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Original Research

Frailty Status and Gait Parameters of Older Women With Type 2 Diabetes

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Key Messages

- Frailty status has a major impact on the gait of vulnerable (prefrail and frail) older women with type 2 diabetes.
- Older vulnerable women with diabetes walked with decreased velocity, cadence and step length and had increased stance time compared to robust older women with diabetes and to robust and vulnerable older women without diabetes.
- Double support time was the only gait parameter similar between the vulnerable older women with diabetes and the robust older women with diabetes.
- Vulnerable older women with type 2 diabetes are at higher risk for falls and disability; therefore, screening this group for frailty status is important and is recommended.

A R T I C L E I N F O

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A B S T R A C T

Objectives: Gait decline in individuals with frailty status is associated with comorbidities, falls and reduced mobility, reflecting changes in gait. The prevalence of frailty in individuals with type 2 diabetes is higher compared to individuals without diabetes. However, the consequences of frailty status on gait in older women with diabetes are unclear. The objective of the study was to investigate gait changes in older women with diabetes who are classified as vulnerable, having 1 or more frailty conditions, or robust, having none of the conditions, according to the Fried phenotype.
Methods: Participants included 203 older women: 112 without diabetes and 91 with diabetes. The nondiabetes robust group included 59 older women: nondiabetes, vulnerable, 53; diabetes, robust, 26; and diabetes, vulnerable, 65. Gait parameters were obtained by using the GAITRite system and included velocity, cadence, step length, stance time and double-support time. Multivariate analysis was conducted followed by post hoc analysis.
Results: Older women with diabetes and vulnerable status used more drugs and had higher body mass indexes than the groups without diabetes who were vulnerable and robust; there was no difference between the diabetes, robust and diabetes, vulnerable groups. Falls history and fear of falling were similar in all groups. Vulnerable older women with diabetes walked with decreased velocity, cadence and step length and increased stance time compared to all groups and with increased double-support time compared to the nondiabetes robust and nondiabetes vulnerable groups.
Conclusions: Gait decline in vulnerable older women with diabetes is worsened by their frailty status. Our study reinforces the importance of screening older women with diabetes for frailty status.

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RÉSUMÉ

Objectifs : Le déclin de la marche chez les individus fragiles est associé à des affections comorbides, à des chutes et à la réduction de la mobilité, qui se reflètent par des changements dans la démarche. La prévalence de la fragilité chez les individus atteints du diabète de type 2 est élevée par rapport aux individus non diabétiques. Toutefois, on ignore les conséquences de la fragilité sur la démarche des femmes âgées atteintes de diabète. L'objectif de l'étude était d'examiner les changements dans la démarche des femmes âgées atteintes de diabète qui, selon le phénotype de Fried, sont classifiées dans la catégorie des personnes vulnérables ayant 1 critère de fragilité ou plus, ou dans la catégorie des personnes robustes n'ayant aucun critère de fragilité.
Méthodes : Parmi les participantes, on retrouvait 203 femmes âgées, dont 112 femmes non diabétiques et 91 femmes diabétiques. Le groupe de femmes non diabétiques et robustes regroupait 59 femmes âgées; le groupe de femmes non diabétiques et vulnérables, 53; le groupe de femmes diabétiques et robustes, 26; le groupe de femmes diabétiques et vulnérables, 65. Les paramètres de la marche obtenus au moyen du système GAITRite étaient les suivants : la vitesse, la cadence, la longueur de pas, la durée de l'appui et la durée du double appui. Nous avons effectué l'analyse multivariée, puis l'analyse *post-hoc*.
Résultats : Les femmes âgées, diabétiques et vulnérables prenaient plus de médicaments et avaient des indices de masse corporelle plus élevés que les groupes de femmes non diabétiques, vulnérables et robustes. Il n'y avait aucune différence entre les groupes de femmes diabétiques et robustes et les groupes de femmes diabétiques et vulnérables. Les antécédents de chutes et la crainte de tomber étaient similaires dans tous les groupes. Comparativement à tous les groupes de femmes, les femmes âgées, diabétiques et vulnérables montraient une diminution de la vitesse, de la cadence et de la longueur de pas et une augmentation de la durée d'appui et, comparativement aux groupes de femmes non diabétiques et robustes, et aux groupes de femmes non diabétiques et vulnérables, elles montraient une augmentation de la durée du double appui.
Conclusions : La fragilité aggrave le déclin de la marche chez les femmes âgées, vulnérables et diabétiques. Notre étude accroît l'importance du dépistage de la fragilité chez les femmes âgées atteintes de diabète.

Mots clés :
chutes accidentelles
diabète de type 2
personnes âgées fragiles
marche/démarche
personne âgée

Introduction

The gait of individuals with type 2 diabetes mellitus is characterized by decreased velocity and step length and increased stance time, cadence and base of support (1–3). The gait of individuals with peripheral neuropathy demonstrated decreased ankle range of motion, peak ankle moment and power during push-off, resulting in shorter step length and decreased velocity when compared to their counterparts (4,5). These gait alterations are linked to a variety of factors, but according to Brach et al, health status—determined by the number of chronic conditions and medications—and lower muscle strength explained the greatest proportion of the association between gait alteration and diabetes (6).

Decreased muscle strength is a result of lower skeletal muscle mass, a condition called sarcopenia, and is more pronounced in individuals with diabetes (7). Although sarcopenia is a normal aging physiologic process, individuals with diabetes present with accelerated loss of muscle mass and function (8,9). Attempts to explain lower muscle strength in older adults with diabetes are extensive but inconclusive; however, poor glycemic control and muscle fat infiltration results in loss of muscle density (10). One of the consequences of sarcopenia is functional decline. In 2012, the Invecchiare in Chianti; aging in the Chianti area (InCHIANTI) study of 835 participants (11.4% with diabetes) showed that muscle density, strength and power accounted for a full 25% of the slower gait velocity compared to the group without diabetes (2). Similarly, Leenders et al showed that differences in muscle mass and strength were associated with poor performance on the sit-to-stand test; the group with diabetes spent significantly more time than the group without diabetes (7). Furthermore, differences in gait speed, muscle strength and power between individuals in these 2 groups were independent of the presence of neuropathy and peripheral arterial disease, suggesting a direct effect of diabetes on functional performance (2,11).

Sarcopenia is also a major component of frailty (12). According to the physical frailty phenotype described by Fried et al, individuals with 3 or more of the following components are considered frail: decreased gait speed, handgrip strength and physical activity; exhaustion; and weight loss. Those with only 1 or 2 components are considered prefrail (13). The prevalence of frailty in type 2 diabetes is 11.9% compared to 8% in individuals without diabetes who are older than 65 years of age (14). It is also greater in older individuals with diabetes and those who are 80 to 90 years of age, compared to those 60 to 69 years of age and community-dwelling adults over the age of 65 (15). In a recent population-based study (16), frailty surpassed cardiovascular and cerebrovascular disease as a risk factor for death and disability in older adults with type 2 diabetes.

Gait characteristics in older adults with differing frailty statuses showed that prefrail individuals walk more slowly, have shorter step lengths and larger bases of support and have a longer double support time than nonfrail individuals (17). In a similar study, Montero-Odasso et al showed that gait velocity, stride time and step width were significantly different among all frailty groups; cadence, stride length and double support time were different between frail and nonfrail individuals and between prefrail and nonfrail individuals. Stride-time variability was significantly higher in frail people compared to nonfrail people, and step width variability was different among frail, prefrail and nonfrail people (18). Frailty is also associated with lower cognitive performance, reduced health self-perception, comorbidities, falls and reduced mobility, reflecting changes in spatiotemporal and gait variability parameters (18–21). Description of gait changes in frail individuals with type 2 diabetes is less clear. Toosizadeh et al showed that prefrail status hides gait differences between those with diabetes and with peripheral arterial disease and controls; however, the sample size was small (22).

Knowledge of the consequences of frailty on the gait of older adults with type 2 diabetes could improve the geriatric assessment as well as the functional performance of these patients. Therefore, the objective of this study was to understand the effects of frailty status on gait parameters of older women with type 2 diabetes classified as vulnerable (with 1 or more frailty conditions) or robust (with none of the conditions) according to the Fried phenotype (13).

Methods

Study design and ethics

This was a cross-sectional observational study. The Research Ethics Committee of Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil, approved this study (#ETIC 442/08). All participants were informed about the contents of the research and gave written informed consent prior to the data collection.

Participants

A convenience sample of 209 older women with and without type 2 diabetes was recruited from senior citizen centers in the city of Belo Horizonte, Brazil, and from the databases of previous research projects with older adults that had been conducted by our research group. The inclusion criteria were women 65 years of age or older, living independently in the community and able to ambulate without walking-aid devices. The exclusion criteria were cognitive impairment detectable by the Mini-Mental State Examination using the Brazilian cut-off points based on the degree of formal education (<13 for illiterate individuals, <18 for those with fewer than 8 years of schooling, and <26 for those with 8 or more years of schooling) (23); vestibular symptoms; motor sequel due to rheumatic, orthopedic and/or neurologic diseases; strong pain in the spine or lower limbs; accentuated postural deviation; severe foot deformity; and visual impairment not correct by lenses. The inclusion criterion for the group with diabetes was an affirmative answer to the following question: “Has a physician ever said that you have a diagnosis of diabetes mellitus?”

Measurements

Sociodemographic and clinical variables. Trained research assistants conducted face-to-face interviews using a standardized questionnaire to collect the following information: age, years of formal education, comorbidities and medications used regularly in the past 3 months. In addition, anthropometric measures, such as body mass and height, were obtained to determine the body mass index (BMI).

Frailty status. Participants were classified considering the 5 criteria proposed by Fried et al, as follows: unintentional weight loss, self-reported exhaustion, weakness, low physical activity and slow walking speed. Individuals with 3 or more of the 5 criteria were classified as frail; those exhibiting 1 or 2 criteria were classified as prefrail, and those with no criteria were classified as nonfrail (13).

Unintentional weight loss was determined by an affirmative answer to the question: “In the last year, have you lost more than 4.5 kg unintentionally (i.e. not related to diet or exercise)?” Self-reported exhaustion was assessed by 2 questions from the Center for Epidemiological Studies-Depression Scale: “How often in the last week did you feel that everything you did was an effort?” and “How often in the last week did you feel that you could not get going?” Answering “a moderate amount” or “most of the time” to 1 of the questions was considered positive for this criterion. Handgrip strength of the dominant hand (mean of 3 measurements) was assessed using a handheld JAMAR dynamometer (Lafayette Instrument Company, Lafayette, Indiana, United States), and weakness was determined based on the cutoff points proposed by Fried et al (13). Participants’ activity level was measured using the Brazilian version of the Minnesota Leisure Time Activities Questionnaire, which measures, in kilocalories, a person’s energy expenditure during the past 2 weeks (24). The physical-activity criterion for frailty was positive if the energy expenditure per week was below 383 kcal/week for men and below 270 kcal/week for women. The walking speed of participants was evaluated as the time spent walking 4.6 meters at a self-selected pace, and their slow walking speed was determined based on the cutoff points proposed by Fried et al (13).

Fear of falling and falls. The Brazilian version of the Falls Efficacy Scale, International (FES-I), was used to assess the level of concern about falls (25). The FES-I contains 16 activities, from simple in-home activities to more demanding physical and social activities. The items of the FES-I can be scored from 1 (not at all concerned) to 4 (very concerned), with total scores ranging from 16 to 64. The higher the score, the more fearful the individual is about falling. The FES-I Brazil demonstrated adequate internal consistency (Cronbach alpha coefficient=.93) and good intra- and inter-rater reliability of the total score (intraclass correlation coefficient=.84 and .91, respectively) when applied to a group of community-dwelling Brazilian older adults. Falls were recorded by asking the participants how many times they had fallen in the past year. Participants were classified as nonfallers if their number of falls was 0 and fallers if they had ≥1 fall.

Gait parameters. Gait variables were obtained by using a rubber electronic mat (5.74 meters in length, 91 cm in width and 0.6 cm in thickness) with 18,432 embedded pressure sensors (GAITRite, CIR Systems, Franklin, New Jersey, United States). As the individual walks on the mat, the system captures the geometry and contact of the foot with the ground in functions of time and distance. The mat was placed in a well-illuminated hallway, free of noise and visual distractions. Participants wore their habitual footwear and performed 6 walks at self-selected paces. Start and stop points were delimited by cones placed 2 meters from the edge of the mat for initial acceleration and final deceleration. The capture frequency of the gait parameters was 120 Hz. The results from the 6 walks were averaged to obtain a single value for each gait parameter. Data were averaged using the GAITRite software v. 3.9.

Gait variables included velocity (cm/s), cadence (steps/min), step length (cm), base of support (cm), swing time(s), stance time(s) and double support time(s), as defined by the GAITRite manual. Variabilities in the gait parameters (velocity, step length, base of support, swing time, stance time and double support time) were quantified by using the coefficient of variation, which is the ratio between the standard deviation and the mean, multiplied by 100.

Statistical analyses

Characteristics of the participants, as well as gait spatiotemporal and variability data were summarized using measures of central tendency and dispersion. The extreme scores and outliers were observed through the Mahalanobis distance (D^2), which measures the “multivariate” distance between each case and the group multivariate mean. The cases were evaluated using the chi-square distribution, with p=0.001. Cases with a Mahalanobis distance ≥24.322 were considered outliers and were eliminated from the data.

Multivariate analysis of variance (MANOVA) followed by Turkey post hoc analysis were applied to the participants’ characteristics: age, body mass index (BMI), Mini-Mental State Examination and FES-I scores, comorbidities and number of drugs in use. A chi-square test of independence was conducted to determine the relationship among groups and the number of fallers. Both fear of falling and fall history have been associated with lower gait velocity (1,17). Therefore, if the scores of the FES-I or the number of fallers proved to be significant among groups, we added them as covariates in the MANOVA analysis with the gait variables.

Then, we conducted a t test on the dependent variables (gait, spatiotemporal variables and gait variability) to determine which variables were statistically different between the groups of women with diabetes (n=91) and older women without diabetes (n=112). Only the statistically significant gait variables (velocity, cadence, step length, stance time and double support time) were added to the MANOVA model conducted with 1 independent variable, group conditions; and the significantly dependent gait variables, followed by Turkey post hoc analysis.

The t test conducted on the gait variability data showed that none of the variables (coefficient of variation of velocity, step length, swing time, stance time, base of support and double support time) were statistically different between the groups of women with and without diabetes. The level of significance was 0.05, but for the multiple pairwise comparisons, a Bonferroni correction ($0.05/6=p<0.008$) was applied to avoid a type I error. SPSS package v. 17 (IBM, Armonk, New York, United States) was used for the analysis.

Results

A total of 203 older women participated in the study: 112 without diabetes and 91 with diabetes. Of the potential participants, 6 were eliminated from the study: 1 older woman without diabetes and nonfrail; 2 with diabetes and prefrail; and 3 with diabetes and frail. Because the number of frail older women in the study was small (13 participants), we decided to unite the prefrail and frail women and call the groups *vulnerable with diabetes* or *vulnerable without diabetes* (older women with 1 or more components of the frailty phenotype described by Fried et al) (13). The nonfrail groups were called robust women with diabetes or robust women without diabetes. The sample was then divided into 4 groups: 1) nondiabetes robust; 2) nondiabetes vulnerable; 3) diabetes robust; and 4) diabetes vulnerable.

The nondiabetes robust group included 59 older women (71.7±4.6 years); the nondiabetes vulnerable group included 53 (73.8±5.0 years); the diabetes robust group included 26 (72.5±5.3 years); and the diabetes vulnerable group included 65 older women (71.4±5.1 years). The proportion of fallers, with 1 or more falls, in the nondiabetes robust group was 30.5% (18/59); in the nondiabetes vulnerable group, 32.1% (17/53); in the diabetes robust group, 26.9% (7/26); and in the diabetes vulnerable group, 30.8% (20/62); data from 3 women who had diabetes and were vulnerable were missing. The relationship between the number of fallers (≥1 fall) and the groups was not significant (χ^2 [3, n=200]=0.283, p=0.963). The scores from the FES-I were also similar between groups (Table 1). Therefore, the MANOVA model was conducted without fear of falling or self-reported fall history in the previous year as covariate variables. Table 1 describes the characteristics of the groups.

A statistically significant Box M test ($p<0.05$) indicated that the equality of the variance-covariance matrices of the dependent variables across levels of the independent variable was violated; therefore, the Pillai trace was used to evaluate the significance of the multivariate effect. A significant Bartlett test of sphericity indicated that the data had sufficient correlation among the dependent variables to proceed with the MANOVA. Using the Pillai criterion, the participants' characteristics were significantly affected by the groups: Pillai trace=0.313, $F(6, 588)=3.807$; $p<0.000$, partial $\eta^2=0.104$. Post hoc analysis showed that BMIs were significantly higher in the diabetes vulnerable group when compared to the nondiabetes robust and nondiabetes vulnerable groups.

The diabetes vulnerable group also showed a significantly higher number of comorbidities in relation to the nondiabetes robust group. The number of drugs in use was significantly higher in the diabetes robust group in relation to the nondiabetes robust group; the number was also higher for the diabetes vulnerable group when compared to the nondiabetes robust and nondiabetes vulnerable groups (Table 1).

Similarly, using the Pillai criterion, gait variables were significantly affected by the groups: Pillai trace=0.243, $F(5, 591)=3.470$; $p<0.000$; partial $\eta^2=0.081$. Older vulnerable women with diabetes walked with decreased velocity, cadence and step length, spent more time in stance compared to all the other groups, and walked with increased double support time compared to nondiabetes robust and nondiabetes vulnerable groups (Table 2). Figure 1 shows the comparison among groups. Independent of the t test results, we conducted a MANOVA on the gait variability data. The results showed

Table 1
Multiple comparisons of the characteristics of the groups of older women who participated in the study (N=203)

Variables	Groups mean (SD)				Multiple comparisons p value					
	NDR n=59	NDV n=53	DR n=26	DV n=65	NDR vs. NDV	NDR vs. DR	NDR vs. DV	NDV vs. DR	NDV vs. DV	DR vs. DV
Age (years)	71.7 (4.6)	73.8 (5.0)	72.5 (5.3)	71.4 (5.1)	.097	.889	.994	.675	.046	.788
BMI (kg/m²)	27.0 (4.1)	26.7 (3.7)	27.7 (4.1)	30.0 (4.4)	.977	.905	.001*	.755	.000*	.122
MMSE (score)	27.0 (2.5)	26.3 (2.8)	26.5 (2.4)	26.4 (3.0)	.596	.847	.672	.998	.998	.999
Number of comorbidities	2.8 (1.6)	2.9 (1.6)	4.0 (1.7)	3.8 (1.7)	.953	.011	.003*	.043	.022	.974
Number of drugs in use	2.7 (1.6)	3.3 (2.0)	4.3 (2.2)	4.6 (2.0)	.663	.003*	.000*	.122	.002*	.974
FES-I (score)	23.3 (6.6)	24.8 (7.3)	21.2 (5.0)	24.6 (8.1)	.679	.604	.883	.157	.973	.265

BMI, body mass index; *DR*, diabetic robust; *DV*, diabetic vulnerable; *FES-I*, Falls Efficacy Scale, International; *MMSE*, Mini-Mental State Examination; *NDR*, nondiabetic robust; *NDV*, nondiabetic vulnerable; *SD*, standard deviation.
* Significant at p<0.008.

Table 2
Multiple comparisons of the gait variables in the groups of vulnerable and robust older women with and without diabetes who participated in the study (N=203)

Gait variables	Groups Mean (SD)				Multiple comparisons p value					
	NDR n=59	NDV n=53	DR n=26	DV n=65	NDR vs. NDV	NDR vs. DR	NDR vs. DV	NDV vs. DR	NDV vs. DV	DR vs. DV
Velocity (cm/s)	130.6 (18.5)	127.7 (13.8)	127.9 (12.9)	112.6 (14.4)	.763	.877	.000*	.999	.000*	.000*
Cadence (steps/min)	120.9 (8.3)	120.9 (7.3)	120.6 (6.2)	114.6 (8.1)	.999	.997	.000*	.997	.000*	.006*
Step length (cm)	64.7 (7.0)	63.3 (4.7)	63.6 (5.4)	59.0 (5.7)	.606	.876	.000*	.995	.000*	.003*
Stance times	0.60 (0.03)	0.60 (0.04)	0.60 (0.03)	0.63 (0.05)	.996	.999	.000*	.988	.000*	.001*
Double support times	0.20 (0.02)	0.20 (0.03)	0.20 (0.02)	0.23 (0.04)	.960	.990	.000*	.898	.000*	.011

DR, diabetes robust; *DV*, diabetes vulnerable; *NDR*, nondiabetes robust; *NDV*, nondiabetes vulnerable; *SD*, standard deviation.
* Significant at p<0.008.

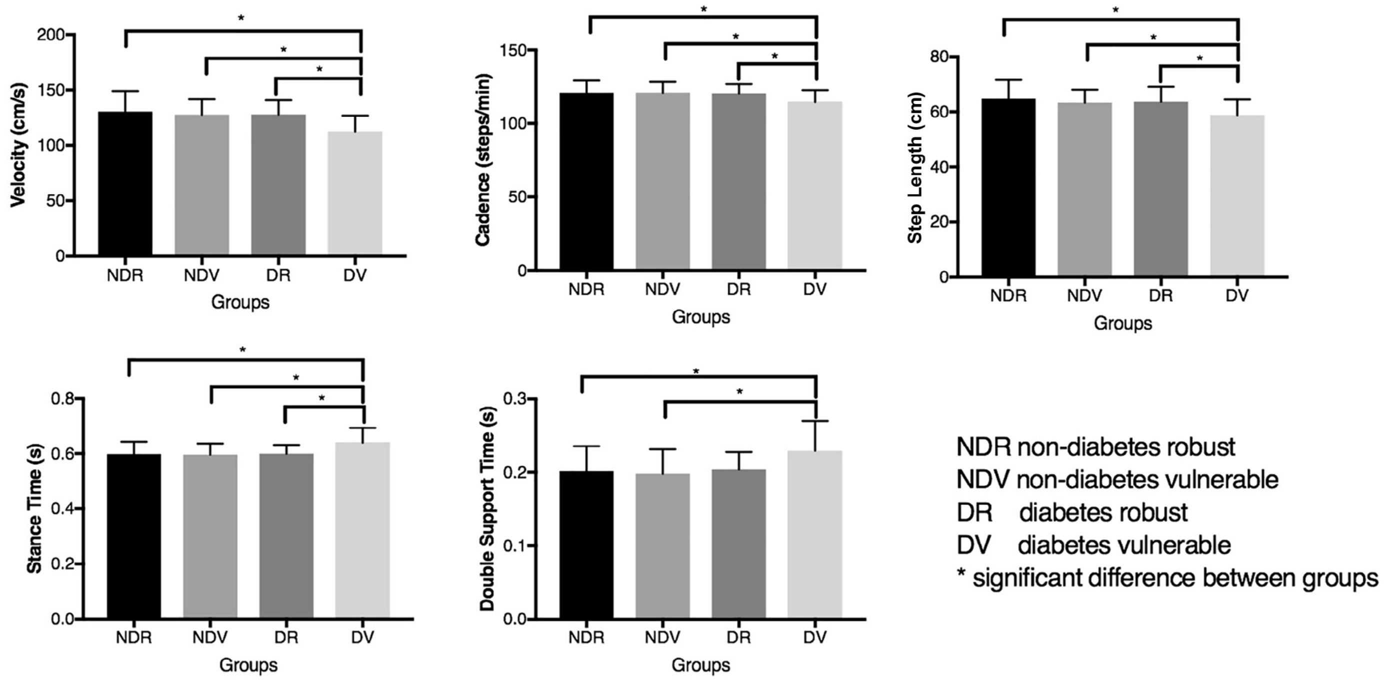

Figure 1. Comparison of the gait variables that were significantly different in groups of vulnerable and robust older women with and without diabetes (N=203).

that the dependent variables were not affected by the independent variable groups (p=0.377).

Discussion

The results of the study show that vulnerable older women with type 2 diabetes present significant changes in gait spatiotemporal parameters, placing them at higher risk for falls and disability. Decreased gait velocity lowers health status, muscle strength and, to a lesser extent, BMI, cognition, mood and pain (6). In our study, vulnerable older women with diabetes had more diseases, used more medications and had higher BMIs than older women who were robust and vulnerable without diabetes; however, their characteristics were similar to those of robust older women with diabetes. Thus, having diabetes and being vulnerable resulted in a greater decline in gait compared to being vulnerable without diabetes. The results also indicated that vulnerable older women with diabetes differ significantly from robust older women with diabetes. The robust older women with diabetes had a higher gait velocity (127.9 cm/s × 112.6 cm/s) compared to the women who had diabetes and were vulnerable. Therefore, physical prefrail and frail statuses seem to have a major impact on the gait of older women with diabetes.

The association of diabetes with frailty has been shown previously (26,27). Individuals with diabetes tend to age faster compared to their counterparts, increasing the chances of developing sarcopenia and frailty earlier in life (20). Diabetes accelerates the loss of skeletal muscle mass and strength, leading to sarcopenia, which is a key component of physical frailty (15). Recent studies show that insulin resistance in diabetes predicts incident frailty because it inhibits muscle protein synthesis; and severe hyperglycemia leads to muscle protein breakdown, resulting in decreased muscular mass and function (28). Recently, Veronese et al showed that frail and prefrail conditions are also predictors of type 2 diabetes mellitus in older men and women (29). In 2010, Hubbard et al, using a clinical frailty scale based on functional status, determined that the risk for mortality in older people is defined primarily by frailty status rather than by age, sex, diabetes or comorbidities (30). Therefore, our study reinforces the importance of screening individuals with type 2 diabetes for frailty status.

Frailty and diabetes are associated with an increased fall risk (17,27). A previous study showed that prefrail elderly people walk with decreased velocity and step length and spend more time in double support than in single support compared to nonfrail elderly people (17). In the same study, falls were explained by decreased gait velocity, step length and single support and increased double support time (17). The risk of falls in diabetes has been demonstrated in several epidemiologic studies (31–33). In the present study, we expected to find significantly more falls in vulnerable older women with diabetes. Although changes in gait parameters increase the risk for falls, the causes of falls are multifactorial and include musculoskeletal pain, insulin therapy, peripheral neuropathy and weakness of the lower limb muscles, among other factors, which are potential mechanisms for sarcopenia/frailty and, consequently, falls (33–35). We overlooked these measurements in our study; therefore, some of these factors might have prevented the occurrence of more falls in the groups of older women with diabetes.

MacGilchrist and collaborators found that fallers with diabetes were significantly weaker in ankle plantarflexion, dorsiflexion, inversion and eversion (36). Decreased strength in ankle dorsiflexion and gait velocity were independent risk factors for falls (36). Gait is a continuous and cyclic movement; a change in 1 phase reflects on all the other phases. For example, decreased push-off during terminal stance, due to weakness of the plantar flexors, decreases step length and the time spent in the swing phase and increases the time in stance and double support (37). Weak plantar flexors decrease power generation at push-off, decreasing the forward momentum of the body and friction demands, between foot and ground, that could lead to instability and falls (38). Weakness of the subtalar joint movements (inversion and eversion) compromises full pronation in mid stance—adduction and plantar flexion of the talus and eversion of the calcaneus—an important phase when the single-stance leg has to support the weight of the body (39). In addition, there are reports of sensation loss in people with diabetes, even without neuropathy (5,2,6). These factors together could result in greater instability during gait stance, leading to falls.

In a recent systematic review, gait velocity was found to play a key role in identifying older adults with various frailty statuses and other health conditions (40). There is some evidence that prefrail status is associated with changes in gait temporal parameters, and frail status is associated with changes in spatial parameters such as step length (40). Our results prevent us from confronting this statement because our group of vulnerable older women with diabetes was composed mostly of prefrail older women. However, gait variables are highly correlated; it is unlikely, for example, that increased stance time would be unaffected by step length and gait velocity. The robust group with diabetes differed from the vulnerable group with diabetes in all gait variables except double support time. Maybe it is an indication that these primary gait changes are a direct consequence of the frailty status. However, the cross-sectional design of this study prevented the establishment of any causal relationship. Or robust older women with diabetes might have some preserved muscle force and power, preventing changes in velocity and stance time, hence being able to keep their pace. This is just a hypothesis because we lack measurements of lower-limb muscle strength. Gait variability is another marker for identifying frail individuals (18), although in our study, variability was similar in all groups. In a recent study, gait variability was clearly a characteristic of older women over 80 years of age, which is older than our groups (41). Differing definitions of frailty status lead to differing results in gait parameters, especially gait velocity, and step width variability.

In a recent study, Moreira et al found a higher prevalence of a fear of falling among older individuals with diabetes than without diabetes (14). In addition, fear of falling and fall history have been associated with lower gait velocity (1,31). In our study, the groups were similar in their concern about falls (FES-I) and in the number of falls. These findings suggest that in this specific group of community-dwelling older women, frailty status could be responsible for the gait changes associated with diabetes.

This study has some limitations. The frail group was small; therefore, the vulnerable groups had more prefrail than frail older women. Second, the participants had diagnoses of diabetes given by a physician, but we were unaware of their glycemic control and the presence of peripheral artery disease or neuropathy at the time of the research. These variables should be considered in future studies. Future studies should also include male participants and measures of muscle strength in the lower limbs to determine whether strength is preserved in robust individuals with diabetes compared to vulnerable individuals.

Conclusions

This is the first study that has investigated changes in gait parameters according to the frailty status of older women with and without type 2 diabetes. Frailty status affects the gait of vulnerable older women with diabetes compared to robust older women with diabetes, and it appears that it is not a confounder, as suggested by Toosizadeh et al (22). Vulnerable older women with diabetes walked with decreased gait velocity, step length and cadence and increased stance and double support time. The take-home message from this study is the importance of screening older women with diabetes for physical frailty. Treatment of decreased muscle mass and strength in diabetes include medication, nutrition and exercise, especially in the early stages of the disease (9,42). Individuals with type 2 diabetes could benefit from early resistance-training programs to delay sarcopenia and frailty and changes in gait parameters that lead to falls and disability.

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Author Disclosures

Conflicts of interest: None.

Author Contributions

Kirkwood and Moreira were responsible for study conception and design; Borém, Ferreira, de Almeida and Guimarães acquired and organized the data; Kirkwood and Sampaio analyzed and interpreted the data; Kirkwood, Borém, Ferreira, de Almeida and Guimarães drafted the manuscript; and Sampaio and Moreira provided critical revision.

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