al.*[20] found that obesity may lead to an increase in total sitting time in a cohort of Australian adults, but the association in the other direction was not clear. Similarly, results from the Whitehall II Study are consistent with the lack of association between sitting time and obesity (both in cross-sectional and prospective assessments).[25]

Two different systematic reviews have assessed the proposed association in the present study.[26,27] One of them found a relationship of self-reported sedentary behaviour during childhood with weight gain and mortality in adulthood;[27] whereas the other one reported that greater amounts of daily total sitting time increased the risk of all-cause mortality, and this association was attenuated by moderate-to-vigorous physical activity.[26] Our study reports that spending ≥8 hours in sitting position per day is associated with greater prevalence of obesity using three different anthropometric markers. Our results agree with other cross-sectional studies reporting a higher probability of obesity among those spending at least 4 hours in sitting position.[11,12,24,28–30] Interestingly, a cross-sectional assessment of the Swiss Cohort Study found that sitting time was directly related to per cent body fat assessed by bioimpedance analysis, but not with BMI or WHR as in our results.[31]

According to our results, the prevalence of obesity can be very different if using BMI, WC or WHR. As previously pointed out, WC and WHR indicate central obesity and fat mass, whereas BMI only indicates general obesity. WHR has been reported to be better than BMI to detect several

 

**Table 1** Relationship between hours in a sitting position and socio-demographic variables taking into account the multistage design of the study

| | *Sitting time (hours/day)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | *<4* | | *4 to <8* | | *8+* | | |
| | *n* | *(%)* | *n* | *(%)* | *n* | *(%)* | P-*value* |
| Gender | | | | | | | |
| Male | 965 | (22.0) | 2205 | (54.9) | 818 | (23.1) | 0.17 |
| Female | 1001 | (21.1) | 2625 | (57.5) | 973 | (21.4) | |
| Age (years) | | | | | | | |
| <30 | 366 | (15.3) | 1313 | (57.1) | 614 | (27.6) | <0.001 |
| 30–44 | 791 | (24.2) | 1668 | (54.9) | 576 | (20.9) | |
| 45+ | 809 | (24.2) | 1849 | (56.5) | 858 | (19.3) | |
| Education | | | | | | | |
| <6 years | 512 | (28.2) | 1040 | (56.1) | 271 | (15.8) | <0.001 |
| 6–11 years | 1064 | (23.4) | 2531 | (57.0) | 853 | (19.6) | |
| 12+ years | 390 | (15.7) | 1259 | (54.9) | 667 | (29.4) | |
| Socioeconomic level | | | | | | | |
| Lower | 836 | (27.7) | 1844 | (58.6) | 402 | (13.7) | <0.001 |
| Middle | 619 | (23.3) | 1394 | (53.4) | 599 | (23.3) | |
| Upper | 511 | (17.1) | 1592 | (56.3) | 790 | (26.6) | |
| Region of origin | | | | | | | |
| Coastal | 735 | (20.1) | 2071 | (59.4) | 742 | (20.5) | <0.001 |
| Highlands | 932 | (27.8) | 1596 | (48.1) | 568 | (24.1) | |
| Jungle | 299 | (13.4) | 1163 | (61.4) | 481 | (25.2) | |
| Place of residence | | | | | | | |
| Rural | 1209 | (31.3) | 3332 | (56.7) | 1501 | (12.0) | <0.001 |
| Urban | 757 | (19.3) | 1498 | (56.0) | 290 | (24.7) | |
| Leisure-time physical activity | | | | | | | |
| No | 965 | (21.3) | 2205 | (54.9) | 818 | (23.8) | <0.001 |
| Yes | 1001 | (22.5) | 2625 | (59.8) | 973 | (17.7) | |

outcomes, including incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality.[9] In addition, Peruvian population spent about 6 hours/day in sitting position. A systematic review found that daily total sitting time was not linearly associated with greater all-cause mortality: the risk of death was greater among those spending more than 7 hours/day of total sitting (hazard ratio = 1.05; 95% CI: 1.02–1.08). Therefore, there is an increasing need to promote physical activity and reduce the sitting time in our population.

Obesity can be attributable to a misbalance between metabolic factors, physical activity and diet patterns. Whereas diet has changed towards increased consumption of processed foods and sugar-sweetened beverages, with the subsequent increase in calories intake, reduction in physical activities and increase in sedentary behaviours have also emerged.[32] Our results show a stronger association between sitting time and obesity assessed as BMI than WC and WHR. As explained previously, BMI indicates general obesity ignoring changes in the physical characteristics of the person or differences between lean mass and fat mass,[7] whilst WC and WHR indicate specific changes in central obesity and fat mass.

Our results suggest the implementation of public health measures aimed at reducing the sitting time in the Peruvian population, and thus, the prevalence of obesity. Previous studies have reported the feasibility of such interventions.[13,33] Thus, it is needed to identify the most common sedentary behaviours in a population and accordingly create interventions encouraging the reduction of sitting time, either in front of the TV, at work, in front of a computer, among others, which can be done using simple and inexpensive tools.[34,35]

Although there are several interventions reported worldwide, there is still little evidence on the implementation of these interventions at the population level. Usually, the work place is where people spend most of the day in sitting position. As a result, it can be important to encourage public and private companies to reduce sitting time to improve health indicators. For example, an intervention study developed in Australia reported the use of office sit-stand desks that potentially increase the standing time at work without reducing productivity.[36] However, according to current consensus, standing up is not enough to decrease the negative impact of sitting time on health. Thus, a meta-analysis of nine experimental studies reported that sitting breaks with at least light-intensity activity only had a positive effect on glycaemia and not in other cardiovascular markers; but the same report found an association between sitting breaks and obesity indicators as in observational studies.[37] On the

 

**Table 2** Relationship between indicators of obesity and socio-demographic variables taking into account the multistage design of the study

| | *Obesity* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *BMI (>30 kg/m²)* | | | *WC (>80/90 cm)* | | | *WHR (>0.5)* | | |
| | *n* | *(%)* | P-*value* | *n* | *(%)* | P-*value* | *n* | *(%)* | P-*value* |
| Gender | | | | | | | | | |
| Male | 454 | (12.2) | <0.001 | 1652 | (44.0) | <0.001 | 2889 | (72.8) | <0.001 |
| Female | 944 | (20.6) | | 3369 | (73.2) | | 3839 | (83.2) | |
| Age (years) | | | | | | | | | |
| <30 | 158 | (6.8) | <0.001 | 803 | (34.5) | <0.001 | 1267 | (54.3) | <0.001 |
| 30–44 | 533 | (16.8) | | 1920 | (61.9) | | 2565 | (84.3) | |
| 45+ | 707 | (23.4) | | 2298 | (74.2) | | 2896 | (90.8) | |
| Education | | | | | | | | | |
| <6 years | 303 | (17.8) | 0.03 | 1771 | (60.5) | 0.12 | 1484 | (82.7) | 0.002 |
| 6–11 years | 744 | (17.2) | | 2535 | (57.0) | | 3468 | (77.8) | |
| 12+ years | 351 | (14.3) | | 1415 | (59.9) | | 1776 | (76.0) | |
| Socioeconomic level | | | | | | | | | |
| Lower | 323 | (10.7) | <0.001 | 1467 | (46.7) | <0.001 | 2306 | (75.0) | 0.02 |
| Middle | 446 | (16.1) | | 1577 | (59.5) | | 2057 | (78.6) | |
| Upper | 629 | (19.7) | | 1977 | (64.6) | | 2365 | (79.3) | |
| Region of origin | | | | | | | | | |
| Coastal | 775 | (19.7) | <0.001 | 2461 | (65.2) | <0.001 | 2969 | (80.9) | <0.001 |
| Highlands | 371 | (12.2) | | 1526 | (49.9) | | 2299 | (74.7) | |
| Jungle | 252 | (12.1) | | 1034 | (50.0) | | 1460 | (73.2) | |
| Place of residence | | | | | | | | | |
| Rural | 230 | (8.3) | <0.001 | 1167 | (42.9) | <0.001 | 1879 | (73.0) | <0.001 |
| Urban | 1168 | (18.3) | | 3854 | (62.2) | | 4849 | (79.2) | |
| Leisure-time physical activity | | | | | | | | | |
| No | 1125 | (17.6) | <0.001 | 3918 | (60.0) | <0.001 | 5200 | (79.2) | <0.001 |
| Yes | 273 | (12.6) | | 1103 | (53.5) | | 1528 | (74.3) | |
| Sitting time (hours/day) | | | | | | | | | |
| <4 | 294 | (15.6) | 0.003 | 1069 | (54.5) | 0.002 | 1548 | (79.5) | 0.22 |
| 4 to <8 | 744 | (15.3) | | 2821 | (58.7) | | 3761 | (77.1) | |
| 8+ | 360 | (19.8) | | 1131 | (62.1) | | 1419 | (78.8) | |

BMI, body mass index; WC, waist circumference; WHR, waist to height ratio.

other hand, health-care facilities staff should create awareness and help people to adopt healthy habits aimed at reducing sitting time. In the United States, interventions were conducted using mass campaigns as a mean of preventing obesity and decreasing the sitting time per week.[33] Finally, the promotion of physically active modes

**Table 3** Association between obesity and hours in a sitting position: crude and adjusted models taking into account the multistage design of the study

| | *Obesity* | | | | | |
|---|---|---|---|---|---|---|
| | *BMI (>30 kg/m²)* | | *WC (>80/90 cm)* | | *WHR (>0.5)* | |
| *Sitting time (hours/day)* | *PR* | *95% CI* | *PR* | *95% CI* | *PR* | *95% CI* |
| Crude model | | | | | | |
| <4 | | Reference | | Reference | | Reference |
| 4 to <8 | 0.98 | 0.83–1.16 | **1.08** | **1.01–1.15** | 0.97 | 0.93–1.01 |
| 8+ | **1.27** | **1.05–1.53** | **1.14** | **1.06–1.23** | 0.99 | 0.95–1.04 |
| Adjusted model[1] | | | | | | |
| <4 | | Reference | | Reference | | Reference |
| 4 to <8 | 0.99 | 0.84–1.16 | **1.09** | **1.03–1.14** | 1.00 | 0.96–1.03 |
| 8+ | **1.38** | **1.15–1.65** | **1.20** | **1.12–1.28** | **1.05** | **1.01–1.10** |

[1] Adjusted for gender, age, education level, socioeconomic level, region of origin, place of residence and leisure-time physical activity.
BMI, body mass index; PR, prevalence ratio; WC, waist circumference; WHR, waist to height ratio.
Bold estimates are significant ($P < 0.05$).

of transportation such as jogging, walking or cycling, is also essential.[34]

The strengths of the present study included the population-based nature of the survey with a representative sample at the national level. Moreover, ENAHO provides data collected by well-trained personnel. In addition, obesity was assessed using three different anthropometric indicators with a subsequent more complete assessment of the association of interest. However, the present study has some limitations. First, a reverse causality of the proposed association can be an issue. Also, the cross-sectional nature is useful to assess association between two variables and not causality. Second, our results may not be completely inferable as the population included in the analyses was different from the excluded population. Third, the ENAHO did not collect data on the dietary patterns, so our models were not adjusted for this variable. However, sitting time is an important risk factor for obesity, regardless of diet and physical activity level.[9] Moreover, when adjusting the model for leisure-time physical activity some residual confounding might arise as less than a quarter of the population study performed at least 10 minutes of physical activity during leisure time. However, this kind of physical activity has demonstrated being an appropriate indicator of physical activity levels in Latin America population.[38] Fourth, although a validated method to measure physical activity (i.e. the IPAQ) was used, the sitting time was evaluated using information of the 7 days prior to the survey, and hence, assumed that this represents long-term sitting time. What is more, someone can argue that combining sitting time during weekdays and weekend can show different results.[39] Nevertheless, in post-hoc analyses (data not shown), we found that both variables are highly correlated and the association with obesity markers was similar; so, we decided to use these variables combined. Finally, assessing time position requires a more objective tool than the IPAQ (subjective); yet, the use of an objective measurement is unlikely to be applied in large population-based studies.

In conclusion, longer sitting time was associated with greater probability of obesity, and this association was evident with three different anthropometric indicators. Around 6 hours, on average, were reported in sitting positing in Peruvian population. These findings suggest the need to generate public health actions to reduce sitting time.

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## Conflict of interest

The investigators report not having conflict of interests.

## Authorship

MP-K, SGR-V and AB-O designed the study. MP-K and SGR-V interpreted the results and wrote the first version of the manuscript. AB-O and PM-T conducted statistical analysis and contributed to the intellectual content of the manuscript. All the authors approved the final version submitted for publication.

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## Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

**Table S1** Socio-demographic characteristics of the study population: comparison per inclusion in the analysis.
**Table S2** Relationship between hours in a sitting position and socio-demographic variables without taking into account complex sample design.
**Table S3** Relationship between indicators of obesity and socio-demographic variables without taking into account complex sample design.
**Table S4** Association between obesity and hours in a sitting position without taking into account complex sample design: crude and adjusted models.

 

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Nutrition & Dietetics

**ORIGINAL RESEARCH**

# Availability and composition of weight-loss supplements in Sri Lanka

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**Abstract**

**Aim:** The present study aims to investigate the composition and availability of weight-loss supplements in Sri Lanka and explore the evidence for their effectiveness.

**Methods:** Data were collected by visiting drug stores, searching the Internet for websites and referring to advertisements in national newspapers and magazines from August to October 2017.

**Results:** A total of 100 weight-loss products were identified of which the majority (n = 57) were available from drug stores. Most commonly, products were available in capsule form (36.0%). The number of active ingredients in products varied from 1 to a maximum of 22 with a total of 155 different active ingredients distinguished. The ingredients mainly originated from plants (77.4%) while green tea (*Camellia sinensis*), garcinia (*Garcinia cambogia*) and caffeine anhydrous were the three most common. At least one of the top 10 ingredients was included in 75 of the products sourced. Directions for use were specified in only 72 products, while a further 6 products lacked any information on ingredients. Literature predicted positive weight-loss effects for green tea and ginger while garcinia was reported for both positive and negative effects.

**Conclusions:** The ingredients are reported to have both beneficial and adverse effects. Many consumers may find it challenging to make informed purchase decisions as a number of products failed to provide adequate nutritional information and safety measures. Government regulatory authorities should pay closer attention to the availability and provision of products sold to the general public.

**Key words:** dietary supplements, obesity, Sri Lanka, weight-loss products.

## Introduction

Obesity levels have increased globally at an alarming rate over the past couple of decades. It is estimated that more than 1.9 billion adults (39%) worldwide are overweight and in excess of 600 million adults (13%) are obese.[1] Moreover, if recent trends continue, by 2030 up to approximately 60% of the world's adult population (3.3 billion people) could be either overweight or obese.[2] The escalation in prevalence of overweight and obesity has increased the risk for many chronic non-communicable diseases (NCDs) such as cardiovascular diseases, diabetes, musculoskeletal disorders and several cancers.[3] In 2012, NCDs were responsible for 38 million (68%) of the world's 56 million deaths.[1] In addition, the prevalence and incidence of NCDs are rising, particularly in rapidly developing countries in the Asia-Pacific region.[4] For example, a national survey conducted in Sri Lanka in 2005, identified that the prevalence of overweight, obesity and central obesity among adults was 25.2%, 9.2% and 26.2%, respectively,[5] with a secular increase in prevalence.[6]

A wide variety of approaches are available for treating obesity, including dietary management, physical activity, behaviour modification, pharmacological treatment and surgery.[7] Studies have indicated that a weight loss of 5–10% can be achieved through either lifestyle[8] or pharmacological treatments.[9] However, most interventions using anti-obesity drugs have limited long-term success[10] and weight is regained when treatment is discontinued.[11] Furthermore, optimal and safe dosage of weight-loss drugs is generally unknown.[12] As the adoption of healthy lifestyle behaviours consistent with longer-term weight loss require much discipline and are difficult to maintain,[13] the purchase of widely available non-prescription weight-loss products including

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diet pills has become an appealing alternative.[14] In USA, annual medical care costs per obese individual are $US 3508 with a nationwide total spend of $US 315.8 billion in 2010.[15]

Weight-loss supplements are very commonly used, however, many can be problematic.[16] For example, an Italian survey identified 46 suspected adverse reactions associated with herbal products used for weight control.[17] Traditionally, under-nutrition has been the main health issue in Sri Lanka but the recent emergence of the obesity epidemic has given rise to the availability of numerous weight-loss supplements in the market. Therefore, the present study aimed to better understand the types of weight-loss products available to consumers in Sri Lanka, evaluate their composition, and explore the evidence for their usage.

## Methods

A descriptive, cross-sectional survey was carried out to determine the commonly available weight-loss products in the Sri Lankan market from August to October 2017.

*Search strategy*: Data were collected using three different methods: (i) visiting drug stores; (ii) searching the Internet for websites of weight-loss products and (iii) perusal of advertisements disseminated in national newspapers and magazines.

*Drug stores*: Data were collected from the following sources: (i) three leading pharmacy chains in Sri Lanka (Health Guard *Pharmacy* (https://www.healthguard.lk), Harcourts *Pharmacy* (https://harcourtslifestyle.weebly.com/) and State Pharmaceuticals Cooperation of *Sri Lanka* (www.spc.lk)); (ii) the pharmacy at a leading private hospital (http://www.nawaloka.com/service/pharmacy/); (iii) pharmacy at a specialist medical centre for endocrinology and obesity (http://cdem.lk); (iv) a leading sport supplement store (https://mybusiness.lk/gym-solutions-pvt-ltd/) and (v) the *Sri Lanka Ayurvedic Drug Cooperation* (www.ayurvediccorp.gov.lk). Each place was visited in person by an investigator (AP and PS) to gather data on the range of weight-loss products available. Several branches of the pharmacies were visited until the product types became saturated.

*Internet search*: Weight-loss supplements marketed through the Internet were searched using the Google search engine on 1 October 2017 using the search terms 'weight-loss supplements' AND 'online' AND 'sell' AND 'Sri Lanka'. From the results, only the top six hits were accessed and included the following websites: ikman.lk (https://ikman.lk/), vitawell.lk (http://www.vitawell.lk/), supplement factory (http://www.supplementfactory.lk/), wasi.lk (http://www.wasi.lk/), supplements.lk (http://supplements.lk/) and bodybuilding.lk (https://bodybuilding.lk/). The search was conducted in order to imitate the searching strategies of a typical consumer. All the available weight-loss products were recorded to enable comparison with other methods.

*Newspapers and magazines*: A sample of hard copies of newspapers and a monthly magazine were selected because of their past history of advertising weight-loss products. These included: (i) six popular weekend newspapers ('Sunday Observer', 'Lankadeepa', 'Silumina', 'Mawbima', 'Jana Jaya' and 'Sunday Times'); (ii) two weekly women's newspapers ('Sirikatha' and 'Tharuni'); (iii) one weekly publishing health newspaper ('Arogya'; http://archives.dinamina.lk/arogya/) and (iv) a monthly health magazine ('Suwaya'), published in October 2017. Advertisements on weight-loss products were sourced by an investigator (PS).

*Inclusion and exclusion criteria*: A product was considered eligible for data extraction if the label had made a claim of treatment for obesity, weight-loss/reduction, fat burning, low calories, 'skinny', 'lean', 'trim', 'shape/shaping', 'slim/slimming' or even if it contained an image depicting weight-loss or waist reduction. Products that claimed to be only a metabolism booster, energy booster, muscle gainer, colon cleaner, water weight reducer or any other claim which was not specific to weight or fat loss, were excluded. Furthermore, products including the registered pharmaceutical drug 'orlistat' as an ingredient were excluded (10 products).

*Data extraction and statistical analysis*: Data were extracted from the eligible products by one investigator (PS) using a standardised form and the accuracy was checked by a second investigator (RJ). The form listed the product name, physical state of the product, recommended dosage per serving, claims on the label, active ingredients, presence of directions, concentration of each ingredient and presence of a safety warning. The ingredients were classified according to their origin as plant, animal, vitamins/minerals, enzymes/amino acids, trace metals, macro-elements and synthetic compounds. Synthetic compounds are the substances formed under human control by any chemical reaction, for example, maltodextrin. Any discrepancies in the data extracted in this manner were re-checked and resolved by discussion with the involvement of a third investigator where necessary (PR).

Data were analysed using the SPSS version 20 software (Chicago, IL, USA). Normality test was conducted to identify the normal distribution of the data set. As some variables were not normally distributed, descriptive statistics for such variables were presented as percentages, ranges or as mean ± SD.

## Results

The study identified 100 weight-loss products available in the Sri Lankan market. The majority of products were collected from drug stores (n = 57), followed by Internet sites (n = 41) and newspaper/magazine advertisements (n = 13). Only 1 product was common in all three groups and 7 products could be collected from both drug stores and the Internet. Both drug stores and newspapers/magazines had 3 products in common while newspapers and the Internet held only 2 products in common (Figure 1). When considering the physical state of the product, 25 products were tea infusions, 9 products were powders, 36 products were in capsule form, 11 products were fluid extracts, 9 products were tablets, 3 products in balm or paste form and the rest of the products were meal replacements (n = 7).

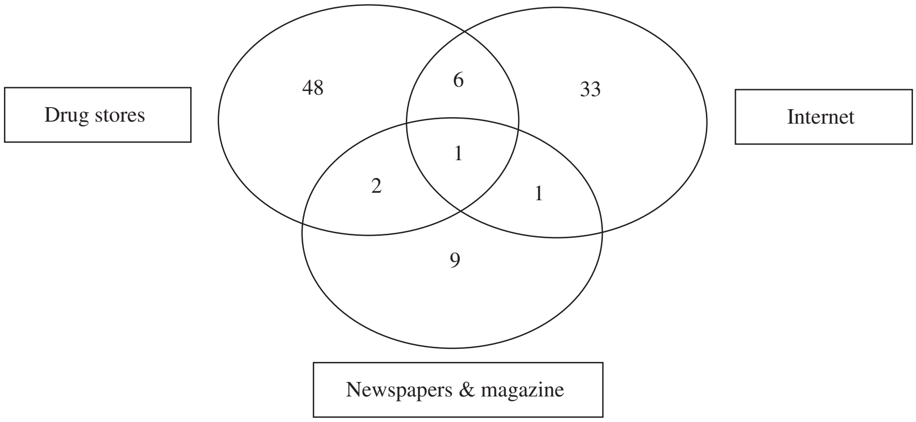


**Figure 1** Weight-loss products collected from different information sources.

*Product ingredients*: A list of active ingredients was mentioned in the labels of 94 products of which 20 contained only one active ingredient whereas 74 had more than one active ingredient. From the total of 155 ingredients identified, the maximum number of ingredients contained in a single product was 21. In total, products contained 155 separate ingredients the majority of which were of plant origin (n = 120, 77.4%), while 12 ingredients were vitamins/minerals (7.7%) and 10 ingredients (6.5%) originated from animals or insects (Table 1).

Table 2 lists the top 10 most frequent active ingredients identified across all products in descending order along with the descriptive information of the items containing the respective ingredient. A total of 75 products contained at least one of the identified top ingredients of which 70.7% (n = 53) included directions for usage on the label. Among the supplements containing the top 10 ingredients, 34 items contained a warning statement concerning a variety of potential adverse effects or conditions under which usage should be terminated. All the products containing L-carnitine tartrate (n = 9) as an active ingredient had some type of warning on the label.

*Instructions and warnings to patients*: Directions for usage (amount per serving and/or daily frequency) were specified in 72 products. Among the 100 supplements collected, the recommended daily intake varied as once (n = 14), twice (n = 24) or three times (n = 11) per day. The remaining items (n = 23) only specified the amount that should be taken per serving and lacked information on daily frequency. The mean quantity (±SD) of the drug recommended to be taken per serving was 19.9 ± 13.3 g.

**Table 1** Classification of ingredients based on their origin

| *Origin of ingredients* | *No. of ingredients* | *Percentage* |
|---|---|---|
| Plants | 120 | 77.4 |
| Vitamins/minerals | 12 | 7.7 |
| Animal | 10 | 6.5 |
| Enzymes/amino acids | 6 | 3.9 |
| Synthetic compounds | 4 | 2.6 |
| Macro-elements | 2 | 1.3 |
| Trace metals | 1 | 0.6 |

## Discussion

*Obesity* is imposing an increasingly heavy burden on the *world's* population in rich and poor nations similarly. There are at least two key points of attraction for alternative treatments for patients with obesity. Firstly, many view such products as natural and therefore safer than prescribed drugs and secondly, there is no perceived need for professional assistance with these approaches.[18]

To our knowledge, this is the first ever research to investigate the availability of weight-loss products in a South Asian country. The current study identified a total of 100 products, including 155 diverse ingredients with different combinations, which were available in the market during the study period. A similar investigation conducted in Columbia, South Carolina identified 402 products containing 4053 separate ingredients with a mean number of ingredients per product of 9.9 ± 8.9.[12] A cross-sectional survey undertaken in Liverpool, UK, recognised a total of 159 different products stored in community pharmacies, multiple grocers and health stores.[19] The aforementioned study reported green tea and *Garcinia cambogia* as top ingredients, which is comparable to the findings of the present study. Another piece of research evaluated the availability of information to consumers on Internet websites marketing herbal weight-loss dietary supplements in USA. A total of 32 herbal weight-loss products, containing kelp (*Fucus vesiculosus*, *Fucus macrocystis*, *Fucus laminaria*, *Fucus ascophyllum*, or unspecified species, 43.3%), green tea (*Camellia sinensis*) extract (40%), bitter orange (*Citrus aurantium*, *Citrus naringin*; *synephrine*) extract (40%), guarana (*Paullinia cupana*, 36.7%), *G. cambogia* (hydroxycitric acid, HCA, 33.3%) and ginger (*Zingiber officinale*, 26.7%) were the top five common active ingredients.[20]

In the present study, the majority of products were collected from drug stores followed by the Internet and newspapers, respectively. This may be because of the preference of Sri Lankan consumers to purchase over-the-counter

**Table 2** Top 10 active ingredients in 100 weight-loss products included in the study

| Active ingredients (species) | Percentage of products with AI | Percentage of products with AI having directions on label | Percentage of products with AI having a label warning | Amount (mg) of ingredient per serving in products, mean ± SD (range) | Number of ingredients in products with the ingredient, mean ± SD (range) |
|---|---|---|---|---|---|
| 1. Green tea (*Camellia sinensis*) | 30 | 50 | 36.7 | 250.00 ± 195.66 (25–600) | 4.43 ± 3.80 (1–21) |
| 2. Garcinia (*Garcinia cambogia*) | 19 | 63.2 | 26.3 | 213.18 ± 110.30 (30–500) | 3.84 ± 2.24 (1–8) |
| 3. Caffeine anhydrous | 14 | 85.7 | 71.4 | 144.68 ± 81.29 (22.5–250) | 6.93 ± 4.55 (1–21) |
| 4. Cinnamon (*Cinnamomum*) | 12 | 58.3 | 8.3 | NM | 4.83 ± 2.17 (1–8) |
| 5. Ginger (*Zingiber officinale*) | 11 | 63.6 | 36.4 | 70.00 ± 70.00 (20–150) | 6.00 ± 2.19 (2–10) |
| 6. Green coffee bean (*Coffea arabica*) | 9 | 88.9 | 55.6 | 1690.00 ± 3306.13 (50–7600) | 7.00 ± 5.77 (1–21) |
| 7. L-carnitine tartrate | 9 | 88.9 | 100 | 323.60 ± 189.96 (100–500) | 4.22 ± 2.28 (1–7) |
| 8. Aralu (*Terminalia chebula*) | 8 | 87.5 | 50 | NM | 4.63 ± 1.85 (2–7) |
| 9. Black seed (*Nigella sativa*) | 8 | 87.5 | 37.5 | (25)[1] | 5.38 ± 2.67 (2–10) |
| 10. Bitter orange (*Citrus aurantium*) | 7 | 85.7 | 57.1 | 210.00 ± 360.65 (10–750) | 5.57 ± 0.98 (4–7) |

AI, active ingredient; NM, not mentioned.
[1] Per serving information was available on only one product.

products at drug stores rather than purchasing medicine online. Although Sri Lanka leads the South Asian region with its high literacy rate, computer literacy indicators are unremarkable compared to developed countries.[21] Almost all the products in the present study (except 6), indicated the ingredients included with many being plant-based (77.4%). Previous studies have also confirmed that many of the products used for weight control contain botanical ingredients[17] with the largest proportion being in capsule form (36.0%). According to our results, 72 products included directions for usage on the label, however, only 49 products had information on daily dose. The rest of the products only specified the amount per serving. A study by Jordan and Haywood[20] found that in general, most websites selling herbal weight-loss dietary supplements posted minimal labelling information and items necessary for a consumer to make an informed decision about a product, such as ingredient strengths and potential contraindications/interactions. Additionally, some evidence shows that many patients do not receive oral or written instructions from their physicians and pharmacists on these products.[22,23] Therefore, the instructions on the prescription container label, especially when using over-the-counter medicines, may be assumed to be of greater importance.

The current study identified green tea, which is made from the fresh leaves of *C. sinensis*, as the most commonly found ingredient. Green tea is a rich source of polyphenols, especially of flavanols and flavonols, which represent approximately 30% of dry weight of the fresh leaf.[24] A complex mixture of polyphenolic compounds, known as catechins, accounts for most of green tea's pharmacologic activity.[25] Catechins are the predominant form of the flavanols.[26] A review by Wolfram *et al*.[27] pooled data from six different studies that have revealed anti-obesity effects of green tea and green tea catechins in humans. Most of these studies reported a decrease in body weight (BW) and fat mass, of which two studies[28,29] reported effects were statistically significant compared to the control group. The results of a meta-analysis confirmed that epigallocatechin gallate (a flavanol present in green tea) and caffeine mixtures, have a positive effect on weight-loss and weight maintenance ($\hat{\mu} = -1.31$, 95% CI: −2.05 to −0.57; $P < 0.001$).[30] Moreover, the meta-analysis by Jurgens *et al*. revealed green tea appears to induce a small, statistically non-significant weight-loss in overweight or obese adults although the change is not clinically significant.[25] Furthermore, it was also mentioned that green tea had no significant effect on the maintenance of weight loss.[25]

Ginger root is another common ingredient in anti-obesity drugs.[12] A systematic review and meta-analysis by Maharlouei *et al*. reported that ginger significantly decreased BW (Standardized Mean Difference (SMD): −0.66; 95% CI: −1.31, −0.01; $P = 0.04$) and waist-to-hip ratio (SMD: −0.49; 95% CI: −0.82, −0.17; $P = 0.003$).[31] Ginger is generally considered a safe herbal medicine[32] and recently it has been shown that [6]-gingerol, one of the major components of fresh ginger, is endowed with strong anti-oxidant action both *in vivo* and *in vitro*, in addition to strong anti-inflammatory and anti-apoptotic actions.[33]

*G. cambogia*, the third most common ingredient in the current study, contains HCA, which has been shown to inhibit citrate cleavage enzyme, suppress *de novo* fatty acid synthesis and food intake, and consequently decrease BW gain.[34] There is limited evidence to support the potential effectiveness and long-term benefits of *G. cambogia* for weight loss.[35] *G. cambogia* extract has been tested in a number of trials and few mild adverse events for both *G. cambogia* and HCA have been reported.[36] Potential side effects include gastrointestinal symptoms, headache and upper respiratory symptoms.[37]

Several studies have identified potential adverse effects associated with both herbal and non-herbal weight-loss supplements.[17,36,38] For example, research conducted by the Italian National Institute of Health identified 46 adverse reactions associated with natural health products used for weight-loss including cardiovascular, central nervous system, dermatological, gastrointestinal and hepatic reactions.[17] Moreover, many commercially available herbal formulations have been poorly researched in terms of efficacy and safety.[39] Although the long-term effects and safety of most anti-obesity drugs are still unknown, with the increase of obesity worldwide, the market for anti-obesity drugs is expected to witness a moderate *growth* in coming years. A systematic review by Onakpoya *et al*. identified 25 anti-obesity medications withdrawn over the past 60 years because of adverse drug reactions after regulatory approval[40] indicating that regulatory authorities should be far more vigilant with approvals only provided after evaluations of effectiveness through clinical trials.

The current study has several limitations. The results represent only the products available for the 3-month study period within major pharmacies in the Colombo district. Accordingly, products collected via the search strategies identified may not represent availability across the country. Furthermore, as the nutraceutical market is highly competitive and dynamic, there will likely be a move by many retailers to diversify their product range. Additionally, products advertised through other media such as television, radio and social media were not included in the present study. Furthermore, as the study only collected label information and did not measure the effectiveness or analyse the active ingredients in collected products, the results for frequently found ingredients may vary because of incorrect information on the labels. However, the study does reflect most of the available products with carefully specified ingredients and dosages.

A large variety of weight-loss products with numerous active ingredients are available in Sri Lanka. As some products lack important label information, it is essential to provide customers with accurate safety and efficacy details prior to purchase. It is most important that all products include nutritional and safety information to assist consumers make informed choices. Although several drugs have promising anti-obesity effects, adverse effects have been reported regarding certain ingredients and underline the importance of further research in this field.

According to the National Medicines Regulatory Authority (*NMRA-Sri Lanka) Act of 2015*, weight-loss supplements belong to the category of 'Borderline products' defined as products having combined characteristics of medicines and foods, medicines and medical devices, or medicines and cosmetics.[41] The Borderline Products Evaluation Committee was established to the evaluate benefits, risks, efficacy, quality, safety, need and cost of such borderline products with pharmacoeconomic analysis necessary in keeping with the National Medicines Policy.[42] Furthermore, it is prohibited to import, sell, transport, distribute or advertise any borderline product, other than registered products, under the authority.[42] Moreover, no person shall label, package, treat, process, transport, distribute, sell, exhibit or advertise any borderline product in a manner that is false, misleading, deceptive or likely to create an erroneous impression regarding its efficacy, safety, quality or composition.[42] Although certain rules and regulations have been established to control the entry of low quality products to the market, it is doubtful whether some manufacturers follow them. Therefore, government and other regulatory bodies should adopt a rigid approach and implement new policies for drug approval and also oversee marketing based on proven safety and efficacy.

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## Conflict of interest

The authors have no conflicts of interest to declare.

## Authorship

RJ generated the research idea. RJ, PR and PS have made substantial contribution to conception and design the study. AP and PS collected data. PS analysed the data. RJ, PS and PR interpreted data. PS, RJ, PR and APH were involved in drafting the manuscript. All authors read and approved the final manuscript.

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**ORIGINAL RESEARCH**

# Development of a Food Frequency Questionnaire for Brazilian athletes

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**Abstract**

**Aim:** Until recently most dietary survey methods have been developed for non-athletic populations. In this study, we aimed to develop a Food Frequency Questionnaire (FFQ) to assess the regular dietary intake of Brazilian athletes.

**Methods:** We interviewed 141 athletes (23.36 ± 7.77 years old) for their dietary intake using 24-hour recalls. After grouping conceptually similar food items into 113 food items, percentage contribution analysis and stepwise regression models were used to highlight foods contributing to at least 90% of the between-person variability of key nutrients.

**Results:** The developed FFQ contained 59 foods which were important predictors of the variance in nutrient intake. Vitamin C and pyridoxine had the lowest number of selected foods. Conversely, 13 food items were required to explain the between-person variation for energy, carbohydrate and magnesium intake.

**Conclusions:** Using a multiple regression analysis we developed a 59-food item questionnaire, which includes culturally specific food items and may represent an important dietary tool to analyse athletic populations. Reproducibility and validity of this FFQ will be verified in future research.

**Key words:** athletes, dietary assessment, dietary methodology, sports nutrition.

## Introduction

Diet has been increasingly recognised as a key component of athlete's success in sport. The balance between energy intake and energy expenditure is crucial to prevent an energy deficit or excess.[1,2] Individuals adopting a diet with low energy availability may develop the relative energy deficiency in sport syndrome, known to compromise protein synthesis, bone health, and the functioning of the cardiovascular, gastrointestinal and immunological systems.[3,4] Furthermore, low energy availability decreases muscle glycogen storage, which may cause fatigue and increased perception of effort, affecting sports performance.[1,4]

Dietary strategies vary according to the sports modalities, personal goals and food preferences.[1] Circumstances occurring both inside and outside the sports arena such as demanding training and travel schedules,[5] sport-specific factors, as well as the cultural aspects of individuals, considerable complicate the nutritional assessment and may impact its accuracy.[6,7] Other factors that can also modify dietary intake include training strategies (e.g. periodisation, adopted across short or long periods to meet the desired body composition and maximise performance)[7–9] and dietary supplements (often consumed as ergogenic aids).[10,11] Consequently, the assessment of the athletes' diet remains a challenge in sports nutrition.

An accurate assessment helps to identify nutritional inadequacies[12] related to the health status or athletic performance.[9,13] Hence, given the importance of assessing nutritional patterns and the difficulties to analyse dietary habits of athletes, there is an increasing need for reliable intake measurement tools to suit this specific group.[14] Among dietary assessment methods, the food frequency questionnaire (FFQ) is widely used in nutritional epidemiology.[15] Besides being fast, inexpensive and self-administered,[15] an

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FFQ is a useful tool to assess habitual and long-term eating patterns in different populations.[16] Nonetheless, few FFQs have been developed for athletes.[17] FFQs have also been used to perform qualitative and quantitative dietary assessments and to rank individuals regarding the frequency of consumption.[18]

The main components of an FFQ are the food list, frequency of consumption and portion size,[18] which can change according to nationality and consumption specificity, as previously mentioned for sportspeople.[8] In this sense, it is expected that the construction of nutrient databases to a target population provides greater reliability for the elaboration of an FFQ. Moreover, the development of a valid, efficient and cost-effective approach to assess the dietary intake of athletes is an important research goal to achieve.[7] Thus, the aim of this study was to develop an FFQ for Brazilian athletes.

## Methods

This study was conducted with 141 athletes/sportspeople (111 males, 30 females) to generate the food list required to develop the FFQ. Dietary habits were obtained from athletes representing different sport modalities: cycling, body building, soccer, American football, futsal, jiu-jitsu, judo, karate, kung-fu, mixed martial arts, muay thai, taekwondo, swimming, tennis, shooting, triathlon and volleyball. Athletes were contacted through sports federations, training centres and sports academy from the State of Mato Grosso, Brazil. Only athletes (classified as individuals who trained with the purpose of competing in regional or international level championships) were considered. This study was approved by the Human Beings Ethics and Research Committee of the University Hospital Júlio Müller, following the National Health Council Resolution 466/2012. Participants or guardians (for athletes under 18 years) were fully informed about all aspects of the study and signed an informed consent upon entering the study.

All athletes who volunteered to participate in this study were interviewed in the Nucleus of Physical Fitness, Informatics, Metabolism, Sports and Health, located at the Federal University of Mato Grosso, Brazil. The intake of food and dietary supplements was assessed by 24-hour dietary recalls (24HR), which investigate detailed information about food intake over a specific day. To increase the power of explanation, we assessed dietary habits from a sample larger than 100 individuals and 24HR were collected across more than a single day for most participants. Athletes were asked to declare all food items, dietary supplements and drinks consumed in the previous 24 hours, describing food preparation methods, ingredients of mixed dishes and brand names of all commercial and ready-to-eat foods.[15]

The dietitians responsible for the dietary interviews were previously trained and adopted the multiple-pass method to reduce bias during data collection from 24HR.[19] In addition, the interviewers relied on photographic records to identify the portion size of the household measures and a standardised guide of frequently asked questions to facilitate the interview.[5] All foods and beverages were estimated and recorded in standardised household measures (glasses, cups, spoons).[18] Supplements and ergogenic aids were recorded according to the serving size suggested by the manufacturer (scoops, capsules, pills).

Foods and supplements reported were grouped into 113 items, based in their conceptual similarity (e.g. fat and energy content, vitamins and minerals content for fruits and vegetables), covering all *foods* and *food groups* recommended in dietary guidelines. The aggregation of items was monitored by registered dietitians as a quality control process. Brazilian table of food composition TACO[20] database was used to calculate the nutrients. The nutrient composition of supplements was catalogued according to the manufacturer's information.

Specific food and supplements contributing to at least 90% of the between-person variability were identified by stepwise multiple regression analysis, performed to select the variables that best explained the variance of the dependent variables (energy and total nutrient intake). Nutrient contribution from each food item was considered as an independent variable.[21] This procedure was undertaken for 13 nutrients as follows: (i) energy; (ii) protein; (iii) fat; (iv) carbohydrate; (v) calcium; (vi) iron; (vii) potassium; (viii) magnesium; (ix) zinc; (x) phosphorus; (xi) niacin; (xii) pyridoxine; and (xiii) vitamin C. Food items in the model accounting up to 90% of the between-person variability and up to 90% of total energy intake were considered for the final questionnaire. These cut-offs were chosen based on previous FFQ development studies,[22–25] being considered achievable of comprehensive coverage. Moreover, up to 90% of total energy intake was considered to avoid neglecting items with a significant contribution to the total energy intake.

Additionally, the percentage contribution of the foods to total energy and nutrients intake, highlighted in the multiple regression analysis, was also calculated. The percentage contribution of nutrient ($k$) by food ($i$) was estimated according to the equation:

$$\Sigma_{ki} \times \frac{100}{\Sigma_{k113}}$$

where $\boldsymbol{\Sigma_{ki}}$ is the total contribution of the nutrient from a specific food and $\boldsymbol{\Sigma_{k113}}$ is the total of nutrient intake from all foods.

The developed FFQ contained 59 foods which were important predictors of the variance in nutrient intake. Selected food items were grouped and ordered based on their nutrient content and dietary intake characteristics.[18] We considered 11 sections: (i) cereals, tubers and legumes; (ii) pasta, dough, pastries and savoury snacks; (iii) meats and eggs; (iv) milk and dairy products; (v) vegetables; (vi) fruits and juices; (vii) sugars and sweets; (viii) assorted drinks; (ix) oils, fats and oilseeds; (x) miscellaneous; and (xi) supplements. Foods not selected, but considered relevant to the population studied, were added in the final version of FFQ.

 

Categories adopted for frequency of food intake were monthly, weekly or daily, with ranges varying between never and once to six times. Portion sizes were determined according to the percentile distribution of measures recorded in the 24HR. The reference portion size (average serving size) was determined to be equivalent to the median (50th percentile). The 'large' and 'small' portion sizes were determined according to the equation:

$$\text{Portion size} = Q_2 \pm \frac{Q_2}{\text{CVIIQ}}$$

where $Q_2$ is the 50th percentile of the size of selected food, and CVIIQ represents the coefficient of variation (ratio of the SD to the mean) of the interquartile range (difference between 75th and 25th percentiles) of all selected foods.

## Results

A total of 240 24HR were obtained from 141 athletes (70.21% from two interviews). Athletes' characteristics and nutrient intakes were presented as mean ± SD (Table 1). Most participants (78.7%) were males, aged 23.36 ± 7.77 years, with body mass of 72.12 ± 16.18 kg, height of 1.73 ± 0.09 m and body mass index of 23.98 ± 4.09 kg/m$^2$. Male athletes had absolute amounts of energy, protein, fat and carbohydrate intake considerably higher than female. Nevertheless, after adjusting to body weight a slight difference was observed; females consumed less energy (11%), protein (18%), fat (5%) and carbohydrate (3%) than male participants. Most males exceeded the estimated average requirements (EARs)[26] for pyridoxine (56%), vitamin C (62%), niacin (91%), iron (95%), phosphorus (89%) and zinc (72%), while most females exceeded the EAR for pyridoxine (52%), vitamin C (61%), niacin (83%), iron (77%), phosphorus (68%) and zinc (71%).

Figure 1 presents the number of items needed to explain the between-person variation and the percentage contribution of the selected nutrients to absolute nutrient intake. A range of 1–13 food items accounted for 90% of the between-person variance in energy and nutrients intake. Pyridoxine and vitamin C had the lowest number of sources (one food item) among analysed nutrients. Conversely, 13 foods accounted for 90% of total variance in energy, carbohydrate and magnesium intake. Furthermore, the regression analysis selected foods covering from 36.13% to 85.78% of the absolute nutrient intake. Food items selected for protein, fat, pyridoxine and vitamin C accounted for less than 50% of the absolute nutrient intake.

Table 2 shows the specific food contributions to the between-person variation and to the energy and total macronutrient intake among athletes. The food items rice, biscuit, fruit, pizza, baked savoury snack, ice cream, and supplements were the foods that best explained the between-person variation for energy and macronutrient intake. In total, 13 foods were highlighted as the major contributors to the between-person variance in energy intake. After ranking by the degree of contribution to total energy intake, we identified meat, chicken, supplements, bread, and milk as the major contributors. However, these five foods accounted for only 37% of the total energy intake. All chosen foods represent slightly more than 65% of the between-person variation in total energy intake. Supplements were the item responsible for the variance in total energy (36%) and protein (89%) intake among athletes. Likewise, supplements accounted for 20%, 14% and 36% of the intake of calcium, pyridoxine and total nutrient intake, respectively.

Furthermore, 13 food items accounted for 75% of the carbohydrate intake variability. Pizza, baked savoury snacks, biscuits, rice and fruits were the top five chosen foods, which represented 62% of carbohydrate intake variance. The best-ranked foods were rice (first); followed by fruit (second), bread (fourth) and soda (fifth). Only two foods were required to explain the variance of protein and fat intake. The food items that best explained the variance in protein intake were the best-ranked items (first and second) and accounted for 42% of total protein intake. Similarly, foods selected for fat variance had high contribution ranked as first and fourth items, covering 39% of total fat intake.

Additionally, vitamins (niacin, pyridoxine and vitamin C) and minerals (calcium, iron, potassium, magnesium, zinc and phosphorus) were evaluated, as shown in Figure 1. A total of 7 and 22 food items were highlighted to explain the variance in vitamin and minerals intake, respectively. Interestingly, all top food items selected by the

**Table 1** Descriptive characteristics and average dietary intake of athletes

| | *Male* | *Female* |
|---|---|---|
| Age (years) | 24.18 ± 7.64 | 20.34 ± 7.62 |
| Body mass (kg) | 77.02 ± 14.34 | 53.98 ± 7.18 |
| Height (m) | 1.76 ± 0.07 | 1.60 ± 0.07 |
| Body mass index (kg/m$^2$) | 24.79 ± 4.11 | 20.99 ± 2.18 |
| Energy (kcal) | 2879.70 ± 1326.46 | 1815.69 ± 521.93 |
| Energy (kcal/kg) | 38.80 ± 19.61 | 34.47 ± 11.62 |
| Protein (g) | 153.81 ± 106.55 | 89.46 ± 44.81 |
| Protein (g/kg) | 2.03 ± 1.33 | 1.65 ± 0.77 |
| Fat (g) | 98.67 ± 62.22 | 65.49 ± 33.72 |
| Fat (g/kg) | 1.33 ± 0.92 | 1.26 ± 0.69 |
| Carbohydrate (g) | 325.11 ± 157.17 | 222.59 ± 97.63 |
| Carbohydrate (g/kg) | 4.38 ± 2.35 | 4.22 ± 1.83 |
| Calcium (mg) | 713.88 ± 670.77 | 460.58 ± 193.03 |
| Iron (mg) | 37.55 ± 191.20 | 11.47 ± 4.80 |
| Potassium (mg) | 2654.30 ± 1442.22 | 1791.91 ± 885.38 |
| Magnesium (mg) | 259.96 ± 164.65 | 187.19 ± 148.92 |
| Zinc (mg) | 15.48 ± 10.96 | 8.66 ± 5.41 |
| Phosphorus (mg) | 1376.11 ± 871.19 | 775.86 ± 301.32 |
| Niacin (mg) | 41.24 ± 56.42 | 19.59 ± 12.96 |
| Pyridoxine (mg) | 3.85 ± 19.88 | 1.54 ± 1.78 |
| Vitamin C (mg) | 304.08 ± 1689.31 | 168.37 ± 277.11 |

Data were obtained from the average of two 24-hour dietary recalls, when available. Values are expressed as mean ± SD.

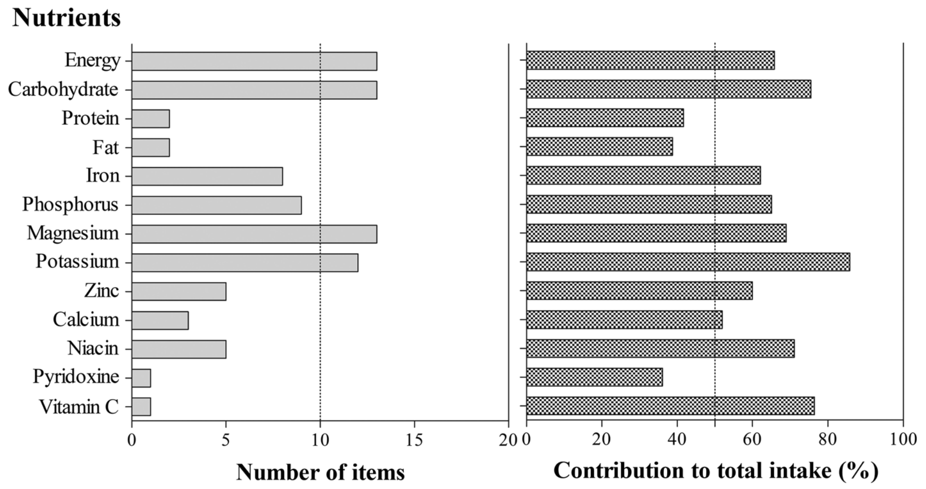


**Figure 1** Number of food items needed to explain 90% of the between-person variation and percentage contribution to total energy and nutrient intake of athletes.

**Table 2** Specific food contributions to the between-person (B-P) variation and total energy, carbohydrate, protein and fat intake of athletes

| | | *Total intake* | | | | *Total intake* | |
|---|---|---|---|---|---|---|---|
| *Food items (energy)* | *B-P variation Cumulative $R^2$* | *Percent [rank]* | *Cumulative percent* | *Food items (carbohydrate)* | *B-P variation Cumulative $R^2$* | *Percent [rank]* | *Cumulative percent* |
| Supplement | 0.36 | 7.13 [4] | 7.13 | Pizza | 0.28 | 4.99 [9] | 4.99 |
| Pizza | 0.52 | 4.30 [10] | 11.43 | Baked savoury snack | 0.39 | 5.10 [8] | 10.09 |
| Baked savoury snack | 0.59 | 5.15 [9] | 16.58 | Biscuits | 0.49 | 5.10 [7] | 15.19 |
| Biscuits | 0.65 | 3.85 [11] | 20.43 | Rice | 0.55 | 14.08 [1] | 29.27 |
| Ice cream | 0.70 | 1.79 [23] | 22.22 | Fruit | 0.62 | 11.97 [2] | 41.24 |
| Meat | 0.74 | 10.78 [1] | 33.00 | Soda | 0.67 | 6.70 [5] | 47.94 |
| Chicken | 0.77 | 7.65 [2] | 40.65 | Spaghetti | 0.73 | 5.15 [6] | 53.09 |
| Bread | 0.83 | 5.87 [5] | 46.52 | Bread | 0.77 | 9.69 [4] | 62.78 |
| Fish | 0.85 | 1.91 [21] | 48.43 | Ice cream | 0.81 | 1.89 [20] | 64.67 |
| Milk | 0.87 | 5.64 [6] | 54.07 | Milk | 0.84 | 3.91 [11] | 68.58 |
| Fruit | 0.88 | 5.64 [7] | 59.71 | Flour/Farofa[a] | 0.87 | 2.61 [15] | 71.19 |
| Soda | 0.89 | 3.03 [17] | 62.74 | Supplement | 0.89 | 2.78 [13] | 73.97 |
| Spaghetti | 0.91 | 3.05 [16] | 65.79 | Cassava | 0.90 | 1.52 [22] | 75.49 |
| *Food items (protein)* | *Cumulative $R^2$* | *Percent [rank]* | *Cumulative percent* | *Food items (fat)* | *Cumulative $R^2$* | *Percent [rank]* | *Cumulative percent* |
| Supplement | 0.89 | 20.40 [2] | 20.40 | Baked savoury snack | 0.60 | 23.60 [1] | 23.60 |
| Chicken | 0.94 | 21.26 [1] | 41.66 | Pizza | 0.94 | 15.14 [4] | 38.74 |

Rank: the order of contributors to total nutrient intake.
[a] Toasted cassava or maize flour mixture.

variability in vitamins intake were the major contributors to total vitamin intake. Chicken (27% to niacin), supplements (90% to pyridoxine), and juice (90% to vitamin C) were the main foods responsible for the vitamin intake variance. Conversely, food items selected to explain minerals intake variance were not the best-ranked foods contributing to total nutrient intake. Supplements (66% to calcium), pizza (44% to iron and 25% to potassium), rice (29% to magnesium), meat (54% to zinc) and chicken (27% to phosphorus) were the top foods selected through between-person variability. On the other hand, milk (calcium), meat (iron and zinc), fruit (potassium), bean (magnesium) and chicken (phosphorus) were the best-ranked food contributors to total mineral intake.

 

Table 3 lists foods and beverages included in the FFQ, as well as the serving size averages proposed to estimate food size intake. Distilled beverages, creatine (supplement) and sweet potato were included in the final list. As previously reported, the frequency of consumption can be indicated as daily, weekly or monthly. Portion sizes of usually eaten foods can be pointed out comparatively to the middle portion. The average serving sizes are presented in household measures and weight (g or mL) to allow food size comparison whether small, large or equal medium portion size. The food list, frequency of consumption and the portion size were included in the formatted version as shown in Appendix S1 (Supporting Information).

## Discussion

In the present study, we highlighted 31 food items (foods/food groups) accounting for up to 90% of the between-person variation and the total energy intake to compose the FFQ for athletes. Few food groups could explain the nutrient intake variability among Brazilians athletes. Overall, from 1 to 13 items were selected to distinguish between-person variance in energy and nutrient intake. Energy, carbohydrate and magnesium had the highest number of selected items in the regression models. In contrast, pyridoxine and vitamin C had the lowest number of selected food items. In this method, the amount and the combination of listed items are attributed to the nutrient content of the most consumed foods (food preference) within a population.[27,28] For instance, our findings show dietary supplements as the major item responsible for the variability in energy, protein, calcium and pyridoxine intake among athletes. Indeed, dietary supplements are a concentrated and sometimes isolated nutrient content source (e.g. protein or multivitamin supplements),[10] with notable relevance for the estimation of athletes' nutrient intake.

There was relatively low variability of food items reported in the 24HR and therefore few variables (113 food items) were included in the regression models. Consequently, a short food list was produced. In fact, it is hoped that few food items capture the intake variation in a population.[28] The FFQ proposed in the present study, consisted of 59 foods, because some foods commonly consumed in Brazil were included (e.g. leafy vegetables, distilled beverages). The other criterion used to include food items was the presence of substances of interest for sport performance (e.g. creatine). This final number of listed items was considered adequate for an FFQ (median of 79).[18] Low variability occurred partly due to athletes' preferences for ready-to-eat foods with high nutrient content. It does reflect a dietary intake characteristic, as well as the food group selected (fruits, bread slices and soda), related to the high frequency of snacking because of the schedules of training.

Multiple regression analysis is often used in epidemiological studies to determine food lists for FFQ.[22,29] This is an alternative for food selection regarding the total intake and frequency of consumption based on selection methods.[21] The coefficient of determination ($R^2$) represent the fraction of variation in the total nutrient intake predicted for food included in the model.[28] In this approach, a food item can be selected for more than one nutrient (e.g. pizza and soda contributed for both, energy and carbohydrate intake) by considering that the daily diet is often a combination of foods, and these foods represent the source of many nutrients at the same time.[28] Consequently, in the present FFQ, the items with low contribution to total intake were selected, for instance, ice cream to energy (1.79%, ranked as 23rd), and cassava to carbohydrate (1.52%, ranked as 22nd).

The portion sizes and frequency of consumption adopted in an FFQ should reflect the dietary intake characteristics of the target population.[18] In this regard, we opted to use the percentile distribution of the food measurements derived from the 24HR to determine the portion sizes. The average serving size was determined to be equivalent to the median (50th percentile) and converted in household measures. Distribution values of 50% are usually used to determine 'large' and 'small' portion sizes (p75 and p25, respectively).[18] Moreover, portion size can be expressed in different ways (e.g. half as much, the same, 1.5 times larger or twice the average serving size).[30] However, some considerations should be addressed regarding the determination of portion sizes. Firstly, the middle 50% of amplitude may not be reliable to estimate the low frequency intake items included, such as fried savoury snacks (reported 12 times). Secondly, the arbitrary determination can lead to portion size bias promoting a serious over or underestimation of food intake. Therefore, the variation coefficient of the interquartile range of chosen foods was used to establish the 'large' and 'small' portion size.

FFQ is a frequently used tool to assess the population-specific nutrient intake because of intrinsic components (list of foods, the frequency of consumption and portion sizes).[16,18] Numerous FFQs have been developed and validated for the Brazilian population;[31] however, none of them for athletes. To the best of our knowledge, only two FFQs have been validated for athletes.[23,25] The first study was conducted with rowing athletes from New Zealand, focusing on antioxidant intake[25] and the second was conducted with Japanese athletes (soccer, basketball, track and field, handball, tennis, judo and volleyball). This FFQ evaluated a broad range of nutrients, however the authors did not include dietary supplements in the food list[23] which may decrease its accuracy.[23] Herein we highlighted that supplements are an important contributor to the total nutrient intake variance among athletes.

Analysing a target population sample by using 24HR was a strength of this study. A group of 141 athletes answered the 24HR, of which 70.2% replied to both interviews. Using 2 days of 24HR has been suggested to capture some intra-individual variation in food and nutrient intakes.[32] This approach has been previously used with small samples and produced satisfactory results.[28] The possible limitations of this study include the lack of differentiation for some foods in the regression models (e.g. apple banana, Cavendish banana and silver banana became 'banana', etc.) and the variation in food

**Table 3** Food list and reference portion size of the FFQ for athletes

| Groups/foods and preparation | Average serving size: Portion size | Average serving size: Household measures | Groups/foods and preparation | Average serving size: Portion size | Average serving size: Household measures |
|---|---|---|---|---|---|
| *Cereals, tubers and legumes* | | | *Sugars and sweets* | | |
| Rice | 106 g | 1 straining spoon or 4 soup spoons | Sugar or chocolate drink powder | 15 g | 1 dessert spoon |
| Beans | 86 g | 1 ladle | Savoury biscuits | 50 g | 8–10 units |
| Potato | 100 g | 1/2 unit | Filled biscuit | 140 g | 1 packet |
| Breakfast cereal | 52 g | 4 soup spoons | Cake | 70 g | 2 slices |
| *Pasta, dough, pastries and savoury snacks* | | | Bread | 50 g | 1 unit |
| Spaghetti | 81 g | 1 straining spoon | *Assorted drinks* | | |
| Fried meat savoury snack | 100 g | 1 unit | Beer | 1.2 L | 2 bottles |
| Baked chicken savoury snack | 120 g | 1 slice or 1 unit | Distilled beverages | 150 mL | 3 servings |
| Potato or Italian Bread savoury snack | 90 g | 1 unit | Sodas | 350 mL | 1 can |
| Sandwich | 220 g | 1 unit | Teas and coffee | 75 mL | 1 cup |
| Snacks | 265 g | 1 unit | *Oils, fats and oilseeds* | | |
| *Meats and eggs* | | | Peanuts | 32 g | 1 serving spoon |
| Beef | 100 g | 1 large steak or 5 soup spoons | Brazil nuts | 15 g | 4 units |
| Chicken | 150 g | 2 filets or 2 thighs | Butter or margarine | 6 g | 1 tea spoon |
| Egg | 100 g | 2 eggs or 3 whites | Olive oil | 3 mL | 1 tea spoon |
| Fish | 120 g | 1 filet or 1 small paste | | | |
| *Milk and dairy products* | | | *Miscellaneous* | | |
| Yoghurt | 180 g | 1 cream-cheese cup | Jelly | 125 g | 1 bowl |
| Milk | 208 mL | 1 cream-cheese cup | Popcorn | 100 g | 1 tub |
| Mozzarella cheese | 13 g | 1 slice | Pizza | 260 g | 2 slices |
| Cheeses | 50 g | 1 slice | Mayonnaise salad | 108 g | 4 soup spoons |
| *Vegetables* | | | Flour/Farofa[a] | 70 g | 3.5 soup spoons |
| Leafy vegetables | 16 g | 2 leaves or 1 serving spoon | Ice cream | 170 g | 2 balls |
| Tomato | 57 g | 1/2 unit | Cassava | 64 g | 2 soup spoons or 1 slice |
| Carrot | 27 g | 1 soup spoon | *Supplements* | | |
| Cabbage | 36 g | 1 serving spoon | Meal replacements | 120 g | 2 scoops |
| Gherkin, okra and eggplant | 80 g | 3 soup spoons | Proteins | 44 g | 1.5 scoops or 4 soup spoons |
| Pears or onions | 22 g | 1 soup spoon | Amino acids | 5 g | 1 scoop or 5 capsules |
| *Fruits and juices* | | | Carbohydrates | 36 g | 1 scoop or 3.5 soup spoons |
| Orange | 250 g | 1 unit | Sport drinks | 473 mL | 1 bottle |
| Pineapple | 160 g | 1 slice | Lipids | 25 g | 3 soft gels |
| Grape | 250 g | 1/2 bunch | Vitamins | 1.5 g | 1 capsule |
| Banana | 86 g | 2 units (apple banana) or 1 unit (others) | Creatine | 9 g | 3 scoops |
| Apple | 152 g | 1 unit | | | |
| Juice | 250 mL | 1 cream-cheese cup or 1 small carton | | | |

[a] Toasted cassava or maize flour mixture.

 

intake non-corrected for gender, which may affect the validity of an FFQ.[21] Differentiating food items would increase the number of foods in the model and possibly the number of selected items. Moreover, it is not known whether a large food list would have higher accuracy for nutrient intake estimates compared to the actual list reported in the athletes' population. Instead, a short list is desirable because of its higher acceptance between respondents.[18]

In this study, we described the development of an FFQ for Brazilian athletes through 24HR analysis. This FFQ can be a useful tool to assess nutrient intake and monitor athletes' nutritional practices, as well as their implications to health and physical performance outcomes. The measurement of the FFQ reproducibility and validity will be undertaken in future research.

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## Conflict of interest

The authors have no conflicts of interest to declare.

## Authorship

The study was designed by AMG, CFCR and EVJ. Data were collected by AMG and CFCR, and analysed by AMG, CFCR and EVJ. Manuscript preparation was undertaken by AMG, CFCR, RR and EVJ. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere.

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## Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

**Appendix S1** Food Frequency Questionnaire for athletes.

 

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**ORIGINAL RESEARCH**

# Low-carbohydrate, healthy-fat eating: A cost comparison with national dietary guidelines

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**Abstract**

**Aim:** A low-carbohydrate, healthy-fat (LCHF) dietary approach has been demonstrated as an effective strategy for improving metabolic health; however, it is often criticised for being more expensive than following a dietary approach guided by the national, Ministry of Health nutrition guidelines. This study compared the cost of these two nutritionally replete dietary approaches for one day for a family of four.

**Methods:** In this descriptive case study, one-day meal plans were designed for a hypothetical family of four representing the average New Zealand (NZ) male and female weight-stable adult and two adolescent children. National documented heights, a healthy body mass index range (18.5–25.0 kg/m$^2$), and a 1.7-activity factor was used to estimate total energy requirements using the Schofield equation. Total daily costs were compared based on food prices from a popular Auckland supermarket. Meal plans were analysed for their nutritional adequacy using FoodWorks 8 dietary analysis software against national Australian and NZ nutrient reference value thresholds.

**Results:** The total daily costs were $43.42 (national guidelines) and $51.67 (LCHF) representing an $8.25 difference, or $2.06 per person, with the LCHF meal plan being the costlier option.

**Conclusions:** We consider this increased cost for an LCHF approach to be negligible. In practice, less costly food items with similar nutrition qualities can be substituted to reduce costs further should this be a goal. The LCHF approach should therefore not be disregarded as a viable dietary approach for improving health outcomes, based on its perceived expense.

**Key words:** cost, LCHF, low-carbohydrate, healthy-fat, national nutrition guidelines.

## Introduction

When it comes to the promotion of optimal health, prevention and management of chronic disease, we base our dietary guidance on the national Ministry of Health (MOH) food and nutrition guidelines.[1] More recently, an alternate option for dietary guidance has emerged, that is a wholefood-based approach, characterised by a reduced carbohydrate, higher natural fat intake, also termed low-carbohydrate, healthy-fat (LCHF). This approach is becoming increasingly employed in clinical practice as an equally suitable, and in some cases more effective management strategy for a variety of chronic conditions, in particular, diabetes.[2–4] It has also been shown to be effective both in the short and long term for its beneficial outcomes on metabolic health.[5–9] Eating according to the LCHF approach is often criticised as being more expensive than eating following standard dietary guidelines, yet there is no literature to draw on to confirm or refute this.

The cost of food plays a central role in determining food choices for New Zealanders. In a national 2010 survey, cost was highlighted as the main influencer of food and drink purchases by 75% of the population surveyed (n = 1740), regardless of ethnicity and neighbourhood deprivation.[10] While the bulk of the literature alludes to a greater cost of healthy foods in general, compared with unhealthy foods, this might depend on the food classification systems used in studies. Cross-sectional observational studies in Australia and Europe have shown foods considered to be healthier, defined by a higher nutrient density, lower energy density, or through meeting government guidelines, tend to cost more.[11–14] A systematic review and meta-analysis of

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10 countries, including New Zealand (NZ), found healthier diets, on average tend to cost US$1.48 more per day than unhealthy diets.[15] In contrast, an NZ study investigating 10-year trends in food costs defined healthy food by the degree of food processing, and found processed foods to be NZ$0.51 more expensive than minimally processed foods; however, the price difference between ultra-processed and minimally processed foods was negligible.[16]

When it comes to comparing healthy eating approaches with each other rather than isolated foods or ultra-processed food-based diets, few studies have examined such cost variances. Wilson *et al.*[17] compared the cost differences between a nutritionally adequate, typical NZ male diet (excluding alcohol), and an Asian and a Mediterranean-style dietary approach and found the latter two to be significantly less expensive than the former. A further cost comparison between Mediterranean, Paleo and Intermittent Fasting (IF) diets found no significant differences in costs between diets.[18]

Ultimately, where eating well is a key factor in promoting good health and the reduced risk of lifestyle-related disease, a healthy diet not only needs to be nutritionally replete, and sustainable to follow long term, but also financially viable. There is no documented literature that we are aware of on the costs associated with the LCHF approach. With the growing widespread use and interest in this dietary approach, we decided that this was an important aspect to explore. The aim of this study was to compare the costs of a nutritionally replete one-day meal plan for a family of four for two dietary scenarios: LCHF and MOH national nutrition guidelines.

## Methods

This descriptive study was conducted using a hypothetical case study scenario defined to represent a family of four living in Auckland, NZ. The family selected was designed to approximate the average Auckland household size according to the 2013 census data.[19] The family included two weight-stable adults (male and female) and two adolescent children (male and female) with no medically diagnosed health conditions. Participant characteristics were defined using anthropometric parameters to represent a healthy body mass index (BMI) (18.5–25.0 kg/m$^2$)[1] based on the estimated mean height of New Zealanders from each age and gender demographic.[20] Individual nutrition requirements of the participants were determined using the Schofield equation for predicting basal metabolic rate[21] and adjusted for gender, anthropometric information and a light-to-moderately active physical activity level (PAL, 1.7).[22] Table 1 presents the demographic data used for the case studies.

Dietary comparison for the two approaches was conducted using an energy-matched estimated one-day's intake for each participant. Meal plans were analysed using the nutrient analysis programme FoodWorks 8 Professional Edition (Xyris Software, Australia). Meal plans representing the MOH nutrition guidelines were developed to be consistent with food group and serving recommendations for NZ adults and adolescents according to the Eating and Activity Guidelines for NZ Adults[1] and Food and Nutrition Guidelines for Healthy Children and Young People.[23] Macronutrient intake was aligned with the acceptable macronutrient distribution ranges (AMDR) to reduce risk of chronic disease (45–65% energy from carbohydrate, 15–25% energy from protein and 20–35% energy from fat with less than 10% energy from saturated fat).[22] For the LCHF meal plans, macronutrient intake was established to align with the AMDR for protein (15–25% of energy). Carbohydrate intake was selected to provide 10–20% energy (60–120 g), with the remaining energy derived from wholefood sourced fat (55–70% of energy). There was no defined restriction for saturated fat intake. All micronutrients for the two diets were assessed on FoodWorks against national Australian and NZ nutrient reference value (NRV) thresholds.[22]

Types of food consumed were standardised across both diets to include traditional meals, to exemplify common dietary choices and to match local food availability of the wider NZ population. Food cost data were collected from shelf prices examined from a reputably inexpensive local supermarket, Pak 'n Save in Albany, Auckland, NZ, in October 2016.[24] Food items selected for inclusion were based on the following criteria: (i) foods that we considered to be, generally, popular and acceptable, rather than any specialty or unusual food that would demand an acquired taste; (ii) lowest cost brands within a food category, apart from eggs, where free range was selected over conventional eggs, for ethical reasons; and (iii) fresh vegetables were chosen in preference over frozen except for green beans, brussel sprouts and spinach. Costs for each one-day sample meal plan for all participants were calculated by price per weight of food product consumed. Where price data were acquired for uncooked weight of foods (such as meat and rice), the weight of foods was adjusted for the cooked version.

## Results

Tables 2 and 3 present the sample meal plans of the male and female case studies for both dietary approaches, and their macronutrient and energy composition, respectively.

**Table 1** Family demographics

| *Family member* | *Age (years)* | *Height (cm)* | *Weight (kg)* | *BMI (kg/m$^2$)* | *PAL* | *EER (kJ)* | *EER (Cal)* |
|---|---|---|---|---|---|---|---|
| Adult male | 45 | 176.0 | 72 | 23 | 1.7 | 12 085 | 2888 |
| Adult female | 45 | 162.9 | 60 | 23 | 1.7 | 9483 | 2266 |
| Adolescent male | 14 | 169.8 | 65 | 23 | 1.7 | 12 964 | 3098 |
| Adolescent female | 12 | 156.1 | 55 | 23 | 1.7 | 10 268 | 2454 |

BMI, body mass index; EER, estimated energy requirement; PAL, physical activity level.

**Table 2** MOH nutrition guidelines and LCHF meal plans for each family member

| MOH nutrition guidelines meal plans | | | | LCHF meal plans | | | |
|---|---|---|---|---|---|---|---|
| *Adult male* | *Adolescent male* | *Adult female* | *Adolescent female* | *Adult male* | *Adolescent male* | *Adult female* | *Adolescent female* |
| Breakfast | | | | Breakfast | | | |
| *Toast with tuna/avocado*: Mixed grain bread, three slices; margarine, 2 tsp; tuna, 90 g; Mixed grain bread, three slices; avocado, ½; trim milk, 1 c | *Fruity oats*: Oats, raw, 1 ¾ c; trim milk, 1 c; banana, 1 medium; frozen blueberries, ½ c | *Fruity oats*: Oats, raw, ⅔ c; trim milk, 150 mL; banana, ½ medium; sunflower seeds, 15 g; iodised salt, ¼ tsp | *Fruity oats and smoothie*: Oats, rolled, raw, ½ c; reduced fat fruit yoghurt, ½ c; frozen blueberries, ½ c; *Smoothie*: Trim milk, 1 c; reduced fat fruit yoghurt, ½ c; banana, 1 medium; frozen blueberries, oats, rolled, raw, ¼ c | *Scrambled eggs with vegetables*: Egg, 3 size 6; mushroom, 15 g; tomato, 100 g; onion, ¼ c; butter, 1.5 tbsp; iodised salt, ⅛ tsp | *Scrambled eggs with vegetables*: Egg, 4 size 6; mushroom, 17 g; tomato, 120 g; onion, ¼ c; butter, 1.5 tbsp; iodised salt, ⅛ tsp | *Scrambled eggs with vegetables*: Eggs, 3 size 6; mushroom, 15 g; tomato, 75 g; onion, ¼ c; butter, 3 tsp; cheese, cheddar, 40 g; iodised salt, ⅛ tsp | *Fruit smoothie*: Whole milk, 1 c; yoghurt, full fat Greek-style, 1 c; frozen blueberries, ½ c; banana, ½ medium; sunflower seeds, 2 tbsp |
| Lunch | | | | Lunch | | | |
| *Two Ham and salad sandwiches:* Mixed grain bread, four slices; ham, 95 g; lettuce, ½ c; tomato, 30 g; carrot, ⅓ c; mayonnaise, reduced fat, 3 tsp; Muesli bar, multigrain; Apple, 1 fruit | *Two Ham and salad sandwiches:* mixed grain bread, four toast slices; margarine, 3 tsp; spinach, raw, ½ c; cheese, Edam, 30 g; ham, 95 g; Muesli bar, multigrain; Banana, 1 medium | *Beef and rice salad:* Mesclun salad, 1 c; brown rice, 1.5 c; lean beef, 80 g; reduced fat vinaigrette dressing, 1 tbsp; Multigrain crackers, 6 biscuits; cheese, Edam, 40 g | *Beef and cheese pitas:* Wholemeal pita, 2; lean beef, 60 g; mesclun salad, ½ c; carrot, raw, ½ c; mayonnaise, reduced fat, 3 tsp Banana, 1 medium Muesli bar, multigrain, 50 g | *Chicken and vegetable salad*: Chicken thigh, roasted, 130 g; sweet potato, 110 g roasted in 1 ½ tbsp olive oil; ⅛ tsp iodised salt; pumpkin seeds, 2 tbsp; sunflower seeds, 1 tbsp; spinach leaves, 1 c; capsicum, 83 g; cheese, cheddar, 80 g | *Chicken and vegetable salad:* Chicken thigh, roasted, 100 g; sweet potato, 145 g roasted in 2 tbsp olive oil; ⅛ tsp iodised salt; capsicum, 166 g; carrot, 110 g; avocado, ½; cheese, cheddar, 50 g | *Roast beef salad*: Beef brisket, braised, 80 g; mesclun salad, 1 c; tomato, 120 g; cucumber, ½ c; carrot, ½ c; olive oil, 1 tbsp; pumpkin seeds, 2 tbsp | *Roast beef salad*: Beef brisket, braised, 80 g; mesclun salad, 1 c; tomato, 120 g; cucumber, 1 c; carrot, 1 c; olive oil, 1.5 tbsp; pumpkin seeds, 2 tbsp; cheese, cheddar, 50 g |

**Table 2** Continued

| MOH nutrition guidelines meal plans | | | | LCHF meal plans | | | |
|---|---|---|---|---|---|---|---|
| *Adult male* | *Adolescent male* | *Adult female* | *Adolescent female* | *Adult male* | *Adolescent male* | *Adult female* | *Adolescent female* |
| Dinner | | | | Dinner | | | |
| *Roast chicken and veg*: Chicken breast, 130 g; broccoli, 1 c cooked; potato, 2 c cooked; spinach, 1 c raw; olive oil, 1 tbsp | *Roast chicken and veg*: Chicken breast, 130 g; potato, 2 c cooked; broccoli, 1 c cooked; pumpkin, 1 c cooked; spinach 1 cup, raw; olive oil, 1 tbsp | *Roast chicken dinner*: Chicken breast, 80 g; pumpkin baked, ⅔ c; spinach steamed, ½ c; broccoli cooked, 1½ c; potato, 1 c; olive oil, 3 tsp; iodised salt, ¼ tsp | *Roast chicken dinner*: Chicken breast, 90 g; potato, cooked 1 c; broccoli, cooked, 1 c; pumpkin, baked, ½ c; spinach, steamed, ½ c; olive oil, 2 tsp; iodised salt, ¼ tsp | *Roast chicken and veg*: Chicken thigh, 130 g; pumpkin, 1 c cooked; broccoli, 1 c cooked; spinach, steamed, ½ c; olive oil, 2 tbsp | *Roast chicken and veg*: Chicken thigh, 130 g; pumpkin, 1 c cooked; broccoli, 1 c cooked; spinach, steamed, ½ c; olive oil, 2 tbsp | *Roast chicken dinner*: Chicken leg, 80 g; broccoli, cooked, 1 ½ c; pumpkin, baked, 1 c; spinach, steamed, ½ c; olive oil, 3 tsp; iodised salt, ¼ tsp | *Roast Chicken dinner*: Chicken leg, 90 g; broccoli, 1 c cooked; pumpkin, baked, 1 c; spinach, steamed, ½ c; olive oil, 2 tsp.; iodised salt, ¼ tsp |
| Snacks | | | | Snacks | | | |
| Yoghurt, plain, low fat, ½ cup; banana, 1 medium chopped; Multigrain crackers, 10 biscuits; cream cheese, reduced fat, 80 g Kiwifruit, 1 fruit | Smoothie: trim milk, 250 mL; banana, 1 medium Mixed grain bread, two toast slices; jam, 2 tsp (on one slice); natural peanut butter, 2 tsp (on one slice) Fruit yoghurt, ½ c; almonds, 7 g; raisins, 13 g | Smoothie: trim milk, 200 mL; kiwifruit, 2 fruits; oats, raw ⅓ c Yoghurt, plain, low fat, 1 c; apple, 1 fruit, chopped | Yoghurt, fruit, low fat, ½ c; apple, 1 chopped; almonds, 12 g Mixed grain bread, two slices; margarine, 2 tsp; marmite spread, 1 tsp; cheese, Edam 40 g | Apple, 2 fruits, chopped, dipped in natural peanut butter, 3 tbsp Yoghurt, Greek-style, full fat, 1 c; frozen blueberries, 1 c Brazil nuts, 38 g | Yoghurt, Greek-style, full-fat, 1 c; frozen raspberries, ½ c; natural peanut butter, 3 tbsp Almonds, 24 g; sunflower seeds, 30 g Banana, 1 fruit | Smoothie: whole milk, 250 mL; kiwifruit, 1 fruit Yoghurt, full fat Greek-style, 1 c; sunflower seeds, 30 g; almonds, 18 g | Cucumber, Lebanese, 1, with spread natural peanut butter, salted, 3 tsp Almonds, 18 g; cashew nuts, 50 g Apple, 1 fruit |

LCHF, low-carbohydrate, healthy-fat; MOH, Ministry of Health.

**Table 3** Total energy and macronutrient distribution for the MOH nutrition guidelines, and LCHF meal plans

| | *MOH nutrition guidelines* | | | | *LCHF* | | | |
|---|---|---|---|---|---|---|---|---|
| *Nutrient breakdown* | *Adult male* | *Adult female* | *Adolescent male* | *Adolescent female* | *Adult male* | *Adult female* | *Adolescent male* | *Adolescent female* |
| Energy | | | | | | | | |
| kJ | 12 742.2 | 9494.0 | 13 035.2 | 10 679.9 | 12 773.1 | 9442.2 | 13 045.2 | 10 310.3 |
| Cal | 3045.5 | 2269.1 | 3115.5 | 2552.6 | 3052.8 | 2256.7 | 3117.9 | 2464.1 |
| Carbohydrate | | | | | | | | |
| g | 352.9 | 277.5 | 394.2 | 325.1 | 102.3 | 63.1 | 103.9 | 114.3 |
| % | 46.2 | 48.8 | 50.3 | 50.6 | 13.0 | 10.8 | 12.9 | 18.0 |
| Protein | | | | | | | | |
| g | 158.6 | 129.3 | 163.0 | 139.6 | 150.6 | 131.5 | 142.6 | 122.8 |
| % | 21.2 | 23.2 | 21.3 | 22.2 | 20.0 | 23.7 | 18.6 | 20.3 |
| Fat | | | | | | | | |
| g | 96.1 | 60.1 | 82.1 | 59.6 | 220.5 | 159.3 | 230.7 | 161.8 |
| % | 27.9 | 23.4 | 23.3 | 21.7 | 63.9 | 62.4 | 65.4 | 58.1 |
| Saturated Fat | | | | | | | | |
| g | 23.9 | 18.9 | 21.3 | 18.7 | 70.1 | 62.2 | 62.4 | 56.2 |
| % | 6.9 | 7.4 | 6.0 | 6.3 | 20.3 | 24.0 | 17.7 | 20.2 |

LCHF, low-carbohydrate, healthy-fat; MOH, Ministry of Health.

Cost comparisons for the one-day meal plans are presented in Figure 1. The total combined costs for the diets of all four family members were $43.42 for the MOH nutrition guidelines (average cost per person: $10.86) and $51.67 for LCHF (average cost per person: $12.92). The difference between the two dietary approaches was $8.25, with the LCHF diet being the more expensive option. Taken as an average cost per family member, this amounted to $2.06.

All versions of the meal plans were replete for all the micronutrients as compared against their recommended dietary intake (RDI) or specific dietary target (SDT) thresholds apart from the mineral selenium, which reached 95% of the RDI for the adolescent male in the MOH guidelines plan (see Appendix I). The maximum SDT for sodium for the adult male and female, and the adolescent female for the MOH guidelines meal plans was exceeded.

## Discussion

This is the first study to compare the food costs of a nutritionally replete meal plan for a wholefood-based LCHF approach with that of an MOH national nutrition guidelines-based approach. The key finding was that in this instance, the LCHF was the costlier set of meal plans of the two amounting to an additional $8.25 per day for a family of four, or an average of $2.06 per person. Extrapolated to one week totals $361.69 and $303.94 for the LCHF and MOH plans, respectively; however, these figures should be interpreted with caution. Purchased meals, snacks and beverages consumed outside of the home environment, as well as different meal varieties could either overestimate or underestimate costs over the week for both dietary conditions.

Our findings differed from those reported by Wilson *et al.*[17] This research group reported an Asian and Mediterranean meal plan at NZ$4.95 per day and NZ$5.64 per day, respectively; with both meal plans less costly than that of a typical NZ male (as guided by national survey data from the National Nutrition Adult Nutrition Survey),[25] costed at $17.29 per day. In this NZ study, nutrient thresholds were assessed against estimated average requirements (EARs), that is the intake required to meet the needs of half of the population; hence it represented a 1000kJ lower dietary energy requirement than that used in our study. Researchers also used a selection of micronutrients for comparison rather than the full spectrum as we did (i.e. vitamin B1—thiamine—to represent all the B vitamins, upper limits for sodium and vitamin A) and undertook analyses for males only.

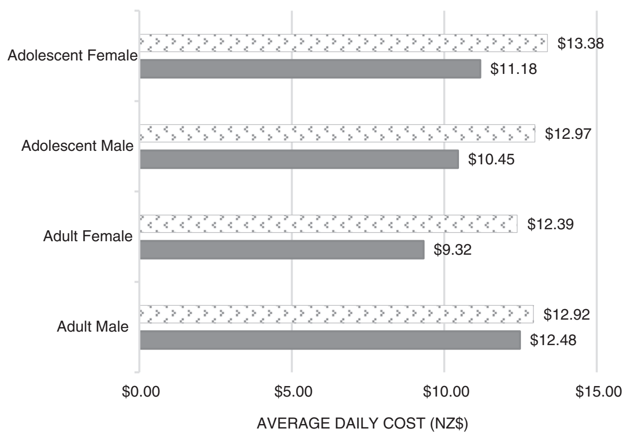


**Figure 1** Cost comparison analyses for one-day sample meal plans (LCHF, low-carbohydrate, healthy-fat; MOH, Ministry of Health; NZ, New Zealand). (▫) LCHF; (■) MOH national guidelines.

In contrast, our cost findings for LCHF ($12.92) were similar to those reported by Park who conducted a dietary adherence study using weighed dietary records with actual participants. Park reported no significant difference between average daily costs of three diets: Mediterranean diet: $11.27; Paleo diet: $12.85 and IF on a non-fasting day, where the participants could eat whatever they wished: $12.06. One would assume a cost similarity between Paleo and LCHF dietary approaches as they share a common dietary philosophy, that is a focus on the consumption of whole unprocessed foods. However, this argument does not hold true considering the similar costs seen for IF on a non-fasting day.[17,18]

Despite the costlier outcome for LCHF meal plans in this study, there are several important points that warrant consideration when it comes to estimating the cost of different diets, especially LCHF. The first of these is that whichever style of eating you adopt, there are mechanisms for reducing the cost of foods, even when foods are matched for nutrient composition. For example, extra virgin olive oil, fresh salmon, macadamia nuts and broccolini, foods often used with LCHF but not limited to it, would be considered expensive options, yet their less costly, approximate nutrient-equivalents such as standard olive oil, sardines, linseed and frozen spinach are substantially cheaper. Ethical perspectives could also alter food costs. In this exercise, we used free-range eggs (eggs were only used in the LCHF plan); however, using standard caged-eggs would have been a less costly option, bringing the daily cost of the one-day LCHF plan down by $2.00, and thereby, reducing the daily difference between the plans from $8.25 to $6.25.

In the context of the LCHF approach, there are some foods known to be less expensive than their equivalent following an MOH nutrition guidelines approach. For example, standard mince, rump steak and chicken thighs or wings with skin all have a higher natural fat content and are less costly than leaner cuts of meat such as premium mince, eye fillet steak and skinless chicken breasts. This point was reflected in our work as the ‘Meats’ food group comparative costs for the family were $16.41 for the MOH approach, and $12.67 for the LCHF approach. On the other hand, there are some foods known to be more expensive compared with their non-LCHF counterparts, the notable one being almond flour (almond meal) *versus* standard white flour, an ingredient frequently used as a lower carbohydrate alternative for baking. In this case, there is also a vast difference between the nutritional content of these two flours, with almond flour being nutritionally superior.[26] In these meal plans, we did not include any homemade baking products, and have therefore not captured this as a significant cost difference.

When other food groups were compared, there were similarities noted in the total amounts as follows: ‘fruit’: $5.25 *versus* $5.04; ‘dairy’: $5.27 *versus* $6.35; ‘fats, oils, spreads’ $1.34 *versus* $2.26; for the MOH plans and the LCHF plans, respectively. The main cost discrepancies were noted in the remaining food groups, ‘nuts and seeds’, ‘grains’ and ‘vegetables’, and were largely due to the different proportions of these foods used in the two sets of meal plans. The cost differences were as follows: ‘nuts and seeds’: 87c *versus* $8.64; ‘grains’: $6.49 *versus* $0 and ‘vegetables’: $7.80 *versus* $16.58, for the MOH *versus* LCHF plans, respectively. The total cost difference between these food groupings was $10.06, with LCHF being costlier than MOH. The greater use of nuts, seeds and vegetables in the LCHF plans was a necessary trade-off from the absence of carbohydrate-heavy grains, to ensure the macronutrient, micronutrient and fibre thresholds were met. The grains selected for the MOH plans were all wholegrain, rather than their known less costly refined counterparts. Despite this, grain-based foods still tend to be a less costly option than nuts, seeds and vegetables based on the proportions used to satisfy certain nutrient requirements, in particular fibre and certain B vitamins. Modelled as family eating behaviours, our analysis included family-style meals that allowed for strategic shopping, meal planning, purchasing in bulk and avoiding waste; known strategies to make weekly shopping affordable.[27] In our study, foods were selected for both nutrition approaches equally with general affordability in mind. We selected low cost brands, seasonal fresh produce and frozen alternatives to more expensive fresh varieties. Whether either style of eating is considered affordable for low-income families is important, but beyond the scope of this work.

The second important point to consider is the value people place on the foods they purchase in relation to their overall health. While LCHF may be a costlier dietary approach in this instance, for some the additional $2.06 per person per day (which accumulates, hypothetically, to $57.69 per week for the whole family) may be viewed as a worthy investment for the perceived health benefits and overall reduction in health-related costs it may imply. Food purchasing is a complex issue; one only needs to consider the extent of discretionary food and beverage spending (i.e. weekly coffee consumption in 2015 ranged from $12.09 to $14.02 per person in different regions of NZ[28]) to realise that food purchasing behaviours can be influenced by both affordability (or lack of) and priorities, which differs markedly between individuals and families.

We were able to achieve nutrient-replete diet plans for both dietary approaches (apart from the mineral selenium for the adolescent boy in the MOH guidelines plan—which can be remedied by the addition of one Brazil nut). This finding corroborates with previous LCHF plan nutrient analyses.[29] MOH national nutrition guidelines promote a carbohydrate-dominant, lower fat dietary approach, with adults and adolescents advised to eat a minimum of six servings of grain-based foods daily as a main source of dietary energy (in the form of carbohydrate) as well as fibre, vitamins (B group vitamins excluding B12 and E) and minerals (magnesium, calcium, iron, zinc and selenium).[1] Alternate low carbohydrate choices are believed to raise the cost of obtaining these essential nutrients either resulting in nutritional inadequacy or additional food cost.[30] This was shown to some extent in our work, despite previous nutrient-driven cost analyses showing LCHF-appropriate wholefoods such as eggs, meat, dairy, dry beans, nuts, seeds, vegetables and fruit, among the lowest cost food sources of protein, fibre, vitamin A, vitamin C, calcium, iron and potassium.[31]

Our study had several limitations; however, none of them single out or bias any one style of eating but rather apply to both LCHF and MOH nutrition guidelines equally. The first is that only a one-day sample meal plan was examined and therefore does not consider the variety that would usually be seen over the course of a week. As a result, the application of these findings to larger and more diverse groups over a longer duration is limited.

Another limitation was that food costs were determined from off-shelf price information from an Auckland supermarket over a one-week period. This did not account for usual budgeting strategies that involve taking advantage of food specials one might see at a different supermarket. Neither did it include the purchase of foods from vegetable shops, markets and the butcher, where often foods can be obtained more inexpensively, or foods from vegetable or herb gardens. However, this is not necessarily problematic, in that the aim of this study was not to undertake an exercise in cost-effectiveness or affordability of food in general, but rather to compare the costs of two eating approaches. These limitations can be applied equally to both nutrition approaches and does not bias seasonal price or food choice variation.

The fact that these were theoretical case studies was a limitation as food preference was unable to be considered in food selection. Furthermore, there was potential for researcher bias in determining menu items and 'typical' food choices for the theorised participants.

A strength of the study is that an accurate, professional and local food composition database for dietary analysis was used. A further strength was the exclusion of specialty, fortified and unpopular foods in food selection to avoid bias towards nutrient density in any one dietary approach.

In conclusion, this study demonstrated that a nutrient-replete LCHF meal plan was costlier in this instance than an MOH nutrition guidelines plan for a family of four. Whether \$2.06 per person per day is considered a minor or a major difference in costs is subjective. Either way, we do not believe this constitutes a meaningful enough difference to warrant disregarding LCHF as a viable dietary approach for improving health outcomes, based on its perceived expense.

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## Conflict of interest

Dr CZ has co-authored four books on the topic of the LCHF dietary approach. All other authors declare no conflict of interest.

## Authorship

CZ and GH contributed to the study idea and design. CM undertook the data collection. CM, SN, KD and CZ contributed to the data analysis and interpretation. All authors contributed to the development of the manuscript. All authors approved the final manuscript and declare that the content has not been published elsewhere.

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# Appendix I

**Table A1** Micronutrient analysis for MOH nutrition guideline and LCHF diet plans for each family member

| | *MOH nutrition guidelines* | | | | | | | | *LCHF* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Micronutrients* | *Adult male* | *% RDI (unless otherwise specified)* | *Adult female* | *% RDI (unless otherwise specified)* | *Adolescent male* | *% RDI (unless otherwise specified)* | *Adolescent female* | *% RDI (unless otherwise specified)* | *Adult male* | *% RDI (unless otherwise specified)* | *Adult female* | *% RDI (unless otherwise specified)* | *Adolescent male* | *% RDI (unless otherwise specified)* | *Adolescent female* | *% RDI (unless otherwise specified)* |
| Thiamin (mg) | 3.3 | 274 | 2.4 | 220 | 2.5 | 207 | 2.7 | 305 | 1.4 | 114 | 1.4 | 131 | 1.5 | 129 | 1.4 | 160 |
| Riboflavin (mg) | 5.2 | 402 | 3.3 | 296 | 3.7 | 282 | 3.9 | 434 | 3.4 | 262 | 3.7 | 338 | 3.7 | 286 | 3.1 | 355 |
| Niacin (mg) | 48.1 | NA | 21.1 | NA | 25.9 | NA | 22.0 | NA | 23.2 | NA | 10.4 | NA | 29.7 | NA | 13.1 | NA |
| Niacin equivalents (mg) | 81.3 | 508 | 48.0 | 343 | 59.0 | 369 | 46.6 | 389 | 59.5 | 372 | 40.8 | 291 | 65 | 406 | 40 | 333 |
| Vitamin C (mg) | 218.6 | 486 | 443.6 | 986 | 191.8 | 480 | 165.3 | 413 | 307.7 | 684 | 278.7 | 619 | 438.8 | 1097 | 185 | 462 |
| Vitamin B6 (mg) | 7.3 | 563 | 3.6 | 280 | 4.3 | 333 | 3.6 | 360 | 3.0 | 232 | 2.24 | 172 | 4.6 | 354 | 2.4 | 237 |
| Vitamin B12 (μg) | 8.5 | 354 | 5.9 | 246 | 6.2 | 257 | 5.4 | 299 | 7.7 | 320 | 6.8 | 285 | 7.3 | 302 | 4.7 | 259 |
| Folate (dietary folate equivalents, μg) | 1373.9 | 342 | 518.1 | 130 | 473.5 | 118 | 796.6 | 266 | 737.3 | 184 | 6.37 | 159 | 692.4 | 173 | 467.2 | 156 |
| Total vitamin A equivalents (μg) | 963.2 | 107 | 1760 | 252 | 1994.7 | 222 | 2048.7 | 341 | 3881.7 | 431 | 3803.4 | 543 | 4300.1 | 478 | 4225.2 | 704 |
| Magnesium (mg) | 552.2 | 131 | 593.9 | 186 | 766.6 | 187 | 592.4 | 247 | 630.7 | 150 | 563 | 176 | 541.1 | 132 | 664.3 | 277 |
| Calcium (mg) | 1236.4 | 124 | 1723.5 | 172 | 1913.5 | 147 | 1899.7 | 146 | 160.4 | 160 | 1630.8 | 163 | 1371.8 | 106 | 1672.1 | 129 |
| Potassium (mg) | 6399.7 | 136[a] | 5389.3 | 115[a] | 7254.0 | 154[a] | 5426.0 | 115[a] | 5199.8 | 111[a] | 4494.4 | 96[a] | 5880.7 | 125[a] | 4930.2 | 105[a] |
| Phosphorus (mg) | 2571.7 | 257 | 2507.2 | 251 | 2882.6 | 231 | 2414.5 | 193 | 2573.6 | 257 | 2375.4 | 238 | 2407.3 | 193 | 2326.7 | 186 |
| Iron (mg) | 25.6 | 319 | 18.4 | 102 | 26.1 | 237 | 19.0 | 237 | 18.8 | 235 | 18.7 | 104 | 16.3 | 149 | 17.7 | 221 |
| Zinc (mg) | 16.4 | 117 | 13.7 | 171 | 15.3 | 117 | 15.5 | 258 | 20.1 | 144 | 18.5 | 231 | 19.3 | 148 | 19.5 | 326 |
| Selenium (μg) | 125.2 | 179 | 60.5 | 101 | 66.8 | 95 | 78.7 | 157 | 572.5 | 818 | 95.1 | 159 | 108.6 | 155 | 62.9 | 126 |
| Iodine (μg) | 151.8 | 101 | 195.5 | 130 | 156.2 | 104 | 121.4 | 101 | 194.7 | 130 | 183.2 | 122 | 208.2 | 139 | 125.3 | 104 |
| Sodium (mg) | 3981.6 | 199[b] | 2211.5 | 111[b] | 1761.8 | 88[b] | 2370.6 | 119[b] | 1935.8 | 97[b] | 1520.0 | 76[b] | 1707.3 | 85[b] | 1575.4 | 79[b] |
| Fibre (g) | 61 | 161[a] | 45 | 159[a] | 66 | 173[a] | 58 | 208[a] | 39 | 103[a] | 30 | 107[a] | 39 | 103[a] | 36 | 130[a] |

[a] Potassium and fibre are presented as a percentage of the minimum SDT.
[b] Sodium is presented as a percentage of the maximum SDT.
NA, not applicable; LCHF, low-carbohydrate, healthy-fat; MOH, Ministry of Health, RDI, recommended dietary intake; SDT, suggested dietary target.

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