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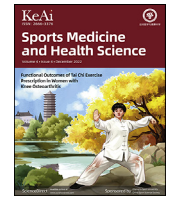

Original Article

Dynapenia in all-cause mortality and its relationship with sedentary behavior in community-dwelling older adults

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ABSTRACT

The aim of the present study was to investigate the relationship of dynapenia combined with sedentary behavior (SB) on the risk of mortality in older adults living in a Brazilian community. A total of 322 participants aged ≥ 60 years from the ELSIA (Longitudinal Study of Elderly Health in Alcobaça) prospective cohort were included. Dynapenia was diagnosed when the handgrip strength was < 27 kg for men and < 16 kg for women. The exposure time to SB was assessed considering the total time spent sitting during one day in the week and one day on the weekend. When combined with dynapenia, we derived the construction of four groups: best behavior (absence of dynapenia and low SB), intermediate behavior (absence of dynapenia and high SB; presence of dynapenia and low SB) and worst behavior (presence of dynapenia and high SB). Mortality was assessed by the follow-up time until death and/or censorship. During the 5-year follow-up of the study, 55 participants progressed to death. In the adjusted models, the dynapenia and the time spent exposed to SB were analyzed in a combined way, the older adults with worse behavior (high SB and dynapenia) had higher risk ratios for mortality (hazard ratio 2.46; 95% confidence interval 1.01–5.97) than the best behavior group. Older adults with dynapenia are at greater risk for all-cause mortality, which is aggravated by the addition of longer exposure to SB.

Introduction

Aging is linked to a progressive loss of muscle performance that affects the physical function of the older person.[1] One of the striking changes in this process is the decline in muscle strength, called dynapenia,[2] which increases the probability of greater physical disability.[3] In turn, this makes it difficult for older adults to perform basic daily tasks[4] and restricts their mobility and independence due to the reduction in skeletal muscle function and performance.[5] These alterations expose older adults to a greater risk of falls and fractures,[6] increasing the incidence of hospitalizations,[7] thus becoming a potential predictor of morbidity and mortality in the adult and elderly population.[8]

This condition manifests itself as an important public health problem, with a prevalence that varies. Dynapenia is present in 22.5% of older European adults, 38.2% of Americans aged 65 years and older,[9] 17.2% of the population aged 50 years or older in Brazil, and among individuals aged 65 years and older in Brazil, the prevalence of dynapenia is up to 28.2%.[10] The prevalence of dynapenia was 27.7% in women and 39.6% in men living in senior housing or assisted living facilities.[11]

Recent longitudinal studies have been engaged in investigating the role of muscle strength in predicting mortality.[8,12] Their results highlight that the age-related decline in muscle strength is strongly related to poor health conditions and mortality, unlike muscle mass.[13] This finding shows that strength is a more important marker of muscle quality than quantity in estimating the risk of mortality.[14]

Nevertheless, the reasons why strength is more impactful than muscle mass for such an outcome have not yet been fully elucidated. What is known is that the pathophysiological process underlying the loss of muscle strength with age comprises a series of interactions among genetic, environmental and lifestyle factors,[15] such as sedentary behavior (SB), which has been identified as a possible predictor for dynapenia and mortality.[16,17]

Taken in isolation, a sedentary lifestyle is one of the main underlying causes of illnesses and disabilities, consequently leading to death.[18] In this scenario, older adults represent the population most exposed to SB. It is estimated that this population spends a mean of 8–12 h per day in sedentary activities.[19] What has been reported in the literature is that

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Abbreviations

SB	Sedentary Behavior
ELSIA	Estudo Longitudinal da Saúde do Idoso de Alcobaça
MMSE	Mini Mental State Examination
IPAQ	International Physical Activity Questionnaire
BMI	Body Mass Index
SD	Standard Deviation
IQR	Interquartile Range
HR	Hazard Ratio
CI	Confidence Intervals

exposure to only 5 h or more per day in sedentary activities, such as watching television, is already sufficient for an association with all-cause mortality.[20]

Nonetheless, few studies have shown the relationship between muscle dysfunctions, such as dynapenia associated with SB, and mortality risks in older adults. Studies such as that of Loprinzi and Frith[16] investigated lower limb muscle strength, physical activity, SB and mortality separately, where only SB was found to be associated with mortality. Another study carried out by Celis-Morales et al.[21] analyzed whether the associations of discretionary screen time and mortality could be modified by handgrip strength, showing that greater handgrip strength mitigated the effects of screen time associated with mortality. The study performed by Li et al.[13] investigated the associations of mass and muscle strength with mortality among older American adults, showing that low muscle strength was associated with a high risk of mortality, regardless of time in SB.

Even in the face of the need to evaluate high exposure to SB and declines in muscle strength, the mutual effects of the presence of dynapenia combined with SB on the influence of mortality have not yet been explored in the literature. Therefore, the aim of the present study was to investigate the relationship of dynapenia combined with SB with the risk of mortality in older adults living in a Brazilian community. We hypothesized that individuals presenting with dynapenia and reporting longer amounts of sedentary time would be at higher risk for all-cause mortality.

Materials and methods

Design and population

This research is characterized as a prospective and observational cohort, using exploratory methods such as surveys and physical performance tests, part of the Estudo Longitudinal da Saúde do Idoso (ELSIA), whose main purpose is to analyze the association between the level of physical activity and frailty syndrome based on the deficit accumulation index with adverse health factors (history of hospitalization, falls, medication consumption, functional limitations).

Details on the study design and sampling were previously published.[22] Briefly, baseline data collection was conducted in 2015, and inclusion criteria included living in the urban area, registered in the Family Health Strategy, aged 60 years or over, in the city of Alcobaça, Bahia, Brazil. It consisted of 473 individuals.

The exclusion criteria adopted were as follows: not meeting the minimum score (12 points) of the Mini Mental State Examination (MMSE),[23] adapted for the Brazilian population, independent of education level;[24,25] having severe difficulty in visual and/or hearing acuity; making use of wheelchairs; having severe sequelae of a stroke, with localized loss of strength; and having end-stage illnesses.

In the follow-up held in 2020, 105 were not found after three attempts, 36 moved to another city, totaling 141 segment losses. The follow-up took place from January to February 2020.

The present study used all baseline data from 2015 and the 2020 vital status update. Of the 473 individuals, 141 segment losses and 10 were excluded due to the lack of data on handgrip strength, totaling a final sample of 322 individuals (Fig. 1).

Ethical procedures

All participants were informed about the procedures, and informed consent was obtained before data collection. All procedures were previously approved by the Human Research Ethics Committee of the Federal University of Triângulo Mineiro (Ordinance n° 966.983/2015) and the University of the State of Bahia (Ordinance n° 3.471.114/2020) and were in accordance with the principles outlined in the Declaration of Helsinki.

Mortality

The primary outcome of this study was all-cause mortality, assessed at the moment of death, loss of follow-up and/or at the end of the follow-up period (February 29, 2020). The follow-up time was calculated as the period from the first visit in 2015 to the date of death or the date of the last contact. Vital status was confirmed by using family records with presentation of the death certificate, information obtained by the municipal registry (Registration of Civil Register of Natural Persons [RCPN, as per its Portuguese acronym] in Alcobaça) and/or the Court of Justice of the State of Bahia (https://www.tjba.jus.br/registrocivil/consultaPublica/search).

Dynapenia

Dynapenia was defined according to the criteria of Manini and Clark[26] and was considered an age-related decline in muscle strength and power. It was performed by using the handgrip strength test through the SAEHAN brand hydraulic dynamometer as an instrument. With reliability of $r = 0.986$ and validity of $r = 0.981$ by the intraclass correlation coefficient.[27] The hand dynamometers used for data collection were previously calibrated following manufacturer's recommendations.[28] The subjects were instructed to remain to stand, with their elbows extended; when holding the dynamometers, they were asked to exert as much force as possible. The size of the handle was adjusted for each participant. The highest value of three attempts for the dominant hand was used for analysis.[29] Dynapenia was established based on the cutoff points proposed by Dodds et al.[30] adopted by the European Working Group on Sarcopenia in Older People (EWGSOP2), classified as < 27 kg for men and < 16 kg for women.[31]

Sedentary behavior

Sedentary behavior was assessed by using the long version of the International Physical Activity Questionnaire (IPAQ) validated for the Brazilian elderly population.[32,33] The domain “sitting time” consists of two questions: 1) How much time in total do you spend sitting during a weekday? 2) How much time in total do you spend sitting during a weekend day? The response was quantified in minutes/day. SB was determined by the total sitting time (minutes/day) from the weighted arithmetic mean of the sitting time of each individual on a weekday multiplied by five, added to the sitting time on a weekend day multiplied by two and dividing the total by seven. To classify the time of exposure to SB, a cutoff point was determined from the cutoff points of the time spent in sedentary behavior to predict mortality, identified through receiver operating characteristic (ROC) curves.

For analytical purposes, the combinations between dynapenia and SB were jointly constructed, which established four groups with varied behaviors: the best behavior (low SB and absence of dynapenia), intermediate behaviors (low SB and presence of dynapenia; high SB and absence of dynapenia) and the worst behavior (high SB and presence of dynapenia).

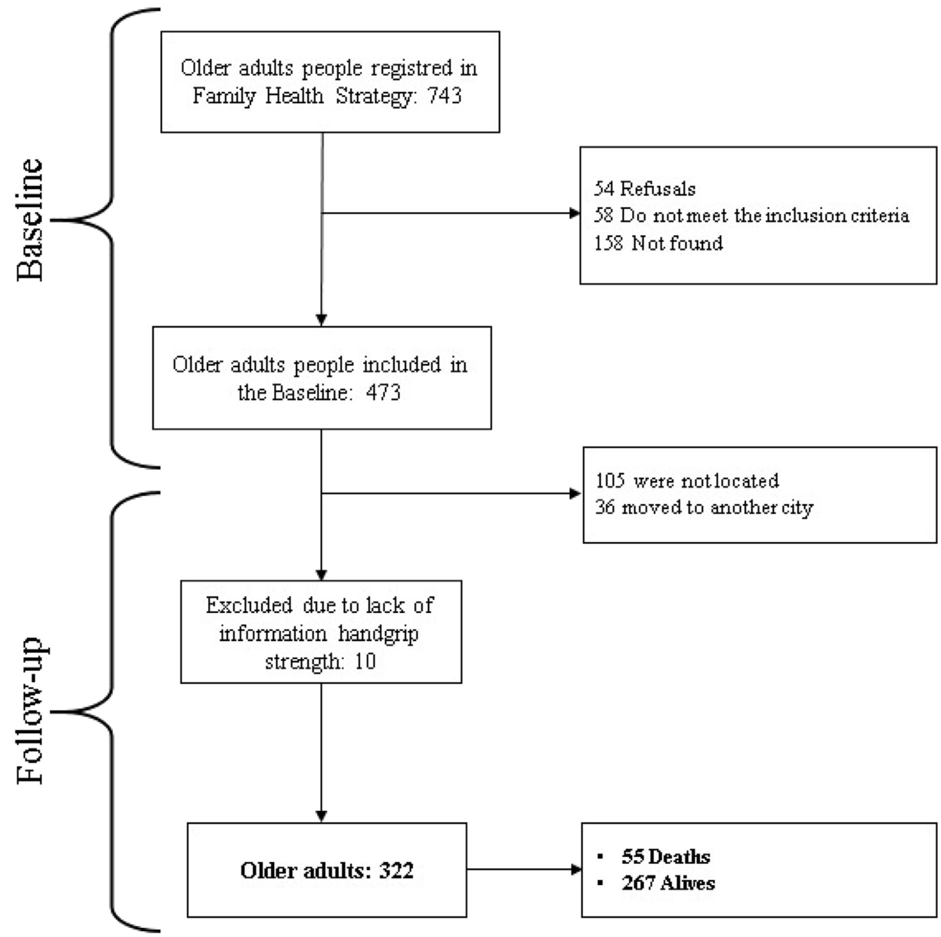

Fig. 1. Flowchart ELSIA 2015–2020, Alcobaça, Bahia, Brazil.

Covariables

Body mass index (BMI) was assessed as the ratio of the measure of body mass (kg) to height (m) squared (kg/m^2). Sociodemographic data included age, sex (male and female), race/ethnicity (white, black, brown and indigenous), schooling (illiterate, elementary school, high school and higher education) and behavioral characteristics, such as physical activity level (minutes/week), tobacco consumption (yes or no) and alcohol consumption (yes or no).

Statistical analysis

To prepare the database, Epidata software, version 3.1b, was used, and the analyses were performed using the SPSS package, version 23.0.

The Kolmogorov–Smirnov normality test was used to test the normality of the data. Descriptive statistics were used to characterize the subjects: frequency distribution (absolute and relative frequencies) and calculation of central tendency measure (mean, standard deviation [*SD*], median and interquartile range [IQR]). Differences in sample characteristics according to the presence of dynapenia were performed by means of Pearson chi-squared inferential analysis (qualitative variables) and the Mann–Whitney *U* test (continuous variables).

The predictive power and cutoff points of SB and all-cause mortality were identified through receiver operating characteristic (ROC) curves, which are frequently used to determine cutoff points in diagnostic tests. Values identified through ROC curves at cutoff points should provide a balance between sensitivity and specificity for the time in exposure to all-cause mortality and under the ROC curve at 0.60, which determine whether the predictive ability of time exposed to SB is not by chance.

The time in SB minutes/day to predict or risk of death in the older adults was identified under the ROC curve. The 95% confidence interval (*CI*) was used.

Deaths occurring during the 5-year follow-up were analyzed between baseline and follow-up. As a premise, the Kaplan–Meier test was used to graphically check the existence of proportionality of risks and to examine the difference between the survival curves through the log-rank (Mantel-cox), Breslow (generalized Wilcoxon) and Tarone-Ware tests for the variables “dynapenia”, “SB” and the combinations of both factors, giving rise to four groups. The reference category used was best behavior low SB and absence dynapenia. The assumptions of the crude and adjusted hazard ratios were estimated by Cox proportional hazards regression. Model 1 was without adjustment, Model 2 was adjusted for sociodemographic characteristics (age, sex, race/ethnicity and schooling) and Model 3 for behavioral characteristics (tobacco consumption and alcohol consumption, BMI), in addition to physical activity. The hazard ratio (*HR*) estimator was used, with 95% confidence intervals (*CI*) for all-cause mortality, with survival time in months. A 5% significance level was adopted.

Results

A total of 322 older adult citizens were evaluated at baseline, of whom 55 (17.1%) died, with a mean time until the follow-up period of 49.70 months (*SD* = 9.07). Table 1 displays the sociodemographic, health and behavioral characteristics of the participants according to their vital status. The median age of the population was 69.0 (*IQR* = 13.0) years, of which 63.7% were female. Among the older adults who died, 43.6% had dynapenia, and the majority (76.4%) had high sedentary behavior.

Table 1
Characterization of older adults according to dynapenia, Alcobaça, Bahia, 2015–2020.

Variables	Vital status			
	All (n = 322)	Alive (n = 267)	Dead (n = 55)	p*
	Median (*IQR*)	Median (*IQR*)	Median (*IQR*)	
Age (years)	69.0 (13.0)	68.0 (11.0)	78.0 (16.0)	< **0.001**
Body mass (kg)	65.95 (19.8)	66.20 (19.3)	63.50 (20.9)	**0.022**
Height (m)	1.56 (14.9)	1.56 (14.9)	1.54 (17.2)	0.291
BMI (kg/m^2)	26.59 (6.9)	26.81 (6.7)	25.47 (8.0)	0.056
Physical activity (min/week)	170.00 (490.0)	210.00 (470.0)	20.00 (205.0)	< **0.001**
Dynapenia (%)				
Presence	26.4	22.8	43.6	**0.001**
Absence	73.6	77.2	56.4	
Sex (%)				
Female	63.7	63.7	63.6	0.996
Male	36.3	36.3	36.4	
Race/ethnicity (%)				
White	30.7	30.3	32.7	
Black	38.2	37.5	41.8	0.172
Brown	30.7	32.2	23.6	
Indigenous	0.3	0.0	1.8	
Schooling (%)				
Illiterate	34.8	34.5	36.4	
Elementary school	48.4	46.8	56.4	0.201
High school	10.6	12.0	3.6	
Higher education	6.2	6.7	3.6	
Tobacco consumption (%)				
Yes	11.2	10.1	16.4	0.180
No	88.8	89.9	83.6	
Alcohol consumption (%)				
Yes	16.5	16.5	16.4	0.983
No	83.5	83.5	83.6	
Sedentary Behavior (%)				
Low	43.2	47.2	23.6	
Higher	56.8	52.8	76.4	**0.001**

IQR: Interquartile Range; BMI: body mass index; *$p < 0.05$.

Regarding the cutoff point for time spent in sedentary behavior as a discriminant for mortality, the area under the ROC curve was 0.622 (95% *CI*: 0.67–0.675; $p = 0.004$), with a time > 382.14 min/day for those with high sedentary behavior.

In the Cox proportional hazards regression, it was found that in Model 1 (*HR*: 2.33; 95%*CI*: 1.34–4.07), older adults with dynapenia had higher risks for mortality. However, in the adjusted models, no associations were found (Table 2).

Table 2
Cox proportional hazards regression by means of dynapenia and sedentary behavior. Alcobaça, Bahia, 2015–2020.

Variables	Vital Status n (%)		Mortality		
			Model 1	Model 2*	Model 3**
	Alive	**Deaths**	***HR* (95%*CI*)**	***HR* (95%*CI*)**	***HR* (95%*CI*)**
Dynapenia					
Presence	61 (22.8)	24 (43.6)	**2.33 (1.34–4.07)**	1.33 (0.73–2.40)	1.29 (0.71–2.34)
Absence	206 (77.2)	31 (56.4)	1	1	1
Sedentary Behavior					
Low	126 (47.2)	13 (23.6)	**2.67 (1.39–5.10)**	**2.27 (1.18–4.36)**	**2.01 (1.03–3.91)**
High	141 (52.8)	42 (76.4)	1	1	1

Model 1: no adjustment; *Model 2: sex, age, race and schooling; **Model 3: Model 2 + BMI, physical activity, tobacco consumption and alcohol consumption; *HR*: hazard ratio; *CI*: confidence interval.

When mortality from SB was checked, participants with a shorter time exposed to SB had, on average, lower risk rates for mortality than those exposed for a longer time. For those exposed to the longest time in SB, after adjusting for behavioral variables and the level of physical activity (*HR*: 2.01; 95%*CI*: 1.03–3.91), this significance was lost in the final model (Table 2).

Fig. 2 shows the curves according to the combinations between dynapenia and sedentary behavior (high SB and presence of dynapenia, low SB and presence of dynapenia, high SB and absence of dynapenia, low SB and absence of dynapenia). When the survival curves were checked, there was a significant difference ($p = 0.000\ 5$), with a greater impact on the shortest survival time for the older adults with high SB and the presence of dynapenia.

When analyzing the combinations between dynapenia and SB, the best behavior was used as a reference (low SB and absence of dynapenia). When observing the worst behavior (high SB and presence of dynapenia), a higher risk ratio was found in 2.46 (95%*CI*: 1.01–5.97) times for mortality when compared to the others, regardless of sociodemographic and behavioral factors and physical activity level (Table 3).

Discussion

The objective of the present study was to investigate the relationship of dynapenia combined with SB on the risk of mortality in older adults living in a Brazilian community. The main findings of the study indicate that, during the 5-year follow-up, older individuals with dynapenia had higher risks for all-cause mortality, and when combined with SB, the risks persist, worsening due to the combination of high SB and the presence of dynapenia, regardless of socioeconomic and behavioral factors and physical activity level. These results corroborate the hypothesis.

Previous investigations have shown the possible effect of SB and muscle strength with different instruments on health outcomes, including mortality.[13,34] The prospective study by Li et al.[13] with 4 449 American participants showed that all-cause mortality was significantly higher among individuals with low muscle strength (*OR*: 2.03; 95%*CI*: 1.27–3.24), and this difference persisted even when adjusted for different levels of SB. Another study, in a five-year follow-up study that verified all-cause mortality in elderly Brazilians, identified a mortality rate of 44.3/1 000 person-years in elderly people with dynapenia and 14.9/1 000 in elderly people without dynapenia, with risks increased by 104% (*HR*: 2.04; 95%*CI*: 1.14–3.37) in elderly patients with dynapenia, demonstrating dynapenia as an independent risk for mortality.[34] What still needs to be explored is the combination of factors for the presence and absence of dynapenia together with the time exposed to SB.

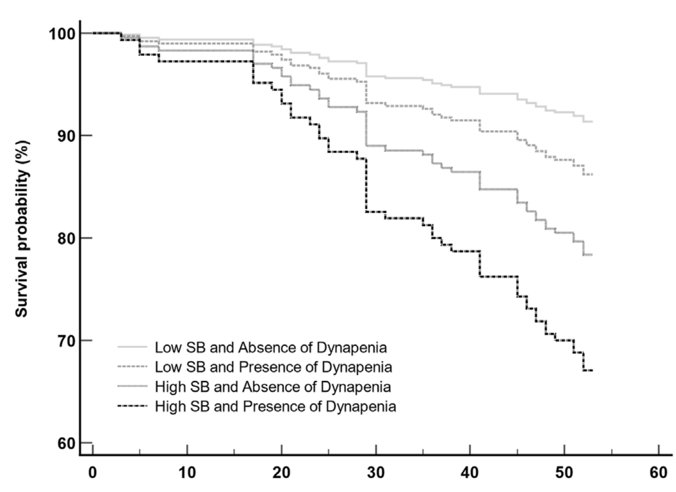

Fig. 2. Survival curves for all-cause mortality according to the combination of sedentary behavior and dynapenia. Alcobaça, Bahia, 2015–2020.

Table 3
Cox proportional hazards regression by means of the combination between sedentary behavior and dynapenia by the mortality outcome. Alcobaça, Bahia, 2015–2020.

Variables	Vital Status *n* (%)		Mortality		
			Model 1	Model 2*	Model 3**
	Alive	**Deaths**	**HR (95%*CI*)**	**HR (95%*CI*)**	**HR (95%*CI*)**
Combination between SB and Dynapenia					
High SB and Presence of Dynapenia	100 (37.5)	9 (16.4)	**5.42 (2.36–12.47)**	**2.81 (1.18–6.72)**	**2.46 (1.01–5.97)**
Low SB and Presence of Dynapenia	106 (69.7)	22 (40.0)	1.80 (0.54–5.97)	1.01 (0.30–3.42)	1.11 (0.32–3.82)
High SB and Absence of Dynapenia	26 (9.7)	4 (7.3)	**2.36 (1.02–5.21)**	1.99 (0.88–4.50)	1.89 (0.83–4.31)
Low SB and Absence of Dynapenia	35 (13.1)	20 (36.3)	1	1	1

Model 1: no adjustment; *Model 2: sex, age, race and schooling; **Model 3: Model 2 + BMI, physical activity, tobacco consumption and alcohol consumption; SB: sedentary behavior; *HR*: hazard ratio; *CI*: confidence interval.

Recent studies have investigated dynapenia as a risk factor for mortality. Volaklis et al.[34,35] in a literature review found that muscle strength is inversely and independently associated with all-cause mortality. A similar result was found in the present study, where the greatest risks of mortality were found in older adults with dynapenia. Another study that reinforces this finding, developed with the *SABE* Brazilian cohort, showed that older adults with dynapenia had a risk ratio 2.19 times (95% *CI*: 1.32–3.62) higher for mortality.[34] These findings corroborate those of the present study, which show that the presence of dynapenia, regardless of socioeconomic and behavioral variables, proved to be associated with a high risk for all-cause mortality.

This association can be explained by neuromuscular factors through decreased muscle contractile capacity,[1] and increased lipid infiltration into muscle tissue, contributing to low muscle strength levels that act as predictors for poor physical function,[36] decreasing an individual's ability to perform activities of daily living. As a consequence, their physical activity levels decrease, leading to greater loss of muscle mass, which is characterized by a decrease in the content of contractile proteins.[37] This can make the older person more vulnerable to accidents, such as falls and injuries, which, in turn, is also linked to an increased risk of mortality.[35]

Behavioral factors such as sitting time have been associated with a decline in muscle physiology.[38,39] They are associated with a lower percentage of muscle mass and greater body fat mass.[40] The study by Loprinzi[41] analyzed the strength of the lower limbs, SB and mortality in older adults aged 50–85 years and showed that strength was inversely associated with all-cause mortality when considering the SB of the individual. Celis-Morales et al.[21] analyzed whether the associations of discretionary screen time and mortality were modified by handgrip strength in middle-aged adult individuals and healthy older adults and found that the 2-h increase in screen time related to all-cause mortality was stronger among participants with the lowest tertile of handgrip strength.

There are strong consistencies that the two factors (SB and muscle strength) independently have mortality risk.[26,42,43] Nevertheless, the results of the present study confirm that this relationship, when high sedentary behavior and low muscle strength are combined concomitantly, increases the risk of mortality by more than 2 times. This result persisted even after adjusting for the individual's level of physical activity. One explanation for this finding may lie in the permanence of chronic and uninterrupted periods of muscle discharge associated with prolonged sedentary time, which can generate detrimental consequences.[44] On the other hand, this combination of factors can also lead to metabolic changes with the accumulation of visceral fat and an increase in proinflammatory cytokines released by adipose tissue, which can have a catabolic effect on muscle by impairing muscle protein synthesis and has been associated with the addition of existing factors to dynapenia and aggravated with SB,[45] thus increasing the risk of mortality.

The present study comes with limitations. First, we used questionnaires to assess SB. Self-report questionnaires are well-known for the possibility of recall bias, overestimation or underestimation of time spend in various activities at particular intensity; however, the MMSE scale was used as a way to track older adults with cognitive deficits to minimize the impact of recall bias. Another limitation of the study is the use of a cutoff point from a cross-sectional design to classify sedentary behavior, as there is no consensus in the literature. In addition to the possible losses of participants due to the follow-up of the last 5 years, this may reflect the findings of the present study. A strength of this study lies in the prospective cohort with a 5-year follow-up design, which evaluated a representative sample of the older adults population living in a low-income region of Brazil. Another strong point is the originality of the study and the importance of its evidence in the epidemiological context, especially in the surveillance of the health of the older population, given that both SB and muscle strength are modifiable risk factors.

Conclusion

Dynapenia and sedentary behavior were independently associated with increased risk for all-cause mortality in the present study. When high sedentary time and the presence of dynapenia were combined in older adults, these risks increased, regardless of the sociodemographic profile or the presence of unhealthy behaviors. Therefore, changes in lifestyle, such as healthy eating and incremental physical activity, with a reduction in the time exposed to sedentary activities can help to reduce the risks of early mortality, together with the conservation and maintenance of muscle strength, which has a direct impact on extending life expectancy with autonomy and independence.

Submission statement

This article has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), is not under consideration for publication elsewhere, has been approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and, if accepted, it will not be published elsewhere, including electronically in the same form, in English, or any other language, without the written consent of the copyright holder.

Authors' contributions

R.R.S designed the study, collected and analyzed data and drafted the manuscript. L.L.G. collected and analyzed data and help drafted the manuscript. D.A.T.S, J.M., J.S.V.J and S.T. conceived and designed the study, collected and analyzed data and helped drafting the manuscript. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Ethical approval statement

All participants were informed about the procedures, and informed consent was obtained before data collection. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Human Research Ethics Committee of the Federal University of Triângulo Mineiro (number 966.983/2015) and the State University of Bahia (number 3.471.114/2020).

Conflict of interest

The authors declare no conflict of interest.

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