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Association between diabetes and frailty, and the moderating role of sex in that association in older adults of the ELSA-Brasil study

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ABSTRACT

Objective: to investigate the association of diabetes and its duration with frailty and evaluate the moderating effect of sex on that association in older adults.
Methods: This cross-sectional study used data from the third visit (2017–2019) of the *Estudo Longitudinal de Saúde do Adulto* (ELSA-Brasil), a multicentre cohort of Brazilian civil servants. The data included were from 4886 participants aged ≥ 60 years. Diabetes was identified on the basis of self-reported diagnosis or laboratory test values. Frailty was evaluated on frailty phenotype criteria. Associations were estimated by way of multinomial regression models.
Results: Adjusted final models showed that older adults classified as having diabetes were 116% more likely to show frailty, and 27% more likely to show pre-frailty, than persons without diabetes. Individuals with a diagnosis before baseline and those with that diagnosis at baseline or during follow-up until visit 3 were, respectively, 145% and 92% more likely to be classified as frail, and 35% and 21% more likely to be classified as pre-frail, than individuals without diabetes. No modification by a multiplier effect of sex was observed in the final models.
Conclusions/interpretation: Older adults with diabetes returned greater odds of pre-frailty and frailty, and the odds were even greater in those with longer times since the diagnosis of diabetes, but sex did not modify those associations. These findings endorse the need for more frequent screening of older adults with diabetes with a view to early prevention and/or intervention.

1. Introduction

Worldwide, more than one billion persons are now over 60 years of age [1]. In Brazil, in 2022, older adults numbered 32.3 million (approximately 15.7 % of the population) [2]. A number of factors have contributed to longer life expectancy, including the advance of science, technology and the health industrial and economic complex [3], increased supply of accessible health services [4] and improved conditions of life afforded by greater economic and social development [5].

The rising prevalence of diabetes is related to population aging [6], and studies have reported diabetes as being a precursor to frailty. One of the mechanisms of action which explains this relationship is the inhibition of muscle protein synthesis caused by insulin resistance and then the degradation of these proteins due to hyperglicaemia [7].

The conceptual model of the frailty phenotype considers a set of signs and symptoms that lead to accentuated loss of strength, muscle mass and performance and to a state of chronic inflammation that occurs mainly in older adults [8–10]. Frailty has impact on the general population and is associated with higher frequencies of hospital admission and death [11–12].

However, as far as could be discovered, few studies have related the duration of diabetes with frailty, although it has been demonstrated that the length of time for which an individual is affected by diabetes, particularly with uncontrolled glycaemic levels, does affect strength and muscle mass [13] and that older adults who have had diabetes for longer (approximately ≥ 10 years) are at greater risk of frailty and pre-frailty

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[9,14].

There are also doubts as to the role of sex in frailty [15]. A systematic review by Qin et al. (2023) [10] showed that, of 62 studies, only 13 (four in Asia, four in Europe, two in North America and three in South America) evaluated the role of sex in the association between frailty and diabetes and, although being female was considered a risk factor, the South American studies were highly heterogeneous (I2 = 84 %, P = 0.002).

In a scoping review published in 2020 [16], 15 studies – 12 in Europe, two in China and only one in South America (Brazil) – identified specific features of the female sex, such as early menopause, hysterectomy, low free testosterone levels and high levels of C-reactive protein, which may increase the likelihood of frailty among women in post-menopause. Other studies have reported that low testosterone levels were also associated with frailty in older adult men [17–19].

Accordingly, this study investigated the association of diabetes, and its duration, with frailty and evaluated the moderating effect of sex on that association in older adults of the ELSA-Brasil longitudinal study of adult health.

2. Methods

2.1. Study design, population and data collection

This cross-sectional study used data from the third visit (2017–2019) of the ELSA-Brasil study, a prospective, multicenter cohort conducted at six higher education and research institutions located in the Northeast, South, and Southeast regions of Brazil. The participants in this cohort are active and retired civil servants aged from 41 to 84 years at the third wave. After signing a declaration of free and informed consent, all participants answered the questionnaires and underwent the tests and measurements, followed standardised techniques applied by trained, certified field researchers [20]. The methodological aspects of ELSA-Brasil are described in greater detail in Aquino et al. (2012) [21] and Schmidt et al. (2015) [22].

The participants selected for this study sample were those aged ≥ 60 years, who answered the questions and underwent testing for the five frailty phenotype criteria, for whom data were available regarding a medical diagnosis of diabetes and/or had undergone the laboratory tests to classify diabetes and whose data for the other covariables were not incomplete.

This study was approved by the ELSA-Brasil research centres involved and by the research ethics committee of the Escola Nacional de Saúde Pública (CEP-ENSP) as in CAAE12596919.2.0000.5240 on December 16, 2021.

2.2. Study variables

2.2.1. Exposure variable: diabetes

Diabetes was investigated by way of clinical parameters and self-reported information. Those with no self-reported diagnosis were assessed for diabetes on the basis of their laboratory results for blood collected after eight-hour night-time fast and were then classified as having diabetes if they met the following criteria: fasting plasma glucose (FPG ≥ 126 mg/dL; 7.0 mmol/L) or two-hour plasma glucose during oral glucose tolerance test (TOTG ≥ 200 mg/dL; 11.1 mmol/L) or glycated haemoglobin (HbA1c ≥ 6.5 %; 48 mmol/mol) [6,23].

The variable was classified in two ways, firstly by the presence of diabetes at visit 3 as: 1) "No" (no self-reported prior diagnosis and no laboratory criterion met to classify as diabetes); or 2) "Yes" (self-reported prior diagnosis and/or at least one laboratory criteria met). The second classification was by the timing of the diagnosis of diabetes and divided the variable into three categories: 1) "No" (no self-reported prior diagnosis); 2) "Yes, before baseline", (participants who self-reported a medical diagnosis of diabetes at visit 1); 3) "Yes, at baseline or during follow-up until visit 3′, (participants who self-reported a medical diagnosis of diabetes after visit 1 and/or returned altered laboratory values at visits 1, 2 or 3).

2.2.2. Outcome variable: frailty

Frailty was assessed on five frailty phenotype criteria investigated at visit 3 of ELSA-Brasil. These were:

(1). Self-reported unintentional weight loss (> 4.5 kg in the prior 12 months) identified by two questions: "In the past 12 months, have you lost weight without dieting?" and "How many kilos have you lost in the last 12 months?" This criterion was considered to have been met if the person reported losing weight without dieting and if that loss was > 4.5 kg [24].

(2). Self-reported fatigue/burnout identified by two questions, relating to the prior seven days: "How often have you felt that you could not get things done (you started something, but couldn't finish it)?" and "How often have you felt that everything you did was an effort?". The possible responses to the two questions were: never or rarely; sometimes; often; or always. This criterion was considered to be met if the answer to any of the questions was positive (often or always) [24].

(3). Muscular weakness measured twice by hand grip strength using a JAMAR dynamometer (Sammons & Preston, USA) with a maximum capacity of 90 kg. Muscular weakness was considered to exist when grip strength was less than or equal to the 1st quintile (20 % weakest) of the sample, adjusted by sex and body mass index (BMI) quartiles (Table s.1). Classification was by the best measurement [25–27].

(4). Slow gait pace measured by the Short Physical Performance Battery walking test in two four-metre walks at usual pace (using assistive devices when necessary) [28]. Pace was considered slow when walk time was equal to or greater than the 5th quintile (20 % slowest) of the samples stratified by sex and median height [24] (Table s.1). The slower of the two walk times was used [25–26].

(5). Physical activity was assessed by the International Physical Activity Questionnaire (IPAQ) long version [29] using only the leisure time physical activity domain (#AFTL) comprising questions about light activities (walks), moderate activities (which demand moderate physical effort and cause faster respiration than normal) and strong activities (that demand strong physical effort and cause much more rapid respiration than normal) [30]. Individuals with non-plausible physical activity (PA) data (> 840 min per week of weak PA, > 630 of moderate PA and > 420 of strong PA) were excluded. Physical activity level was considered low in the lowest quintile of the weighted sum of the week's physical activity for each sex [25–27]. For both men and women, the first quintile was zero.

In this way, frailty was categorised as: 1) Frail, for individuals who met three or more criteria; 2) Pre-frail, for individuals who met one or two criteria; and 3) Robust, for individuals who met no criteria for the presence of the phenotype.

2.2.3. Covariables

The selected covariables were investigated at visit 3 or at annual follow-up interview held by the end of visit 3 data collection and were selected as being a potential confounders between exposure and outcome on the basis of the literature [9,14,23,31,32]. These were: age (continuous in the regression and also categorised into 60 to 64 years; 65 to 74 years; 74 years or more to describe the population); sex (men and women), schooling (up to complete lower secondary, complete upper secondary and complete higher), marital status (separated, single, married/common-law marriage and widowed); race (black, mixed, white, yellow and indigenous); and the following chronic diseases: arthritis, stroke, heart attack, kidney failure, heart failure and high

blood pressure. The potential modifier effect of sex was also investigated.

2.3. Data analysis

The data were analysed using R software version 4.1.1 [33]. Descriptive analysis of the sample was by distribution of absolute and percentage frequencies for categorical variables and means and standard deviations (SDs) for the continuous variable. These analyses were performed to examine for significant differences between the outcome variable and the other categorical variables (chi-square test) and between the outcome variable and the continuous variable (Kruskal-Wallis test), to a 5 % level of significance.

The associations between diabetes and frailty were first modelled by ordinal logistic regression. However, at a 5 % level of significance, evidence of disproportionate odds was found. Therefore, the associations were estimated by means of odds ratios (OR) and their 95 % confidence intervals (95 %CIs) using crude and multinomial models adjusted for sociodemographic variables and chronic diseases. Model fit was evaluated by the Akaike information criterion (AIC). The modifier effect of sex was assessed by including a multiplicative interaction term in the final models.

3. Results

The final sample comprised 4886 individuals, 2191 (44.8 %) of them men and 2695 (55.2 %) women. Fig. 1 shows a flow diagram of the sample selection process.

The total sample was 55.2 % female, 57.1 % with complete higher education, 59.2 % married, 59.2 % white and with mean (SD) age 67.2 (5.6) years. Prevalence of diabetes at visit 3 was 32.3 %, of which 12.0 % diagnosed before baseline and 20.3 %, at baseline or during follow-up until visit 3 (Table 1).

By the frailty phenotype criteria, 53.1 % of older adults were classified as pre-frail and 7.3 % as frail. Mean (SD) age of the pre-frail was

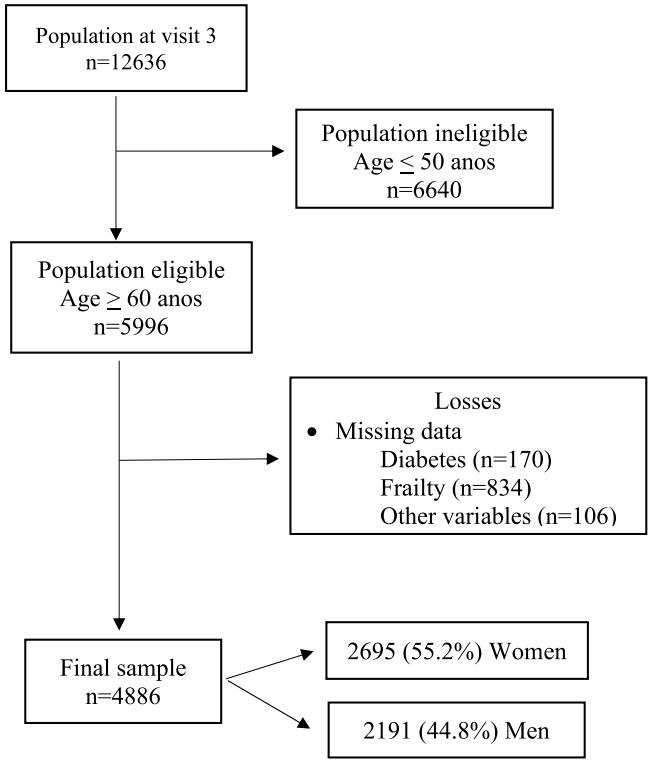

Fig. 1. Flow diagram of study sample selection process. ELSA-Brasil (2017–2019).

Table 1
Distribution of total sample and frailty, by sociodemographic variables and diabetes. ELSA-Brasil (2017–2019).

			FRAILTY		
	Total n (%)	Robust n (%)	Pre-frail n (%)	Frail n (%)	p-value*
Total n (%)	4886 (100.0)	1936 (39.6)	2594 (53.1)	356 (7.3)	
Mean age (± SD)	67.1 (5.6)	66.5 (5.2)	67.3 (5.7)	68.8 (6.2)	< 0.001
Age group					< 0.001
60 to 64	1936 (39.6)	824 (42.6)	1004 (51.9)	108 (5.6)	
65 to 74	2357 (48.3)	933 (39.6)	1252 (53.1)	172 (7.3)	
74 or more	593 (12.1)	179 (30.2)	338 (57.0)	76 (12.8)	
Sex					< 0.001
Men	2191 (44.8)	920 (42.0)	1145 (52.3)	126 (5.8)	
Women	2695 (55.2)	1016 (37.7)	1449 (53.8)	230 (8.5)	
Schooling					< 0.001
Up to complete lower secondary	686 (14.1)	151 (22.0)	428 (62.4)	107 (15.6)	
Complete upper secondary	1409 (28.8)	487 (34.6)	798 (56.6)	124 (8.8)	
Complete higher	2791 (57.1)	1298 (46.5)	1368 (49.0)	125 (4.5)	
Marital status					< 0.001
Married/stable union	2892 (59.2)	1225 (42.4)	1488 (51.5)	179 (6.2)	
Separated/divorced	790 (16.2)	288 (36.5)	440 (55.7)	62 (7.8)	
Single	718 (14.7)	259 (36.1)	401 (55.8)	58 (8.1)	
Widowed	486 (9.9)	164 (33.7)	265 (54.5)	57 (11.7)	
Race/colour					< 0.001
White	2890 (59.2)	1246 (43.1)	1470 (50.9)	174 (6.0)	
Mixed	1171 (24.0)	412 (35.2)	664 (56.7)	95 (8.1)	
Black	610 (12.5)	196 (32.1)	344 (56.4)	70 (11.5)	
Yellow	163 (3.3)	66 (40.5)	84 (51.5)	13 (8.0)	
Indigenous	52 (1.0)	16 (30.8)	32 (61.5)	4 (7.7)	
Diabetes					< 0.001
No	3306 (67.7)	1425 (43.1)	1706 (51.6)	175 (5.3)	
Yes	1580 (32.3)	511 (32.3)	888 (56.2)	181 (11.5)	
Diabetes diagnosed < 0.001					
No	3306 (67.7)	1425 (43.1)	1706 (51.6)	175 (5.3)	
Yes, before baseline	991 (20.3)	341 (34.4)	550 (55.5)	100 (10.1)	
Yes, at baseline or during follow-up until visit 3	589 (12.0)	170 (28.9)	338 (57.4)	81 (13.8)	

Note.
* Chi-square for the categorical variables and Kruskal-Wallis test for the numerical variable (age).

67.3 (5.7) years and, of the frail, 68.8 (6.2) years. The prevalence of frailty increased with age, was greater among women (8.5 %) than men (5.8 %) and decreased with increased schooling, tripling among older adults with up to complete lower secondary school (15.6 %) as

compared with those who completed higher education (4.5 %). Smaller percentages of pre-frailty and frailty were found among married persons and those whose race was white (Table 1).

Among individuals with diabetes, frequencies of pre-frailty (56.1 %) and frailty (11.5 %) were greater than among those without a diagnosis of diabetes (51.6 % pre-frail and 5.3 % frail). Among those with a diagnosed before baseline, 57.4 % were pre-frail and 13.8 %, frail. Meanwhile, of those classified as with diabetes at baseline or during follow-up until visit 3, 55.5 % were pre-frail and 10.1 %, frail. Among those classified as not having diabetes, robust older adults were more frequent (43.1 %) than among those classified as having diabetes at baseline or during follow-up until visit 3 (34.4 %) or diagnosed before baseline (28.9 %) (Table 1).

In the final adjusted models, the older adults classified as having diabetes at visit 3 were found to have 110 % (95 %CI = 1.64–2.70) and 26 % (95 %CI = 1.10–1.44) higher odds of frailty and pre-frailty, respectively, than the older adults classified as not having diabetes (Table 2).

Meanwhile, in the final model, the odds that older adults with a diagnosis of diabetes before baseline would be classified as frail were 145 % higher (95 %CI = 1.75–3.42) and, as pre-frail, 35 % higher (95 % CI = 1.10–1.66), than for older adults classified as without diabetes. With a diagnosis at baseline or during follow-up until visit 3, the older adults were at 92 % (95 %CI = 1.44–2.57) greater odds of being frail and 21 % (95 %CI = 1.03–1.42) of being pre-frail, than those without a diagnosis of diabetes. Because of overlapping of confidence intervals between groups by time since diagnosis of diabetes, it cannot be asserted that they differed, but the dose-response effect is clear (Table 3).

After multiplicative interaction terms were added to the final models, sex was not found to produce any modifier effect (Tables 2 and 3).

4. Discussion

This study found that older adults classified as having a diagnosis of diabetes were at greater odds of being classified as pre-frail and frail than those with no diagnosis of diabetes. When the groups with a diagnosed before baseline and at baseline or during follow-up until visit 3 were classified by pre-frailty and frailty, although the associations continued positive and the specific measurements continued greater in those with a diagnosed before baseline than those diagnosed at baseline or during follow-up until visit 3, there was no statistical difference between them, because the confidence intervals overlapped. Unexpectedly, in the multiplicative model, sex was not found to exert a modifier effect on the association between diabetes and frailty.

One meta-analysis published in 2020 produced a summary measure from eight studies which showed that the odds of frailty in people with diabetes were 48 % greater (OR: 1.48; 95 %CI: 1.33–1.64) than those for people without diabetes [34]. Of those studies, only one offered an odds ratio for pre-frailty, but it was without statistical significance [35].

In a more recent meta-analysis published in 2023, the group measure from eight studies showed that individuals with diabetes were at 81 % greater odds (OR: 1.81; 95 %CI: 3.87–14.90) of frailty than those without diabetes [10]. These findings converge with those of this study, which not only showed that a diagnosis of diabetes was associated with greater likelihood of frailty, but found a stronger association.

As regards the timing of the diagnosis of diabetes, Kulkarni et al. (2023) [14] found that 58.8 % of those diagnosed with diabetes 6–10 years earlier were classified as frail. That percentage rose to 76.5 % for individuals diagnosed with diabetes 11 or more years earlier. In the same study, the mean duration of diabetes in frail individuals was 9.1 (SD 4.9) years, and in robust individuals, 6.4 (SD 3.3) years. Another study showed that 45.1 % of the sample had diabetes for longer than 10 years, corresponding to 37.6 % of the robust subjects, 58.0 % of those who were pre-frail and 45.3 % of the frail [9].

Corroborating the studies above, this study found that prevalences of frailty increased with the length of time since diagnosis: 13.8 % of those diagnosed with diabetes before baseline and 10.1 % of those with diabetes at baseline or during follow-up until visit 3, were frail, that is, frailty was more prevalent among those diagnosed a longer time before baseline.

When odds ratios were considered by time since diagnosis, this study found that individuals diagnosed before baseline were more likely to be frail or pre-frail than those diagnosed at baseline or during follow-up until visit 3. As far as could be discovered, there are no studies reporting odds ratios at different times since diagnosis or by duration of diagnosis of diabetes. One study was found to have investigated early diagnosis of diabetes as the outcome, but the exposure studied was mortality. That study found greater severity and mortality in individuals with an early diagnosis of diabetes (at 30 years of age) and lesser

Table 2
Association between diabetes and frailty. ELSA-Brasil (2017–2019).

	Frailty	
	Pre-frail (OR 95 %CI)	Frail (OR 95 %CI)
Diabetes*		
Model 0[a]		
Yes	1.45 (1.27–1.65)	2.88 (2.29–3.63)
Model 1[b]		
Yes	1.36 (1.19–1.56)	2.50 (1.97–3.19)
Model 2[c]		
Yes	1.26 (1.10–1.44)	2.11 (1.64–2.70)
Interaction with sex[d]		
Yes	$p = 0.10$	$p = 0.50$

Note.
[a] Crude model.
[b] Model 0[a] + adjusted by sociodemographic variables (schooling, sex, age, marital status and race).
[c] Model 1 + adjusted for chronic diseases (high blood pressure, stroke, heart attack, heart failure, kidney failure and arthritis).
[d] Model 2[c] + interaction with sex.
[*] Reference category: No.

Table 3
Association between time since diagnosis of diabetes and frailty. ELSA-Brasil (2017–2019).

	Frailty	
	Pre-frail (OR 95 % CI)	Frail (OR 95 % CI)
Time since diagnosis of diabetes		
Model 0[a]		
Yes, at baseline or during follow-up until visit 3	1.35 (1.16–1.57)	2.39 (1.82–3.14)
Yes, before baseline	1.66 (1.36–2.02)	3.88 (2.85–5.28)
Model 1[b]		
Yes, at baseline or during follow-up until visit 3	1.29 (1.11–1.51)	2.22 (1.67–2.94)
Yes, before baseline	1.50 (1.22–1.84)	3.05 (2.20–4.21)
Model 2[c]		
Yes, at baseline or during follow-up until visit 3	1.21 (1.03–1.42)	1.92 (1.44–2.57)
Yes, before baseline	1.35 (1.10–1.66)	2.45 (1.75–3.42)
Interaction with sex[d]		
Yes, baseline or during follow-up until visit 3	$p = 0.08$	$p = 0.29$
Yes, before baseline	$p = 0.59$	$p = 0.88$

Note.
*Reference category: No.
[a] Crude model.
[b] Model 0[a] + adjusted by sociodemographic variables (schooling, sex, age, marital status and race).
[c] Model 1 + adjusted for chronic diseases (high blood pressure, stroke, heart attack, heart failure, kidney failure and arthritis).
[d] Model 2[c] + interaction with sex.

severity and mortality in individuals with a late diagnosis of diabetes (at 70 years) [36].

Other studies report that longer duration of diabetes can lead to the appearance of psychological distress, which can also occur because of the larger number of chronic complications, greater difficulty in controlling glycaemia and more complex self-management of diabetes [37–38]. Worsening control of glycaemia is related to loss of strength and muscle mass [13], and some studies have demonstrated that controlling glycaemia has a beneficial effect on the relationship between diabetes and frailty [14,39].

Studies have reported that sex is associated with the appearance of diabetes and frailty, with women returning greater prevalences and risk of frailty [15,40] and, although world prevalences of diabetes estimated for men and women from 20 to 79 years of age do not differ greatly, in Brazil, prevalences are higher among women (17.9 million, 10.4 %) than among men (13.8 million, 8.4 %) [41].

Ruan et al. (2020) [16] argue that the specific features of the female sex (hysterectomy, low free testosterone levels etc.) increase the likelihood of frailty among women post menopause. Some of these mechanisms of action in the relation between menopause and frailty have been observed in studies that explain the relationship between diabetes and frailty.

However, although prevalences of frailty are higher in women, as observed in this and other studies [12,15,24], and also higher in women with diabetes, both in this study (data not shown) and in the studies by Kang et al. (2021) [42] and O'Donovan et al. (2021) [43], the hypothesis that sex may be modifying these relationships was not confirmed.

This finding was not entirely unexpected, as the evidence in the literature is not fully consistent. According to the systematic review by Qin et al. (2023) [10], only 13 of the 62 studies assessed sex in the association between frailty and diabetes. Although female sex was often considered a risk factor, the results showed high heterogeneity. One possible explanation is that the biological and behavioral mechanisms linking diabetes to frailty may operate similarly in men and women—for instance, lower testosterone levels, which can increase the likelihood of frailty [16–19].

This study has strengths and limitations. Its strong points are, particularly, the use of the frailty phenotype, a method widely used and validated in various populations and enviornments [34,44] which enables comparisons to be made with this study. Another point is that, as far as could be determined, there are no other studies examining for the modifier effect of sex on the association between diabetes and frailty and few studies considering the relation of time from diagnosis with frailty. Other important strong points of this study are the methodological rigour of the data collection stages and the size and diversity of the study sample [20].

However, certain limitations should be mentioned. One was that all individuals with diabetes were included without differentiating them by diabetes type. One current challenge in diabetes research is to determine exactly the type of diabetes. The different types of diabetes may interfere differently in the relation with frailty, given that they have different physiological and care characteristics. Nonetheless, the International Diabetes Federation (2021) [6] argues that, in adult population data, the trends may possibly be attributed to type-2 diabetes. Another limitation was the assessment of frailty at only one point in time, which limits the possible causal inferences. However, the ELSA-Brasil population was younger when entering the study and, therefore, the people involved were probably not frail at visits prior to visit 3.

There is a strong biological rationale for the directionality described here. The mechanisms linking diabetes to frailty include the release of elevated levels of cytokines such as tumor necrosis factor-alpha and interleukin-6, which stimulate proteolysis and apoptosis in muscle cells [45]; reduced levels of insulin-like growth factor 1, which plays a key role in protein synthesis [46]; mitochondrial alterations in older adults with diabetes, leading to impaired energy production required for muscle contraction [13]; and dysregulation of hormonal levels, such as testosterone and cortisol, as well as nutrients including vitamin D [47–49]. Moreover, the presence of atherosclerosis—one of the most common forms of cardiovascular disease (CVD) associated with both diabetes [41] and premature biological aging [50] —may further compromise muscle performance due to peripheral vascular disease and peripheral neuropathy [46,48]. These complications increase the risk of ulcer development, particularly in the feet, as a result of external trauma and/or abnormal distribution of internal bone pressure [41], leading to a decline in physical function and lower levels of physical activity, thereby exacerbating muscle mass loss [46,48].

One challenge facing frailty research is that different methods based on different conceptual models are used, reflecting a lack of consensus which can produce different findings [34,51]. Hoogendijk et al. (2019) [51] argued that there are difficulties in bringing these studies to bear on clinical practice, because ideally the measurements should be specified and standardised.

This study explores the underexamined roles of sex and diabetes duration in frailty development. Additionally, given that most studies have been conducted in high-income countries, this research provides novel evidence from a middle-income country with lifelong social inequities. The findings underscore the importance of early identification and management of frailty among older adults with diabetes—regardless of sex. It is essential to adopt a new perspective on older adults by establishing health indicators incorporating epidemiological data on frailty. Frailty is potentially preventable and reversible through lifestyle interventions, including physical activity, adequate nutrition, and improved glycemic control (HbA1c 7.6–8.5 %) [52–54].

5. Conclusion

As has been found in studies in high-income countries, so in Brazil, older adults with diabetes are at higher odds of developing frailty and pre-frailty, and also the odds of frailty and pre-frailty are higher in those with longer times since diagnosis of diabetes. Contrary to expectations, no interaction by sex was observed in the association between diabetes and frailty. Accordingly it is suggested that clinical practice include systematic assessment of frailty in individuals with diabetes with a view to early prevention and/or intervention in the development of frailty.

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CRediT authorship contribution statement

Elizabeth Leite Barbosa: Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rosa Weiss Telles:** Writing – review & editing, Validation, Funding acquisition. **Maria de Jesus Mendes da Fonseca:** Writing – review & editing, Validation, Funding acquisition. **Maria Inês Schmidt:** Writing – review & editing, Validation, Funding acquisition. **Sandhi Maria Barreto:** Writing – review & editing, Validation, Funding acquisition. **Bruce Duncan:** Writing – review & editing, Validation, Funding acquisition. **Rosane Harter Griep:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors report there are no competing interests to declare.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjfa.2025.100115.

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