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ORIGINAL ARTICLE

Hypertension, Hypercholesterolemia, and Insufficient Physical Activity Associated with Diabesity in Older Adults: A Cross-Sectional Study

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Abstract

Background: During aging, physiological and behavioral changes occur that lead to the development of diabesity (diabetes + obesity). Hence, the hypothesis that behavioral and health aspects can increase the probability of this outcome is plausible. In this framework, it is essential to carry out health surveys to investigate the factors that increase the probability of diabesity, as this information could be used to help monitor this outcome in the older population more accurately.

Objective: To verify the factors associated with diabesity in older adults.

Methods: This is an epidemiological survey, with a cross-sectional design, conducted with 211 older adults (58.80% women) from Aiquara, Bahia, Brazil. To assess the outcome, body mass index (BMI > 27 kg/m^2) and the concomitant presence of diabetes mellitus were used. In the inferential analyses, crude models and, subsequently, a multiple hierarchical explanatory model were constructed (level 1: socioeconomic variables; level 2: behavioral aspects; level 3: health conditions). This was performed using Poisson regression, with a robust estimator, calculations of prevalence ratios (PR) and their relevant 95% confidence intervals (CI).

Results: The prevalence of diabesity observed was around 9.50%. Furthermore, older adults who were insufficiently active (RP: 2.55; 95% CI: 1.20 to 6.36), those with arterial hypertension (PR: 5.32; 95% CI: 1.10 to 25.73), and those with hypercholesterolemia (PR: 2.80; 95% CI: 1.08 to 7.23) were more likely to have this outcome.

Conclusion: In the older population of Aiquara, Bahia, Brazil, the factors associated with diabesity were insufficient level of physical activity (PA), arterial hypertension, and hypercholesterolemia.

Keywords: Aging; Epidemiology; Heart Disease Risk Factors.

Introduction

Diabetes mellitus has become one of the main public health issues worldwide, recognized as a serious and prevalent condition associated with morbidity, mortality, and reduced life expectancy. This disease can result in microvascular complications (blindness, renal failure, neuropathy) and macrovascular complications (stroke, myocardial infarction, lower limb amputations).[1] Such complications are associated with excess weight and obesity, favored by the adoption of a lifestyle marked, especially, by diets rich in saturated fats and sugar, in addition to insufficient physical activity (PA).[2]

Data from the largest surveillance survey of risk and protective factors for chronic diseases in Latin America, carried out in Brazil in 2023, with data from the 26 state capitals and the Federal District, indicate that approximately 30.30% of the population aged ≥ 65

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Central Illustration: Hypertension, Hypercholesterolemia, and Insufficient Physical Activity Associated with Diabesity in Older Adults: A Cross-Sectional Study

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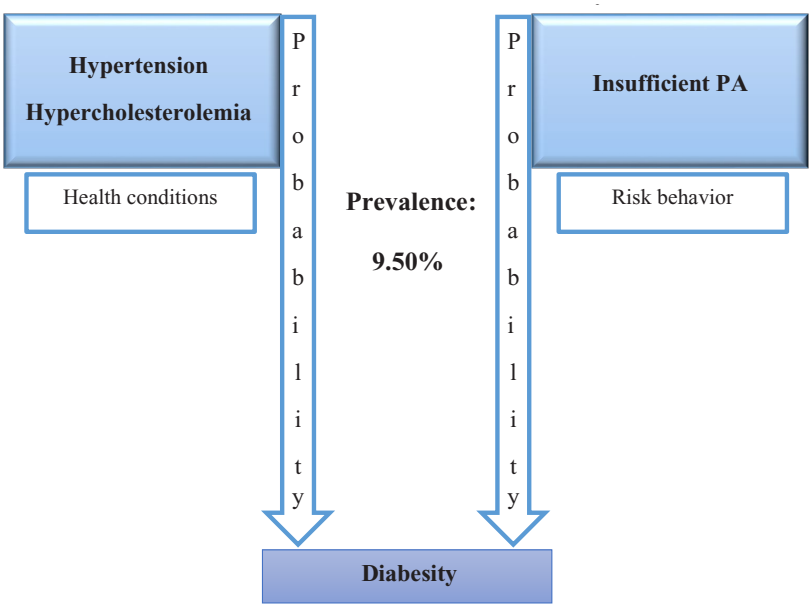

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Factors associated with diabesity in older adults. PA: physical activity

years reported a medical diagnosis of diabetes mellitus, and approximately 22.40% reported obesity.[3] In this scenario, a new condition known as diabesity has emerged, which is understood as the coexistence of both morbidities, diabetes mellitus and obesity, representing a new health epidemic.[4]

In Brazil, the surveillance of non-communicable diseases and conditions does not propose studies that provide an understanding of the coexistence of these morbidities in the population, which, in turn, can provide recognition of the new health epidemic in the territory. However, national studies indicate the need to recognize priority actions to combat this serious public health problem.[5-7]

Data from the National Health and Nutrition Examination Surveys showed a diabesity prevalence of 11% in older adults in the United States of America.[8] The Mexican Health and Aging Study demonstrated a prevalence of 6.90% in older adults in Mexico,[9] while the baseline of the Longitudinal Aging Study in India demonstrated prevalence of diabesity in 6.96% in the group of patients 60 to 64 years old; 7.62% in those aged 65 to 69 years; 8.11% in the those aged 70 to 74 years; 3.99% in those aged 70 to 75 years; and 1.88% among the oldest old (≥ 80 years).[10] This scenario is concerning, as diabesity poses a greater risk of depression, impaired functional performance,[8] cognitive decline, and mortality.[9]

It is noteworthy that, in addition to the excessive accumulation of fat caused by hormonal changes in men[11] and women[12] throughout aging, other physiological changes that occur with advancing age also favor the development of diabetes mellitus, due to changes in the structural aspects of the pancreas, such as reduction in mass and narrowing of the ducts.[13] Some of these factors are directly involved in the pathophysiology of glucose intolerance in older people, such as the increased sensitivity of beta cells to apoptosis and the reduction of their proliferation capacity.[1]

Since obesity and diabetes mellitus are two associated morbidities, with physiological changes arising from aging and the lifestyle habits adopted,[2] the hypothesis that behavioral and health factors can increase the probability of diabesity in older people is quite possible. However, after searching the literature, no epidemiological research with this investigation perspective was found in Brazil.

As a result, there is an important gap and a consequent need to carry out health surveys aimed at verifying the

factors that increase the likelihood of diabesity with aging in Brazil, with a focus on screening more accurately the development of this disease and its outcome in the older population. This will make it possible to outline strategic actions within the scope of primary health care and to ensure greater life expectancy and quality of life for older adults, based on more assertive and well-directed interventions for this target population. Therefore, the present study aimed to verify the factors associated with diabesity in older adults.

Methods

Study design, location, and population

This epidemiological investigation has a cross-sectional design and was carried out using baseline data from the research "Health conditions and lifestyle of older people living in a small municipality."[14] The health survey was conducted with the entire older population living in the urban area of Aiquara, Bahia, Brazil and registered in the Family Health Strategy, which covers 100% of the municipality.[15] Furthermore, the study was structured as suggested in the "Strengthening the Reporting of Observational Studies in Epidemiology."[16]

Ethical aspects

The investigation was carried out in accordance with Resolution number 466/2012 of the Brazilian National Health Council and was approved by the Research Ethics Committee of the State University of Southwest Bahia, under opinion number 171.464 and CAAE number 10786212.3.0000.0055. All participants were informed about the objectives, procedures, and voluntary nature of the survey. Hence, after receiving explanations about the study, the participants signed the free and informed consent form.

Eligibility criteria

The following inclusion criteria were established: age 60 years or over; living in an urban area; sleeping at least 4 nights a week at home; and not being institutionalized.[17] Bedridden older adults were excluded, as well as those who had cognitive deficit ascertained through the Mini Mental State Examination (MMSE)[18] with a cutoff point of < 13,[19] and those who had neurological diseases or hearing problems that would hamper the understanding of the questions.[20]

Data collection

Data collection was carried out in two stages. The first consisted of a home interview in which socioeconomic, behavioral, and health-related data of older adults were obtained. The second stage was carried out 2 to 3 days afterwards at the Municipal Health Department, according to the availability of participants. At this time, anthropometric measurements were performed. More details about the data collection stages and procedures adopted can be found in Santos et al.[21]

Independent variables (predictors)

The socioeconomic predictor variables were: age (in years); sex (male or female); marital status (with or without a partner); education (with or without formal education; lack of formal education was defined as never having attended school and/or not knowing how to write their name); income (≤ 1 minimum wage or > 1 minimum wage); and skin color (Black or non-Black).[21]

The behavioral variables included level of PA verified through the first 4 domains of the long version of the International Physical Activity Questionnaire (IPAQ).[22,23] Older adults who practiced moderate to vigorous PA during less than 150 minutes weekly were considered insufficiently active.[24] Sedentary behavior, quantified by the fifth domain of the IPAQ, which considers the time spent sitting on a common weekday and on a weekend day. The weighted mean sedentary behavior was calculated as follows: [(5 × min/weekday) + (2 × min/weekend day) / 7]. The cutoff point adopted for high sedentary behavior was based on the 75th percentile of the weighted average, with a value of approximately 342.85 min/day (5.71 hours).[25]

Furthermore, the consumption of fruits and vegetables (consumed at least twice a day: yes or no); consumption of eggs, beans, lentils, or soy (consumption at least once a week: yes or no); consumption of meat, chicken, or fish (3 times a week: yes or no); tobacco use (yes or no); and alcohol consumption in the last 30 days before collection (yes or no) were considered as behavioral aspects.

Finally, regarding the health conditions, the following predictors were adopted: self-reported diagnosis of systemic arterial hypertension (yes or no); hypercholesterolemia (yes or no); occurrence of falls in the last 12 months before collection (yes or no); self-perception of health (positive or negative); and suspicion of common mental disorders, verified

using the Self-Reporting Questionnaire (SRQ-20)[26] with a cutoff point of ≥ 7 positive responses.[27]

Dependent variable (outcome)

Body mass was measured using a portable digital scale (Plenna®). The patients remained standing, barefoot, with their arms relaxed at their sides, looking ahead, wearing light clothing. Their height was measured using a portable stadiometer (WiSO®); participants stood barefoot, in an upright position, with feet together, heels, buttocks and shoulder girdle in contact with the wall, and with their eyes fixed on a horizontal axis parallel to the floor (Frankfurt Plane) during inspiratory apnea.[28] Based on that information, the body mass index (BMI) in kg/m^2 was calculated.[29]

The diagnosis of diabetes mellitus was ascertained using the following question: "Has any doctor ever told you that you have high blood sugar, that is, that you are diabetic?" According to the answer, this variable was categorized dichotomously (diabetes: yes or no). Thus, older people with a BMI > 27 kg/m^2,[29] together with a positive response to diabetes mellitus, were considered to have diabesity (outcome).[4]

Statistical analysis

The description of the population's characteristics was carried out by calculating frequencies (absolute and relative) and the response percentage for each variable analyzed. Furthermore, for the descriptive analysis, the means and standard deviations were considered. In inferential analyses, initially, crude models were constructed. To this end, Poisson regression was adopted, with a robust variance estimator, which made it possible to calculate the prevalence ratios (PR) and their respective 95% confidence intervals (CI).

In the crude analyses, the predictor variables that demonstrated a p value less than or equal to 20% ($p \leq 0.20$) were considered for multivariate analyses, which were conducted in a hierarchical model. In this way, socioeconomic aspects constituted the most distal level (level 1); behavioral aspects constituted the intermediate level (level 2); and health conditions constituted the most proximal level (level 3), as shown in Figure 1.

Construction of the model began with the variables at the most distal level, and subsequent levels were gradually added to control for possible confounders and effect modifiers. Thus, intra- and inter-level adjustments

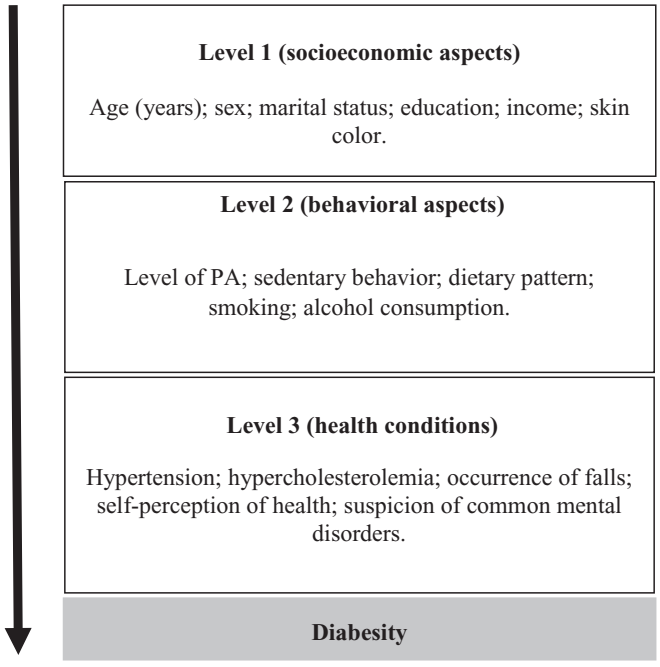

Figure 1 – Hierarchical model used to identify factors associated with diabesity in older adults.
PA: physical activity.

were made, where the effect of each predictor variable on the outcome was controlled by variables at the same level and by variables from previous levels, positioned hierarchically, remaining in the final model only those that maintained a p value ≤ 0.20, observed by the Wald test for heterogeneity. Finally, factors associated with diabesity were considered variables that demonstrated a significance level ≤ 5%. Data analyses were performed using the Statistical Package for Social Sciences (IBM-SPSS 21.0, 2013, Inc, Chicago, Illinois, United States).

Results

After a census carried out in all the households in the urban area of Aiquara, Bahia, Brazil, with the help of the community health agents working in the municipality, 263 older adults were identified.[30,31] Out of these, 211 made up the study population, as shown in Figure 2.

The average age of participants was 72.20 ± 8.10 years for men and 71.20 ± 6.80 years for women. The observed prevalence of diabesity was 9.50%. Furthermore, 58.80% of the participants were female; 61.20% had no formal education; 86.40% reported income less than or equal to minimum wage; 52.10% had an insufficient level of PA; 58.80% were hypertensive. Other characteristics of the population can be found in Table 1.

Table 2 presents the bivariate analyses between the independent variables and diabesity. Age (in years); sex; skin color; level of PA; consumption of fruits and vegetables; consumption of eggs, beans, lentils, or soy; consumption of meat, fish, or chicken; arterial hypertension; hypercholesterolemia; and self-perceived health presented p ≤ 0.20. Therefore, they were selected for multivariate analysis.

After intra- and inter-level adjustments, variables that did not meet the established criteria for remaining in the hierarchical model were removed. Thus, the final explanatory model showed that the following predictor variables were associated with the outcome: insufficient PA level (PR: 2.55; 95% CI: 1.20 to 6.36); arterial hypertension (PR: 5.32; 95% CI: 1.10 to 25.73); and hypercholesterolemia (PR: 2.80; 95% CI: 1.08 to 7.23) (Table 3).

Discussion

This is the first epidemiological investigation of the factors associated with diabesity in an older Brazilian population. The main findings showed that insufficient

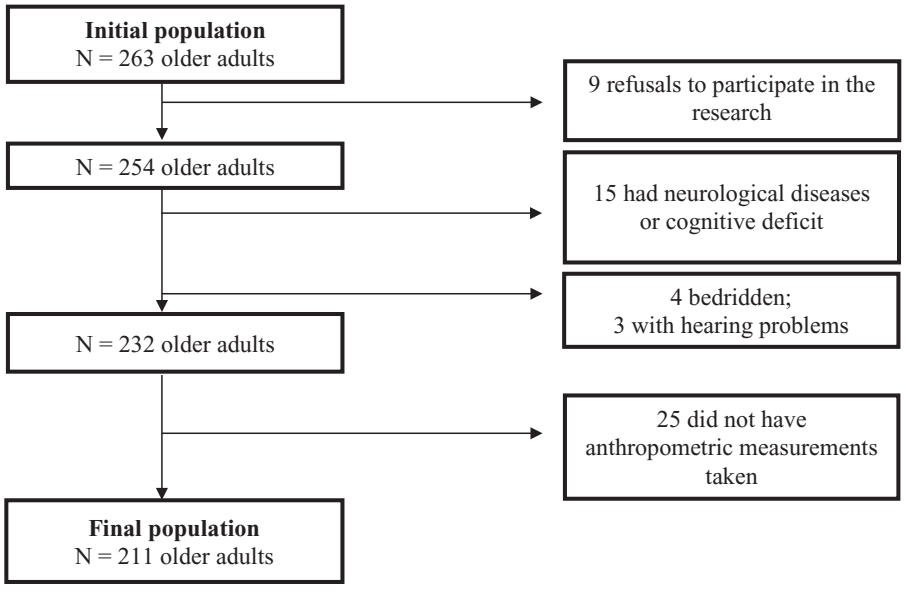

Figure 2 – Diagram of decisions in the process of selecting older adults' participants in the study.

Table 1 – Descriptive analysis of the characteristics of the study population.

Variables	% response	N	%
Sex	100.00		
Male		87	41.20
Female		124	58.80
Marital status	100.00		
With a partner		115	54.50
Without a partner		96	45.50
Education	97.60		
Yes		80	38.80
No		126	61.20
Income	93.80		
> 1 minimum wage		27	13.60
≤ 1 minimum wage		171	86.40
Skin color	96.70		
Non-Black		149	73.00
Black		55	27.00
Level of PA	100.00		
Sufficient		101	47.90
Insufficient		110	52.10
Sedentary behavior	100.00		
Low		160	75.80
High		51	24.20
C. of fruits and vegetables	100.00		
Yes		153	72.50
No		58	27.50
C. of eggs, beans, lentils, or soy	100.00		
Yes		199	94.30
No		12	5.70
C. of meat, chicken, or fish	99.10		
Yes		206	98.60
No		03	1.40
Smoking	100.00		
No		191	90.50
Yes		20	9.50
Alcohol consumption	100.00		
No		165	78.20
Yes		46	21.80

Hypertension	100.00		
No		87	41.20
Yes		124	58.80
Diabetes mellitus	100.00		
No		174	82.50
Yes		37	17.50
Obesity	100.00		
No		130	61.90
Yes		80	38.10
Hypercholesterolemia	100.00		
No		136	64.50
Yes		75	35.50
Diabesity	100.00		
No		190	90.50
Yes		20	9.50
Occurrence of falls	98.10		
No		177	85.50
Yes		30	14.50
Self-perception of health	98.10		
Positive		104	50.20
Negative		103	49.80
Suspicion of CMD	100.00		
No		143	67.80
Yes		68	32.20

%: percentage; C: consumption; CMD: common mental disorders; N: absolute frequency; PA: physical activity.

PA, high blood pressure, and hypercholesterolemia were the factors associated with diabesity. Therefore, these results provide evidence that can help to bridge the important gap regarding the multiple factors that independently increase the probability of the outcome in question in older adults.

The prevalence of diabesity observed in the present study is close to that found in other countries, such as Mexico with 6.90%[9] and the United States with 11%.[8] Even considering the lack of data on the prevalence of diabesity in the older Brazilian population, it is believed that the diabesity estimate obtained from the present study is similar to international values.

Although research with only older adults addressing diabesity as an outcome is scarce in the literature, there are health surveys with adults and older adults.[32] On this topic, a cross-sectional, population-based study stands out, namely, the study performed in India by Sinha, Puri, and Pati[10] with 59,073 patients aged ≥ 45 years (49.94% older adults). This investigation found that hypertension and hypercholesterolemia were associated with diabesity.[10]

Given this scenario, some hypotheses can help clarify the associations found. Among them, it appears that hyperinsulinemia is a condition associated with diabetes mellitus and/or obesity, which possibly explains the high probability of this outcome in older adults with hypertension.[33] Furthermore, the excessive accumulation of fat in adipose tissue results in pathophysiological changes, which can be exemplified by a greater

Table 2 – Prevalence of diabesity according to independent variables in the study population.

Variables	Diabesity		
	Prevalence (%)	Gross PR (95% CI)	P value
Age	-	0.87 (0.76-0.99)[#]	0.186[#]
Sex			0.130[#]
Male	5.70	1	
Female	12.20	2.12 (0.80-5.62)	
Marital status			0.768
With a partner	7.80	1	
Without a partner	11.60	1.48 (0.64-3.42)	
Education			0.699
Yes	8.80	1	
No	10.40	1.19 (0.49-2.85)	
Income			0.676
> 1 minimum wage	7.40	1	
≤ 1 minimum wage	10.00	1.35 (0.30-5.51)	
Skin color			0.111[#]
Non-Black	7.40	1	
Black	14.80	2.00 (0.85-4.72)	
Level of PA			0.038[#]
Sufficient	5.80	1	
Insufficient	14.60	2.52 (1.05-6.07)	
Sedentary behavior			0.895
Low	9.40	1	
High	10.00	1.06 (0.40-2.78)	
C. of fruits and vegetables			0.175[#]
Yes	7.80	1	
No	14.00	1.79 (0.77-4.15)	
C. of eggs, beans, lentils, or soy			0.003[#]
Yes	8.10	1	
No	33.30	4.12 (1.63-10.43)	
C. of meat, chicken, or fish			0.130[#]
Yes	9.30	1	
No	33.30	3.95 (0.68-18.85)	
Smoking			0.939
No	9.50	1	
Yes	10.00	1.05 (0.26-4.22)	

Alcohol consumption			0.443
No	10.40	1	
Yes	6.50	0.63 (0.19-2.05)	
Hypertension			0.011#
No	2.30	1	
Yes	14.60	6.36 (1.51-26.73)	
Hypercholesterolemia			0.006#
No	5.10	1	
Yes	17.60	3.02 (1.24-7.33)	
Occurrence of falls			0.464
No	9.10	1	
Yes	13.30	1.46 (0.56-4.08)	
Self-perception of health			0.064#
Positive	5.80	1	
Negative	13.70	2.38 (0.95-5.95)	
Suspicion of CMD			0.414
No	8.40	1	
Yes	11.90	1.42 (0.61.3,17)	

%: percentage; C: consumption; CI: confidence interval; CMD: common mental disorders; PR: prevalence ratio; PA: physical activity. #P value ≤ 0.20

production and circulation of adipokines, whose consequences include mechanisms of blood pressure control and lipid profile.[33,34]

The mechanisms of hyperinsulinemia include the decline of lipoprotein lipase, whose function in lipid metabolism is the hydrolysis of chylomicron triglycerides in very low-density lipoprotein (VLDL), and the transfer of surface phospholipids and apolipoproteins to high-density lipoprotein (HDL). These changes result in a greater atherogenic effect, reflected by an increase in total blood cholesterol.[33,34] In addition, positive insulin balance and insulin resistance constitute a compensatory mechanism in an attempt to restore energy balance and stabilize body mass, which consequently leads to the development of arterial hypertension.[33]

Sympathetic hyperactivity, as a result of hyperinsulinemia caused by diabesity, is facilitated by sympathetic nerve terminals, due to AT1 receptors in the pre-sympathetic region and in adipocytes, which, when activated, stimulate the release of noradrenaline. This mechanism contributes to an increase in the density of angiotensin II type 1 receptors as well as thermogenesis and blood pressure, both with tubular sodium reabsorption. In this way, a global increase in sympathetic activity may occur, in addition to effects at the renal level that together contribute to an increase in arterial blood pressure. When established, arterial hypertension alters the enzyme 11-β-hydroxysteroid dehydrogenase type 1 (11-βHSD1), responsible for controlling blood levels of glucocorticoids through the catalysis of the conversion of cortisone into cortisol, which promotes insulin resistance and seems to provide positive feedback to the situation.[33-35]

Regarding PA, it appears that, at a sufficient level, the physiological aspects of adipocytes are altered, such that there is an increase in lipolysis, a decrease in inflammatory cytokines, an increase in anti-inflammatory adipokines, and a decrease in insulin resistance.[36] These aspects are corroborated by evidence reported in a systematic review carried out by Sirico et al.,[37] in which the concentration of adiponectins and adipokines, involved in the anti-inflammatory response and the regulation of energy balance and leptin, showed better values in people who performed regular PA, when compared to those

Table 3 – Final hierarchical model of the association between independent variables and diabesity in the study population.

Level	Variables	Diabesity	
		Adjusted PR (95% CI)	P value
1	Age	0.96 (0.91-1.01)	0.110
	Sex		0.146
	Male	1	
	Female	2.10 (0.77-5.71)	
	Skin color		0.088
	Non-Black	1	
	Black	2.17 (0.92-5.08)	
2	Level of PA		0.044
	Sufficient	1	
	Insufficient	2.55 (1.20-6.36)	
	C. of eggs, beans, lentils or soy		0.182
	Yes	1	
	No	2.18 (0.69-6.87)	
3	Hypertension		0.037
	No	1	
	Yes	5.32 (1.10-25.73)	
	Hypercholesterolemia		0.033
	No	1	
	Yes	2.80 (1.08-7.23)	

C: consumption; CI: confidence interval; PR: prevalence ratio; PA: physical activity.

who did not, which possibly explains the positive association of insufficient PA with the outcome in the present study.

It is worth highlighting that the practice of PA has the potential to reduce plasma levels of leptin, interleukin 6 (IL-6), C-reactive protein, and tumor necrosis factor alpha (TNF-α), which seem be related to reduced inflammation in obesity, improved insulin response, and decreased insulin resistance.[36,37] Indeed, there is evidence that leptin inhibits insulin secretion and impairs the insulin response in adipocytes, which is correlated with reduced plasma leptin levels after moderate weight loss in obese people.[37]

Consequently, by reducing leptin levels and insulin resistance, the ability of PA, when at a sufficient level, to prevent diabetes mellitus is observed. In addition, it can result in an improvement in obesity, due to the increase in adiponectin concentrations, whose anti-inflammatory effects, decreased adiposity, stimulation of the consumption of fatty acids, and antiatherogenic factor are positively associated with the decrease in body fat.[34,38]

In the present study, arterial hypertension was the factor that demonstrated a greater magnitude of association with diabesity, followed by hypercholesterolemia; thus, in the studied population, there was a possible high burden of morbidities that make up metabolic syndrome and lead to a higher risk of mortality in older people.[39] Concomitantly, the observation that insufficient level of PA was the third variable that led to a greater probability of diabesity shows that the adoption of a behavioral pattern,

consisting of an active lifestyle, presents a possible strategy for the prevention or non-drug treatment for such chronic diseases.[24]

In this framework, the World Health Organization[24] and the Brazilian Ministry of Health[40] recommend for older adults the practice of at least 150 minutes of aerobic PA at moderate intensity per week or at least 75 minutes of vigorous PA. However, they highlight the possibility of a satisfactory level from the combination of both intensities. Furthermore, they recommended performing muscle strengthening exercises on at least 2 non-consecutive days during the week.[24,40]

The present study has some limitations, including the self-reported diagnosis of diabetes mellitus, arterial hypertension, and hypercholesterolemia, morbidities that can manifest silently without initially generating serious symptoms, which might not motivate some older adults to seek medical care. Furthermore, there is a possibility that some people have not received such diagnoses because they do not frequently seek health services for routine health evaluations.

Another possible limitation refers to the quantification of time spent practicing PA and indirect sedentary behavior, which can result in the over- or underestimation of such variables, as well as the self-reported identification of eating frequency. However, the use of the MMSE as an exclusion criterion for older adults with cognitive impairment is noteworthy. This approach aims to mitigate the impact of memory bias in such situations

On the other hand, the census perspective of the present study stands out as a strong point, because it allowed the evaluation of the older population of a small municipality in the Northeast Region of Brazil, which has low socioeconomic indicators and difficulties in offering health services.[14] Therefore, it is expected that the evidence presented can serve as a basis for the actions of health professionals in the framework of primary health care, with at the aim of preventing diabesity and carrying out interventions that would improve the prognosis of older adults with this outcome, not only in Aiquara, Bahia, Brazil, but also in other locations with similar characteristics.

Conclusion

This investigation's evidence corroborates the hypothesis set forth, as the main results demonstrate that the insufficient level of PA, high blood pressure, and hypercholesterolemia were positively associated with diabesity in the older population of Aiquara, Bahia, Brazil.

Acknowledgments

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Author Contributions

Conception and design of the research, analysis and interpretation of the data, writing of the manuscript and critical revision of the manuscript for intellectual content: Godinho GA, Valença Neto PF, Almeida CB, Meira SS, Roriz BC, Barbosa RS, Casotti CA, Santos L; acquisition of data: Valença Neto PF, Casotti CA, Santos L; statistical analysis: Valença Neto PF, Santos L.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Universidade Estadual do Sudoeste da Bahia under the protocol number 171.464. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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