Rev Med Chile 2024; 152(6): 645-654. DOI: 10.4067/s0034-98872024000600645

Association between body mass index and all-cause mortality in older people: A prospective analysis of the Chilean National Health Survey 2009-2010

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Asociación entre índice de masa corporal y mortalidad por todas las causas en personas mayores: Un análisis prospectivo de la Encuesta Nacional de Salud de Chile 2009-2010

ABSTRACT

There is a divergence in the results of studies that have explored the association between body mass index (BMI) and health outcomes in different contexts. ***Aim:*** *This study investigated the association between BMI and all-cause mortality in older Chilean people.* ***Methods:*** *1.205 participants (≥60 years) from the Chilean National Health Survey 2009–2010 were included. The association between BMI categories and all-cause mortality was carried out using Cox proportional regression models, adjusting by confounding factors.* ***Results:*** *Over a median follow-up of 10.9 years (interquartile range: 8.7-11.0), 404 individuals died (33.5%). In the minimally adjusted model (model 1), the participants underweight had 1.46-times (95 CI %: 1.10;1.94) higher mortality risk, while those with obesity II exhibited a 1.73-times (95 CI %: 1.05; 2.83) higher risk of dying due to all-causes compared with the normal-weight. After adjusting for models 2 and 3, the observed association remained significant.* ***Conclusion:*** *Older people categorized as underweight and obese II had a higher risk of all-cause mortality than their normal-weight peers, regardless of confounding factors.*

Keywords: *Aged; Body Mass Index; Chile; Malnutrition; Mortality.*

RESUMEN

Existe divergencias en los resultados de estudios que han explorado la asociación entre el índice de masa corporal (IMC) y resultados de salud en diversos contextos. ***Objetivo:*** *Este estudio investigó la*

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Funding: This work did not receive any financial support of any kind.

Conflicts of Interest: The authors declare no conflicts of interest.

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Received: May 15, 2024.
Accepted: August 16, 2024.

asociación entre el IMC y la mortalidad por todas las causas en personas mayores chilenas. ***Métodos:*** *Se incluyeron 1.205 participantes (≥60 años) de la Encuesta Nacional de Salud de Chile 2009-2010. La asociación entre categorías de IMC y mortalidad por todas las causas se realizó mediante modelos de regresión proporcional de Cox, ajustando por factores de confusión.* ***Resultados:*** *Durante una mediana de seguimiento de 10,9 años (rango intercuartil: 8,7-11,0), murieron 404 personas (33,5%). En el modelo mínimamente ajustado (modelo 1), los participantes con bajo peso tenían un riesgo de mortalidad 1,46 veces (IC 95%: 1,10; 1,94) mayor, mientras que aquellos con obesidad II presentaban un riesgo 1,73 veces (IC 95%: 1,05; 2,83) mayor de morir por todas las causas en comparación con las personas con peso normal. Después de ajustar por los modelos 2 y 3, la asociación observada siguió siendo significativa.* ***Conclusión:*** *Las personas mayores categorizadas como bajo peso y con obesidad II tenían un mayor riesgo de mortalidad por todas las causas que sus pares con peso normal, independientemente de los factores de confusión.*
Palabras clave: *Chile; Desnutrición; Índice de Masa Corporal; Mortalidad; Persona mayor.*

Aging is a physiological, universal, clarity and natural process that causes changes in body systems during the life cycle[1]. In addition to the anatomical and physiological changes that accompany aging, metabolic changes such as alterations in body composition are observed, characterized by a progressive loss of muscle mass and an increase in the amount and redistribution of fat tissue[2,3]; the latter can affect the health of people favoring malnutrition[4].

Malnutrition (either undernutrition or overnutrition) causes adverse effects on different organs and bodily functions, turning older people into a population prone to developing functional impairment and different diseases[4], as well as mental health problems such as isolation and depression[5,6].

In Chile, population studies have shown that 76.8% of older adults are overweight and obese[7], a worrying background given that the increase in the prevalence of these conditions generates adverse trends in the incidence and mortality from coronary heart disease, stroke, diabetes mellitus and some types of cancer[8]. On the contrary, 1.5% of this population is underweight, which has also reported consequences such as reduced muscle mass, increased risk of frailty, sarcopenia, cachexia, increased risk of cognitive impairment, and increased mortality[9,10].

One way to quantify the nutritional status is through the body mass index (BMI). Even if the index has several limitations (for instance, it does not discriminate against age-related changes in body composition), it is still considered cheap and easy screening tool in the clinical nutritional evaluation[11]. Moreover, it has been recognized as a strong predictor of cardiovascular diseases, diabetes, and mortality in this population[12,13].

International studies have used BMI to associate nutritional status with all-cause mortality in larger populations[13,14,15]; however, evidence has been conflicting. Sergi, et al. (2005) reported that a low BMI was a predictor of all-cause mortality in older Italians[16] consistent with litera-

ture developed in the United States[17], France[18], Australia[19] and Japan[20] However, the Prospective Studies Collaboration, which included 900,000 older people, concluded that a higher BMI was associated with a 30% increased mortality risk[21]. Similarly, the National Cancer Institute Cohort Consortium showed that a higher BMI increased the mortality risk at all ages[22].

In contrast, a systematic review identified that BMI in the overweight range was not associated with a significantly increased mortality risk in older adults[23]. Furthermore, several studies have shown that overweight and obesity is associated with a lower mortality risk from all causes in older people compared to those with normal BMI or with underweight, even considering overweight and obesity as protectors of mortality[23,24].

In the case of Chile, a study led by Riquelme, et al. (2021) reported that a high BMI was associated with higher mortality rates from cardiovascular and respiratory diseases and cancer, estimating that 21,977 deaths were attributed to high BMI, representing about 31.6% of the top non-communicable disease deaths and 20.4% of all deaths[25]. Considering the divergence of the reported findings, this study aimed to investigate the association between BMI and all-cause mortality in a representative sample of older adults in Chile.

Material and Methods

This cohort study was based on participants from the Chilean National Health Survey 2009-2010 (CNHS 2009-2010). The CNHS 2009-2010 was a large, nationally representative population-based study of biological and lifestyle risk factors, dietary status and health, conducted every six years in Chile, in both urban and rural zones. One participant was randomly selected per household, with pregnant individuals and individuals with violent behaviours excluded, as described elsewhere[7]. Data were collected by trained staff in two visits where individuals were administered questionnaires, and anthropometrical and physiological measures, as well as biological samples, were obtained. From the original sample size (5.293 participants), 1.205 participants ≥60 years which was the target population of this study and which also had available data for the exposure and covariates and were, therefore, included in the analyses. The CNHS 2009–2010 was funded by the Chilean Ministry of Health and approved by the Ethics Research Committee of the School of Medicine at the Pontificia University Catholic of Chile (code 09-113).

Exposure - Body Mass Index

Weight and body height were determined with an electronic scale (TANITA, model TBF 300A, USA) and a height rod (SECA, model A800, USA) with a precision of 100 g and 1 mm, respectively. BMI was calculated as weight/height^2 and classified using the Pan American Health Organization (PAHO) criteria in older adults: underweight: <23.0 kg/m^2; normal: 23.0 to 27.9 kg/m^2; overweight: 28.0 to 31.9 kg/m^2; and obese: ≥32.0 kg/m^2. Moreover, to have better obesity identification, obesity was further split into two groups: obese I: 32.0 to 39.9 kg/m^2 and obese II: ≥40.0 kg/m^2[26].

Outcome - All-cause mortality

The outcome of the current study was all-cause mortality. The date of death was obtained from death certificates linked to the Chilean Civil Registry and Identification. Mortality data were available until the 31st of December 2020. Therefore, mortality follow-up was censored on this date or the date of death if this occurred earlier.

The Ministry of Health's website constantly updates the mortality data for all causes for individuals who participated in the ENS 2009-2010. The information is available at: https://epi.minsal.cl/bases-de-datos/ (section Chilean National Health Survey).

Covariates

Socio-demographic characteristics, including age, sex (men or women) and years of education (≤8 years, 9-12 years, and >12 years), were self-reported.

Smoking status was classified as never, previous, and current; and alcohol consumption was derived using the Alcohol Use Disorders Identification Test (AUDIT) adapted for the Chilean population[27]. This test consists of 10 questions whose options range

from 0 to 4 points. An AUDIT score greater than 8 points was considered indicative of risky alcohol consumption.[27]. Finally, multimorbidity was defined by the presence of 2 or more diseases out of 15 chronic diseases for which data were collected in the CNHS 2009-2010. All antecedents were collected from participants using questionnaires previously validated for the CNHS 2009–2010[7].

Statistical analyses

Descriptive characteristics are presented as means with standard deviation (SD) for continuous variables and percentages with their 95% confidence intervals (CI) for categorical variables.

The cumulative crude hazard rate of BMI categories and all-cause mortality by follow-up time was estimated using the Nelson-Aalen estimator. Associations between BMI categories and all-cause mortality were investigated using Cox proportional hazard models. The proportional hazard assumption was checked using Schoenfeld residuals (the proportional hazard assumptions were all non-significant with a global p-value= 0.806).

Normal-weight category was used as the reference group. The results are reported as hazard ratios (HR) with their 95% CI. Nonlinear associations between the continuous BMI and all-cause mortality were also investigated using penalized cubic splines fitted in Cox proportional hazard model[28]. Time to follow-up was used as the time-dependent variable.

Analyses were adjusted for confounding factors based on previous literature, using the following four models: model 0: unadjusted; model 1 was adjusted for socio-demographic factors (age, sex, and educational level); Model 2: as per model 1 but additionally lifestyle (smoking) and AUDIT score; and Model 3 as per model 2 but additionally for multimorbidity.

All statistical analyses were conducted using STATA V17 software (Stata Corp, College Station, TX) and R 4.2.2 (using the packages 'survival', and 'spline'). A p-value lower than 0.05 was considered significant.

Results

After excluding older people with missing data for BMI, mortality, and covariates, 1,205 participants were included in the analyses (Figure 1). Over a median follow-up of 10.9 years (interquartile range: 8.7-11.0), 404 individuals died (33.5%).

The baseline characteristics of the study population are shown in Table 1. In general, the underweight participants had – on average – 73.7 years, were more likely to be women with lower educational levels, and presented two or more chronic diseases (Table 1).

Similar characteristics were exhibited by overweight (women; 70.0 years; BMI 29.8 kg/m^2) and obese I (women; 68.8 years; BMI 36.2 kg/m^2) participants. Obese II participants were mostly women with a mean age of 69.2 years and a BMI of 47.3 kg/m^2. These participants were more likely to have lower educational levels, did not smoke, and had two or more chronic diseases.

Figure 2 shows the accumulated mortality in older people according to nutritional status in a period of 10.9 years of follow-up. In this figure, people categorized as underweight and obese II were those who exhibited the highest mortality rates.

Associations between the BMI categories and all-cause mortality are presented in Table 2. Across all models, underweight and obese II participants showed a higher risk of all-cause mortality. In the minimally adjusted model (model 1), underweight participants had 1.46-times (95 CI %: 1.10; 1.94) higher mortality risk, while those with obesity II exhibited 1.73-times (95 CI %: 1.05; 2.83) higher risk of dying due to all causes compared with normal weight participants. After adjusting for confounder in models 2 and 3, the observed association remained significant ($HR_{\text{model 3 Underweight}}$:1.44 CI [95%:1.08; 1.92]; $HR_{\text{model 3obese II}}$:1.79 [95% CI: 1.08; 2.95]). No other associations were identified in the other BMI categories.

Finally, nonlinear associations between continuous BMI and all-cause mortality are shown in Figure 3. In general, a U-shaped association was observed, where underweight individuals had 2-times higher risk of mortality compared to 3-times higher risk in older adults with BMI above 50 kg/m^2 (Figure 3).

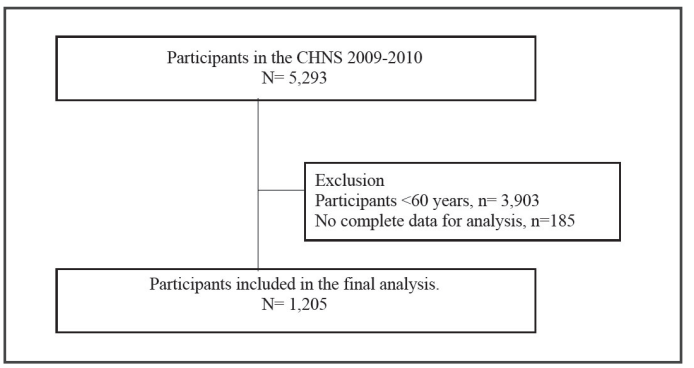

Figure 1: *Participants included in the formal analyses, Chile, CNHS 2009-2010.*

Table 1. General characteristics of the study population by the BMI categories at baseline.

	Underweight (<23.0 kg/m²)	**Normal weight (23.0 to 27.9 kg/m²)**	**Overweight (28.0 to 31.9 kg/m²)**	**Obese I (≥32.0-39.9 kg/m²)**	**Obese II (≥40.0 kg/m²)**
n, (%)	159 (13.2)	437 (36.2)	346 (28.7)	217 (18.1)	46 (3.81)
Baseline age (years), mean (SD)	73.7 (9.15)	70.3 (7.50)	70.0 (7.64)	68.8 (6.63)	69.2 (6.72)
Sex, n (%)					
Women	95 (59.7)	228 (52.2)	209 (60.4)	159 (73.2)	32 (69.6)
Men	64 (40.3)	209 (47.8)	137 (39.6)	58 (26.8)	14 (30.4)
Educational level, n (%)					
Low <8 years	103 (64.7)	250 (57.2)	230 (66.5)	139 (64.0)	31 (67.4)
Middle 8-12 years	46 (28.9)	145 (33.2)	99 (28.6)	65 (29.9)	11 (23.9)
High >12 years	10 (6.29)	42 (9.61)	17 (4.91)	13 (5.6)	4 (8.70)
Smoking					
Never	94 (59.1)	220 (50.3)	167 (48.2)	123 (56.7)	24 (52.2)
Previous	41 (25.8)	140 (32.0)	127 (36.7)	64 (20.5)	17 (36.9)
Current	24 (15.1)	77 (17.6)	52 (15.0)	30 (13.8)	5 (10.9)
Comorbilidity					
None	31 (19.54)	60 (13.7)	54 (15.6)	27 (12.4)	3 (5.52)
1 chronic disease	55 (34.6)	157 (35.9)	109 (31.5)	62 (28.6)	15 (32.6)
2 or more chronic disease	36 (22.6)	75 (17.2)	50 (14.4)	46 (21.2)	12 (26.1)
BMI (kg/m²), mean (SD)	21.1 (1.47)	25.7 (1.31)	29.8 (1.09)	34.6 (2.07)	43.7 (5.50)
Risk consumption ≥8 pts (AUDIT score)(%)	10 (6.29)	28 (6.41)	16 (4.62)	14 (6.45)	1 (2.17)

AUDIT: Alcohol Use Disorders Identification Test; BMI: Body mass index; n: number; SD: standard deviation.

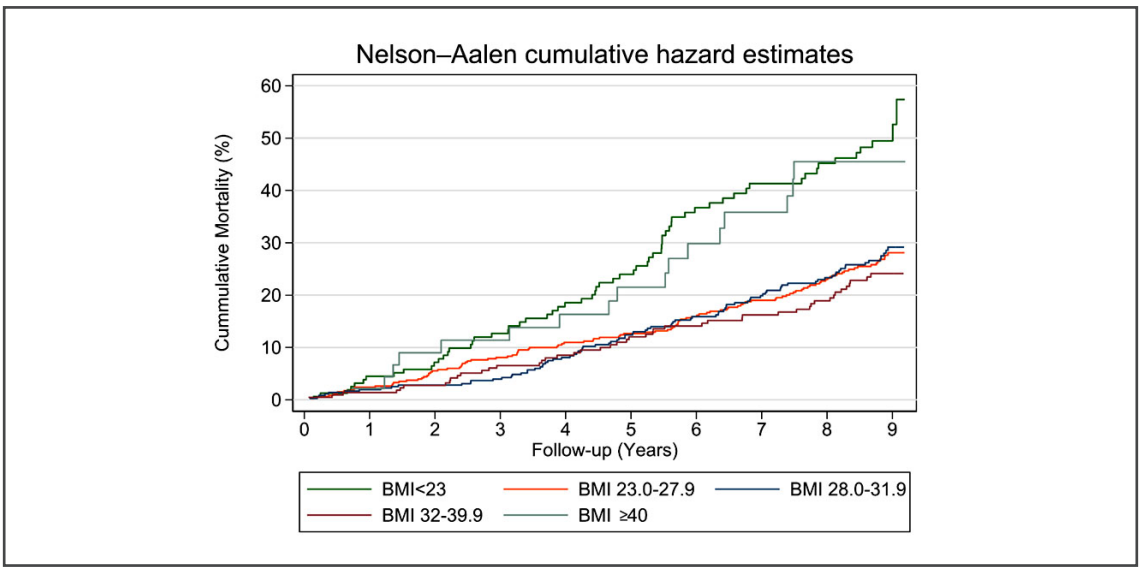

Figure 2: *Cumulative mortality in Chilean older people according to BMI categories.*

Table 2. Associations between BMI categories and all-cause mortality in Chilean older adults.

Normal weight	**Underweight**		**Overweight**		**Obese I**		**Obese II**	
All-cause mortality	**HR (95% CI)**	**p-value**	**HR (95% CI)**	**p-value**	**HR (95% CI)**	**p-value**	**HR (95% CI)**	**p-value**
Model 0 1.00 (Ref.)	1.75 (1.32; 2.32)	<0.001	0.96 (0.74; 1.24)	0.780	0.90 (0.67; 1.22)	0.529	1.36 (0.83; 2.22)	0.216
Model 1 1.00 (Ref.)	1.46 (1.10; 1.94)	0.008	0.99 (0.77; 1.28)	0.988	1.15 (0.85; 1.55)	0.354	1.73 (1.05;2.83)	0.029
Model 2 1.00 (Ref.)	1.44 (1.08; 1.92)	0.012	1.01 (0.78; 1.30)	0.935	1.16 (0.85; 1.56)	0.334	1.79 (1.09; 2.95)	0.021
Model 3 1.00 (Ref.)	1.44 (1.08; 1.92)	0.013	1.01 (0.79; 1.31)	0.896	1.15 (0.94; 1.65)	0.357	1.79 (1.08; 2.95)	0.022

Analyses are presented as HR and their 95% CI. Individuals in the normal weight category were used as the referent. Model 0: No adjusted; Model 1: was adjusted for socio-demographic factors (age, sex; years of education). Model 2: as per model 1 but additionally lifestyle (smoking) and AUDIT score. Model 3 as per model 2 but additionally for comorbidity.HR: Hazard ratio.

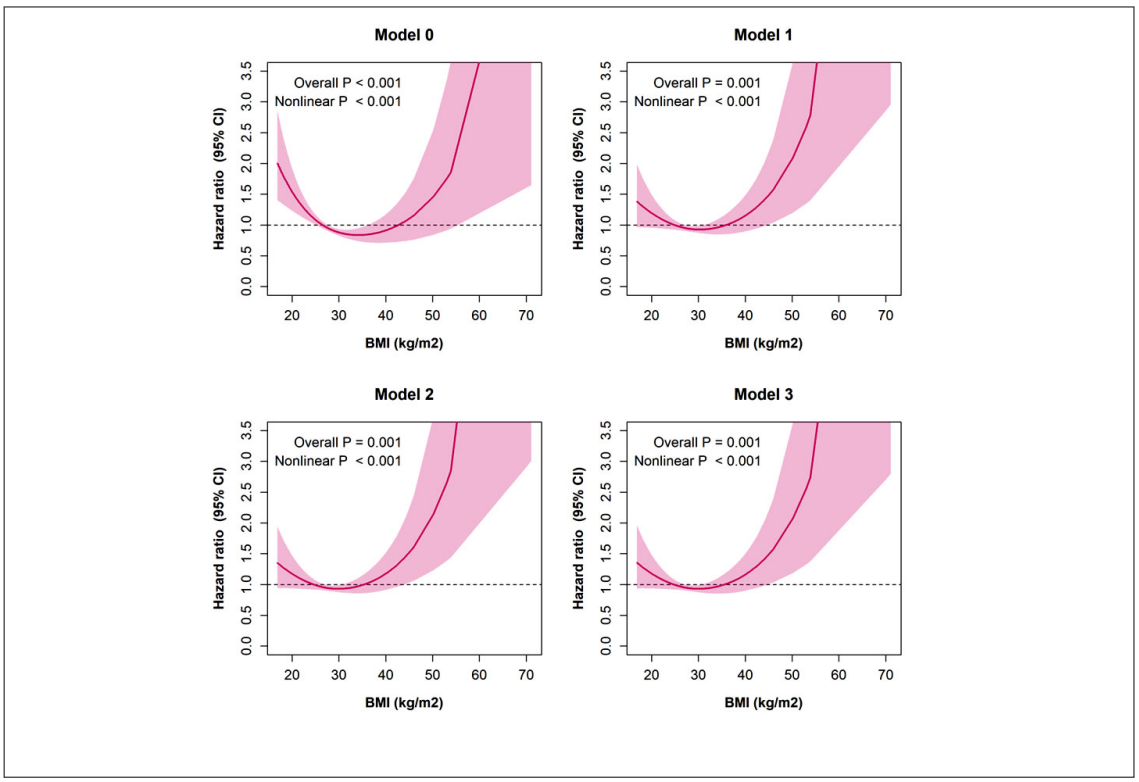

Figure 3: *Associations between BMI categories and all-cause mortality in Chilean older adults. Analyses are presented as HR and their 95% CI. All analyses were adjusted for age, sex, educational level, lifestyle, and comorbidity.*

Discussion

Using data from the CNHS 2009-2010, this study identified that older people categorized as underweight (BMI <23.0 kg/m^2) and obese II (BMI ≥40 kg/m^2) had a fold higher risk of all-cause mortality than their normal weight peers (reference group), after adjusting for confounding factors.

Our findings have important clinical implications since the Chilean population has shown great demographic changes and will become the longest-lived of Latin American countries in the 2030 year[29]. Therefore, considering the largest proportion of older adults in the country, estimating the association between BMI and all-cause mortality contributes to understanding the harmful physiological effects and the impact that BMI could have on public health[7].

Our results are consistent with previous studies that revealed significant associations between low BMI and all-cause mortality in this population[30]. For instance, the study led by De Souto Barreto, et al. (2017) – which included 3.741 residents over 60 years – reported that the mortality risk increased in people with low BMI (HR= 1.65 [95% CI: 1.29; 2.12]) compared to people of normal-weight[31]. Similarly, Nakajima y Yuno (2022) pointed out that low body weight in older people should be considered a strong risk factor for increased mortality[32]. Finally, a meta-analysis that included 19,538 older people concluded that compared with normal-weight status, those with low weight had a significantly increased risk of all-cause mortality (HR= 1.41 [95% CI: 1.26; 1.58]) and that low nutritional status could also be

considered a risk factor for death from infections and both cardiovascular and cerebrovascular diseases[23]. The causes of the increased risk of death associated with a low BMI are not still fully known; however, it could be assumed that a low weight exacerbates the age-related loss of muscle mass, favoring the development of sarcopenia, a highly prevalent geriatric syndrome in the older population, leading to increased risk of frailty, adverse health events, and ultimately, mortality[10,33].

Another finding of this research revealed that belonging to the obesity II category also increased the mortality risk. These results support, to some extent, previous literature that suggest that the risk of mortality rises up to 1.5 times among people with BMI levels greater than 35.0 kg/m^2 and that there is a strong association between overweight/obesity assessed through BMI, with increased mortality from all causes, cardiovascular diseases and cancer[14,34]. Pathophysiological mechanisms may contribute to this association, including chronic inflammation, insulin resistance, and metabolic dysfunction[35]. In addition, obesity can increase the risk of developing chronic diseases such as cardiovascular disease, type 2 diabetes, and some types of cancer, increasing the risk of mortality in this age group[35].

In recent decades, there has been a dramatic increase in the prevalence of obesity in older adults. This brings with it an increase in the number of epidemiological studies that evaluate the associations between body weight and, specifically, BMI with mortality. In addition, there is a need to establish the BMI values considered harmful for health. In accordance with the foregoing, and although various studies have used different BMI values to categorize the population and determine their nutritional status, these investigations, in general, have shown that the lowest risk of mortality is associated with a BMI in the range of 23.0 to 27.5 kg/m^2 regardless of the study population[36,37]. Thus, maintaining optimal nutritional status is associated with the lowest risk of death[37]. Based on these findings, promoting the development of healthy habits and lifestyles, such as a balanced diet, complying with physical activity recommendations and avoiding sedentary behavior, among others, could favor the maintenance of an adequate BMI and thereby reduce the mortality risk.

Finally, being overweight or obese did not increase the mortality risk of the participants in this study. Similar findings were shown by some authors[23,24] and in a recent systematic review[38]. The latter may be related to the phenomenon called the obesity paradox, which states that excess weight and adiposity may be protective factors due to greater robustness and presence of nutritional reserves to combat acute and chronic diseases and, therefore, be associated with more remarkable survival in older people when compared with their underweight peers[39]. Although this paradox has been widely studied in recent years, it is still controversial as it sends unclear messages about the true health risks of being overweight[40].

Strengths and limitations

The CNHS 2009-2010 is a national sample of the adult Chilean population. In addition, including a wide range of variables in the dataset allowed for a comprehensive adjustment of the effects of confounding factors. Similarly, the BMI was obtained through an internationally established protocol. Finally, this study met a representative number of the Chilean older population.

However, this study is not exempt from limitations. For instance, since this is an observational study, causal associations cannot be concluded from the analyses. Another limitation of this study was the use of self-report instruments to measure some variables. Since participants provided information about themselves, there is a possibility that they responded selectively or inaccurately due to perceived social judgment, social desirability, or forgetfulness. This could affect the accuracy and validity of the data collected.

Conclusions

Older underweight and obese II people experienced a higher mortality risk than those of normal weight. Considering that people with low and high BMI are at higher risk of mortality, efforts should be made to help older adults to maintain a healthy body weight.

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