Longitudinal associations between gait, falls and disability in community-dwelling older adults with type II diabetes mellitus: findings from The Irish Longitudinal Study on Ageing (TILDA)

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Abstract

BACKGROUND: Diabetes is associated with gait deficits, future falls and disability, however it is unclear if associations remain after controlling for relevant confounders. This study investigated (i) the effects of type II diabetes on spatiotemporal gait parameters in community-dwelling older adults and (ii) if diabetes status was independently associated with future falls and disability, after controlling for gait and other confounders.

METHODS: Baseline data were obtained from 2,608 community-dwelling adults (≥60 years) participating in The Irish Longitudinal Study on Ageing (TILDA). Diabetes was identified from self-reported doctors’ diagnosis, medications and glycated haemoglobin levels. Gait characteristics were obtained during single and dual task walking using a GAITRite® mat (n=2560). Incident falls and disability were collected over four years follow-up (n=2473). Associations between diabetes status and gait (cross-sectional) and falls and disability (longitudinal) were investigated using regression analysis, adjusting for medications, cardiovascular health, neuropsychological function and fall-related factors.

RESULTS: Diabetes (prevalence = 9.1%) was cross-sectionally associated with shorter dual task step length after adjusting for covariates ($\beta=-1.59$, 95% CI: -3.10, -0.08, p<0.05). Diabetes was independently associated with increased risk of future IADL difficulty in those with no prior difficulty (IRR=1.51, 95% CI: 1.08 2.11, p<0.05) although dual task step length was an important confounder in all disability models. No independent associations between diabetes and falls were observed.
CONCLUSIONS: Diabetes was independently associated with shorter dual task step length and increased risk of future IADL difficulty. Multidimensional interventions addressing poor health and function in those with diabetes may help reduce the risk of gait deficits and future disability.

**Keywords:** cardiovascular, frailty, functional performance, successful aging
Introduction

Diabetes is a leading cause of disability and death worldwide (1,2), with up to 95% of cases being type II diabetes (3). In Ireland, the prevalence of type II diabetes has been reported at 9.5% in community-dwelling adults aged 50 years and over with 10% of these cases being undiagnosed (4). Risk factors for diabetes include increasing age, obesity and physical inactivity (3). Diabetes is associated with an increased risk of cardiovascular disease but also complications such as retinopathy, neuropathy, nephropathy (5), cognitive dysfunction (6) and depression (7). Consequently, diabetes has been associated with reduced physical function, and an increased risk of falls and disability (8-10).

Gait is a common but complex activity that requires integration of the neurological, musculoskeletal and cardiorespiratory systems. Gait impairments are associated with an increased risk for falls and immobility, which contribute to greater disability and institutionalization, increases in health care costs, and death (11-13). In a systematic review, Allet et al (14) reported gait abnormalities (e.g. reduced gait speed and stride length and increased cycle time) during normal walking in the diabetic population. However, most of the referenced studies were limited by small sample sizes, differing methodologies to assess gait, different exclusion criteria and the inclusion of both type I and type II diabetics with/without peripheral neuropathy. Two larger studies, which also did not distinguish between type I and II diabetes, reported that associations between diabetes and reduced gait speed (or pace) are attenuated when including cardiovascular health and medications (15) and cardiovascular risk factors (16) as covariates, suggesting that vascular comorbidity plays an important role.

The dual task paradigm examines walking while carrying out a secondary attention-demanding task. It is often used to examine the relationship between gait, cognition and falls (17) and is considered a further challenge to gait stability over and above a single task test (i.e. just walking). Current evidence supports an association between poorer dual task gait
performance and future fall risk in community-dwelling older adults (18), but studies of dual task gait in diabetic populations are limited. In one of few studies in this population, De Mettelinge et al (19) reported that older adults with diabetes have slower gait speed, shorter strides and higher stride length variability compared to controls during dual task walking. In addition, gait impairments in both single and dual task conditions were greater in those with impaired cognitive function, however these authors did not adjust for any other confounders.

Understanding the independent associations between diabetes and gait during both single and dual task conditions would help to identify limitations in physical function and potential risk of future outcomes such as falls and disability. While many of the falls studies cited in the Yang et al (2016) systematic review adjusted for multiple confounders including objective measures of function (10), the disability studies cited in the Wong et al (2013) review adjusted for fewer and mostly self-reported confounders (9). It is important to determine if associations between diabetes status, falls and disability exist, independent of any gait deficits, cardiovascular, physical, mental and cognitive health and fall-related factors.

Therefore, the aims of this study were to examine (i) spatiotemporal gait characteristics during single and dual task walking in community-dwelling older adults with and without diabetes (cross-sectional analysis) and (ii) the risk of falls and disability over four years follow-up associated with having diabetes at baseline (longitudinal analysis). Both analyses controlled for the effects of physical function, cardiovascular health, medications, neuropsychological function, and fall-related factors. We hypothesised that those with diabetes would display impaired gait characteristics and that any observed associations with future falls and disability would no longer be significant after controlling for gait deficits and other confounders.
Methods

Study design

The Irish Longitudinal Study on Ageing (TILDA) is a large prospective cohort study of the social, economic, and health circumstances of community-dwelling adults resident in Ireland. Details of the sampling, study design and cohort have been published previously (20, 21). Briefly, a stratified two-staged clustered procedure was used to sample from the An Post GeoDirectory, a listing of residential addresses in the Republic of Ireland. A total of 640 clusters (or regions) were randomly sampled from 3,155 clusters nationwide with a probability proportional to size and stratified by geographic, and demographic factors. Forty addresses were randomly chosen within each cluster, and household residents aged ≥50 years and their spouses/partners (of any age) were eligible to participate. Ethical approval was obtained from the Faculty of Health Sciences Research Ethics Committee at Trinity College Dublin and written informed consent was obtained from all participants.

Data collection consisted of a computer-assisted personal interview (CAPI), a self-completion questionnaire (SCQ) and a comprehensive health assessment. The CAPI contained detailed questions on socio-demographic characteristics, wealth, health, healthcare utilisation, social support and participation, with data recorded by social interviewers in the participants’ own homes. After the interview, participants were provided with the SCQ which they completed in their own time and returned to the study coordinators. Finally, participants were invited to take part in a health assessment carried out in a dedicated centre by trained research nurses. This assessment included anthropometric, cognitive, cardiovascular, mobility, strength, bone, and vision tests and blood draws. A modified home-based assessment was available if participants were unable or unwilling to travel to a health centre (22).
Sample

Baseline (Wave 1) data from 8,172 participants aged ≥50 years were obtained between January 2009 and July 2011 with follow-up interview data obtained at Wave 2 (February 2012 - March 2013) or Wave 3 (March 2014 – October 2015). The inclusion criteria for the cross-sectional analysis included age ≥60 years, completion of a Wave 1 CAPI, attendance at a centre-based health assessment, provision of a blood sample for glycated haemoglobin (HbA1c) analysis and valid gait data (n=2,560); those who subsequently participated in either a Wave 2 or 3 CAPI were included in longitudinal analysis (n=2,473), see Figure 1.

Diabetes

Diabetes was identified by the presence of any of the following criteria: self-reported doctor diagnosis of diabetes (n=204), use of diabetes medications identified using the World Health Organisation Anatomic Therapeutic Classification codes ‘A10A’ for insulin and ‘A10B’ for oral anti-glycaemic medications (n=10), or HbA1c levels ≥ 48 mmol/mol as per the American Diabetes Association criteria (3) (n=20). Respondents were not explicitly asked what type of diabetes they had been diagnosed with, therefore, participants who reported being on insulin therapy at the time of the interview and received a doctor diagnosis of diabetes before the age of 40 were excluded due to the suspicion that they may have type I diabetes (n=2).

Gait Assessment

Spatiotemporal gait parameters were obtained using a computerized walkway with embedded pressure sensors (active area 4.88 m) (GAITRite®, CIR Systems Inc, New York, USA).

Participants completed two trials in each of two conditions: i) walking at usual pace (single task) and ii) walking while simultaneously carrying out a cognitive task (reciting alternate letters of the alphabet, i.e. A-C-E, etc.) (dual task). Each trial consisted of one pass over the GAITRite® mat. Participants started walking 2.5 m before the mat and stopped 2 m after the
mat to allow for acceleration and deceleration. They were allowed a practice trial in which they recited alternate letters in a seated position prior to the dual task walking condition.

Gait analysis

Gait speed, step length, double support phase, step width and step length variability were included in the analysis as they have previously been linked to outcomes such as falls. Gait data from the right and left legs were similar (r=0.93-0.99) and results were consistent across both limbs, therefore only data for the right leg are presented. Gait speed was calculated as distance travelled divided by ambulation time (cm/s). Step length was measured from the heel center of the right footfall to the heel center of the previous left footfall (cm). Total double support phase was calculated as the sum of the initial and terminal double support phases occurring during the stance phase of the right foot (%). Step width was defined as the lateral distance from the midline of the right heel to the line of progression of two consecutive left footfalls. Step length variability was reflected by coefficient of variation (CV) of step length. For each pass of the mat, mean data was calculated for each variable; these were then averaged across the two passes in each of the single and dual task conditions. For each gait variable, dual task decrement was calculated as (Single task gait variable – Dual task gait variable). Dual task cost (%) was calculated as ((Single task gait variable – Dual task gait variable) / Single task gait variable) x 100. The number of letters attempted and number of letters correct were also recorded for the first pass in the dual task condition.

Covariates

A number of covariates, that have known associations with diabetes, gait, falls and disability, were obtained during the CAPI and the health assessment. These covariates reflect cardiovascular health (5), cognitive function (6), depressive symptoms (7) and fall-related factors (8,10). Socio-demographic factors such as age, sex and educational level (primary,
secondary, or tertiary corresponding to ≤8, 9-13, and >13 years respectively) were obtained. Participants self-reported a doctor diagnosis of cardiovascular conditions including high blood pressure, high cholesterol, heart attack, heart failure, angina, stroke, transient ischaemic attack, heart murmur and arrhythmia with the number of conditions presented as 0, 1, 2 or ≥3 conditions. The number of medications taken regularly was obtained and participants indicated their smoking status (coded as never smoked, past smoker, current smoker). Participants reported if they had fallen in the past year (coded as 0, 1 or ≥2 falls) and were asked if they were afraid of falling (coded as not afraid, somewhat afraid, very much afraid). Finally, participants rated their steadiness when walking as very steady, slightly steady, slightly unsteady or very unsteady (23); a binary variable was derived denoting steady (very steady) and unsteady (all other responses).

A number of objective measurements were taken during the health assessment. Height and weight were measured using a 240 wall-mounted measuring rod and an electronic floor scales (SECA, Birmingham, UK) respectively. Mean grip strength from two trials on the dominant hand was obtained using a hydraulic hand dynamometer (Baseline®, Fabrication Enterprises, Inc., White Plains, NY). Global cognition was assessed using the Montreal Cognitive Assessment (MoCA) (24). Colour Trail Task 2 (25) time was used to assess executive function and a computer-based choice reaction time test was used to assess processing speed. Depressive symptoms were measured using the 8-item Centre for Epidemiologic Studies Depression (CES-D) Scale (26).

Longitudinal outcome variables

All longitudinal outcomes were dichotomous variables, derived from data available at Wave 2, Wave 3 or both waves. Outcomes were recurrent falls (two or more falls occurring in the past year or since the last interview), injurious falls (injured seriously enough to require medical attention), difficulty in performing at least one activity of daily living (ADL) and
difficulty in performing at least one instrumental activity of daily living (IADL) because of a physical or mental health problem. ADLs included dressing, walking across a room, bathing or showering, eating, getting in or out of bed, and using the toilet (27) whereas IADLs included preparing a hot meal, doing household chores, shopping for groceries, making telephone calls, taking medications, and managing money (28). Routine performance of these activities was not taken into account (e.g. if the participant typically did the food preparation or shopping in the household).

Statistical analysis
Baseline characteristics of those with and without diabetes were summarised using means and standard deviations for continuous variables and frequency counts and proportions for categorical values. Gait characteristics in both single and dual task conditions are presented where data were available. Marginal distributions of gait variables were assessed using histograms and Q-Q plots. All variables were normally distributed except for step length variability which was positively skewed.

Separate linear (for normally distributed variables) and quantile (for skewed variables) regression models were used to examine the association between diabetes status (independent variable) and each gait variable, namely gait speed, step length, double support phase, step width and step length variability in both single and dual task walking conditions, dual task decrement measures, dual task cost measures, number of letters attempted and recited correctly (dependent variables). Regression analysis was deemed the most suitable approach as unequal sample sizes in the diabetes and non-diabetes groups can affect the homogeneity of variance assumption in ANOVA. For each dependent variable, Model 1 was unadjusted while Model 2 adjusted for age, sex, education, height and weight. Each covariate was then added individually to the models with the change in beta coefficients reflecting the confounding effect of that variable. A variable that reduced the beta coefficient to a much
greater extent compared to other variables was deemed to be an important confounder in the observed relationship. Model 3 was adjusted for age, sex, education, height, weight, number of medications, number of cardiovascular conditions, MoCA, choice reaction time, Colour Trail Test 2, depressive symptoms, grip strength, smoking status, falls in the past year, fear of falling and unsteadiness during walking.

For longitudinal analysis, we used generalised linear models with poisson regression to examine associations between diabetes status and falls (recurrent, injurious) and difficulty in ADLs and IADLs occurring over 4 years follow-up. Model 1 was unadjusted while Model 2 adjusted for age, sex, education, height, weight and time between baseline health assessment and follow-up interviews. Once again, the covariates listed above were added individually with the confounding effect of each variable reflected by the change in the incidence rate ratio (IRR). A variable that reduced the IRR to a much greater extent compared to other variables was deemed to be an important confounder in the observed relationship. Model 3 was adjusted for all covariates. Complete case analysis was used for multivariate analyses with all missing data treated as missing at random. We repeated this analysis for each outcome, excluding those with a history of falls in the past year (for the falls models), ADL difficulty at baseline (for the ADL difficulty model) and IADL difficulty at baseline (for the IADL difficulty model) respectively.

All regression models included inverse probability weights created by comparing age, sex, education, marital status and geography of participants to their distribution in the Irish Census 2011. These weights were modified further to reflect the non-uniform probability for participant self-selection into the centre-based health assessment. Significance was considered at the 5% level. All analyses were carried out in Stata v14 (StataCorp, College Station, TX, USA).
Results

Cross-sectional analysis

The final sample for cross-sectional analysis was 2,560 participants for whom Wave 1 diabetes status and gait data were available (Figure 1). 9.1% (n=234) of participants were identified as having diabetes.

Adults with diabetes were more likely to be older, male, heavier in weight, a past smoker, with primary level education (≤8 years), a higher number of cardiovascular conditions and medications, to self-report a history of falls, fear of falling, difficulty with ADLs and IADLs and unsteadiness during walking and to demonstrate poorer cognitive performance compared to those without diabetes (eTable1). Similarly, the diabetes group displayed poorer gait characteristics (i.e. slower gait speed, shorter step length, increased time spent in double support, wider steps and increased step length variability) compared to the non-diabetes group in both single and dual task walking conditions (Table 1).

Results of the regression analyses for single task gait are presented in Table 2. The unadjusted differences in gait characteristics between diabetes and non-diabetes groups are shown in Model 1. The diabetes group had slower gait speed and shorter step length after adjusting for basic socio-demographics (Model 2) but neither of these associations persisted after adjusting for all covariates (Model 3).

Results of the regression analyses for dual task gait are presented in eTable2. The diabetes group displayed slower gait speed, shorter step length and increased double support phase and step width after adjusting for age, sex, education, height and weight (Model 2). Only the association between diabetes and shorter dual task step length remained after adjusting for all covariates in Model 3 (β=-1.59, 95% CI: -3.10, -0.08, p<0.05).
Diabetes status was not associated with any measures of dual task cost or dual task decrement, or number of letters attempted or recited correctly during the dual task condition (data not shown).

Longitudinal analysis

Follow-up data were available for 2,473 participants (median follow-up: 4.3 years; range: 1.5-5.8 years) including 228 participants with diabetes at baseline. The incidence of falls, ADL difficulty and IADL difficulty after four years follow-up, stratified by diabetes status is provided in Table 3. The diabetes group reported higher incidence of recurrent falls, ADL and IADL difficulty compared to those without diabetes while injurious falls were similar in both groups.

Table 4 shows that diabetes was associated with an increased risk of recurrent falls, ADL difficulty and IADL difficulty in Model 1 (unadjusted). Diabetes was associated with an increased risk of ADL difficulty (IRR=1.40, 95% CI: 1.09, 1.81, p<0.01) and IADL difficulty (IRR=1.60, 95% CI: 1.26, 2.03, p<0.001) when adjusting for socio-demographic factors in Model 2, however none of these associations remained significant when adjusting for all covariates in Model 3.

When the analysis was repeated for participants with no history of disability at baseline, diabetes was associated with an increased risk of incident ADL difficulty (IRR=1.47, 95% CI: 1.09, 1.99, p<0.05) and IADL difficulty (IRR=1.78, 95% CI: 1.35, 2.36, p<0.001; eTable3) when adjusting for socio-demographic variables (Model 2). The observed association between diabetes and IADL difficulty remained significant after controlling for all covariates in Model 3 (IRR=1.51, 95% CI: 1.08, 2.11, p<0.05), although this association was not significant when medications and dual task step length were added individually to the models.
There were no associations between diabetes and injurious falls in those with or without a history of falls in the year prior to baseline (data not shown).

Discussion

In this study, diabetes was independently associated with shorter dual task step length in cross-sectional analysis; and an increased risk of IADL difficulty after four years follow-up in those with no prior history of difficulty, when controlling for gait and physical function, cardiovascular health, medications, neuropsychological function, and fall-related factors. Number of medications was the most important confounding factor in the cross-sectional models suggesting that existing co-morbidities and corresponding health status have a considerable impact on gait. Dual task step length was an important confounding factor in the longitudinal models, reflecting the importance of both mobility and cognitive function in carrying out activities of daily living.

To our knowledge, this is the first population-based study to examine both single and dual task gait performance in diabetic and non-diabetic older adults. Our single task gait findings are in contrast to Maksimovic et al (16) who reported that diabetes was associated with a reduction in the pace factor (predominantly made up of gait speed and step length) during single task walking after adjusting for socio-demographics, height, weight, cardiovascular risk factors and medication use. Several other papers have also reported gait deficits in diabetic cohorts, however as these studies used mostly unadjusted or partially adjusted analyses (e.g. age, sex, BMI and individual indicators of health, cognition, etc), they more closely reflect our findings from Models 1 and 2 (16,29,30). The independent association between diabetes and shorter dual task step length observed in our study suggests that individuals with diabetes have greater difficulty in more cognitively challenging walking.
conditions, which is supported by research reporting cognitive dysfunction in those with diabetes (6).

We also found that shorter dual task step length was an important confounding factor in all of the disability models, which likely reflects the mobility and cognitive requirements to perform ADLs, and IADLs in particular. Interestingly, dual task step length had a much stronger confounding effect than individual cognitive function variables (see IRRs in Table 4, Model 2 + individual variables) suggesting that this measure may represent an early indicator of difficulty in tasks requiring executive function and highlighting the potential it has in identifying individuals with future disability.

The association between diabetes and future IADL difficulty in those with no baseline difficulty remained significant even after controlling for dual task step length. This independent association is consistent with findings of studies included in Wong et al’s systematic review (9), highlighting the need to address these functional limitations in older adults with diabetes. In contrast to previous studies (31,32), we found no independent association between diabetes and incident ADL difficulty although we did adjust for objective indicators of cardiovascular function and neuropsychological function, which these previous studies did not do.

The underlying mechanism linking diabetes, dual task gait deficits and future IADL difficulty may be related to vascular risk factors and pathologies. Recently, Liu et al (33) presented evidence of a causal association between type II diabetes and cerebral small vessel disease, indicators of which, include white matter hyperintensities (WMH) and reduced white matter integrity. Ghanavati et al (34) reported that greater volumes of deep WMH and reduced white matter integrity in the cingulum (an area which is important for attention) have been associated with slower dual task gait speed. White matter abnormalities have also been
associated with lower cerebral CO$_2$ vasoreactivity in type II diabetes (35). This may be due to endothelial dysfunction, as a result of hyperglycemia and elevated proinflammatory cytokine levels (36) and/or increased blood-brain permeability (37). Previous studies in those with type II diabetes have shown that lower global cerebral vasoreactivity at baseline is associated with a greater decrease in single and dual task gait speed and dual task cost (38) and decline in IADL scores (36) at two years follow-up. Chung et al (38) also reported a more pronounced decline in cerebral vasoreactivity in those with a longer duration of diabetes. It is known that type II diabetes may go undiagnosed for many years, with micro- and macro-vascular complications often already present at the time of diagnosis (3). The length of time lived with the condition increases the risk of diabetic complications, and these can directly (e.g. through peripheral arterial disease, peripheral neuropathy) or indirectly (e.g. through ulcers, muscle weakness) affect an individual’s walking patterns and/or increase the risk of falls and disability. This highlights the importance of managing vascular risk factors such as hypertension in diabetes to reduce the risk and severity of cerebral small vessel disease and possible effects on gait, falls and disability.

Previous research has shown that polypharmacy is more prevalent in those with diabetes compared to those without (39). In the present study, number of medications was one of the strongest confounders of the associations between diabetes and all outcomes. For example, when number of medications was added to the cross-sectional model for single task gait speed, it reduced β by 86% while adding each of the other confounders reduced β by ≤23% (Table 2, Model 2). A higher number of medications likely reflects greater co-morbidity, the well-established deficits in physical (8,40) and cognitive function (40,41), and higher prevalence of depression (8), sarcopenia and frailty (42) associated with diabetes. Taking multiple medications leads to an increased risk of side-effects and drug-drug interactions, while the medications specifically used to treat diabetes and diabetes-related complications
may also be associated with an increased risk of falls, cognitive changes and heart disease (43). While we did not observe an association between diabetes and falls after adjusting for socio-demographics (see Table 4, Model 2), previous research has reported that medications are an important confounder of this relationship (44,45) along with reduced physical and cognitive function.

The strengths of this study include the large, population based sample of community-dwelling adults, the use of HbA1c to capture undiagnosed diabetes, the comprehensive gait assessment completed by the majority of participants, availability of a range of demographic and health covariates and follow-up data available over four years. The study is limited to those participants who attended a centre-based health assessment who tended to be higher functioning compared to those who selected a home-based assessment (22). The question used to ascertain a diabetes diagnosis in the TILDA interview does not distinguish between different types of diabetes. While we excluded those who were likely to have type I diabetes based on medication usage and age at diagnosis, we were unable to account for other types of the disease, including gestational diabetes or latent autoimmune diabetes which may be present in this population. We did not control for the duration of diabetes or the presence of diabetes-related complications such as leg ulcers, protein in the urine, neuropathy, retinopathy and nephropathy as this information was only available for participants reporting a doctors’ diagnosis of diabetes and the prevalence of reported complications in this group was low. In addition, falls were self-reported which may be subject to recall bias although using recurrent falls (more than one fall in a specified period) and injurious falls (serious enough to require medical treatment) may alleviate this problem to some extent.

In conclusion, community-dwelling adults with type II diabetes had shorter dual task step length and an increased risk of IADL difficulty over four years compared to those without diabetes after controlling for medications, cardiovascular health, neuropsychological function...
and fall-related factors. Number of medications is an important confounder in all observed associations, indicating that the presence of co-morbidities and associated deficits in health and function accounts for much of the gait deficits. Shorter dual task step length is also an important confounder in the association between diabetes and disability highlighting the role of mobility and cognitive function. Recent intervention studies have shown that diet (46) and exercise (47) interventions have the potential to improve lower extremity function, including gait parameters, in older adults with type II diabetes. It is unclear from existing reviews if polypharmacy interventions have led to clinically important outcomes, however some evidence does suggest more appropriate prescribing, highlighting the role that targeted review, appropriate monitoring and personalised medicine can play in reducing the risk of adverse outcomes associated with polypharmacy (48). Multidimensional interventions aimed at addressing poorer health and function in those with diabetes may therefore help to reduce the risk of gait deficits and thus future falls and disability.
Funding

The Irish Longitudinal Study on Ageing (TILDA) was supported by the Irish Government; the Atlantic Philanthropies; and Irish Life plc. This research was additionally supported by the Health Research Board of Ireland (Grant reference: HRA_PHS/2012/30). The sponsors played no role in study design, methods, subject recruitment, data collection, analysis or preparation of paper.

Acknowledgments

Orna Donoghue, Siobhan Leahy, Rose Anne Kenny: Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The authors would like to acknowledge the contribution of the TILDA participants and research team.

Conflicts of interest

None reported.
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Figure Caption

Figure 1. Flowchart of study participants

Table Captions

Table 1. Gait characteristics during the single and dual task walking conditions by diabetes status

Table 2. Associations between diabetes status and gait characteristics during single task walking (right leg)

Table 3: Incidence of recurrent and injurious falls, ADL and IADL difficulty occurring after 4 years follow-up by diabetes status.

Table 4. Associations of diabetes status with recurrent falls, difficulty in ADLs and IADLs at four year follow-up
Table 1. Gait characteristics during the single and dual task walking conditions by diabetes status

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<th>Dual task walking</th>
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<tr>
<td></td>
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<td>Diabetes (n=234)</td>
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<td></td>
<td>No diabetes (n=2304)</td>
<td>Diabetes (n=228)</td>
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<td>Gait Speed (cm/s)</td>
<td>130.79 (20.31)</td>
<td>121.21 (21.33)</td>
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<td>106.15 (25.48)</td>
<td>99.05 (22.43)</td>
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<td>Step length (cm)</td>
<td>68.75 (9.01)</td>
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<td></td>
<td>64.89 (10.81)</td>
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<td>Double support phase (%)</td>
<td>25.70 (4.43)</td>
<td>27.71 (5.41)</td>
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<td>Step length variability (%)</td>
<td>2.78 (1.73)</td>
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Table 2. Associations between diabetes status and gait characteristics during single task walking (right leg)

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<th>Double support phase</th>
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<td>β (95% CI)</td>
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<td>β (95% CI)</td>
<td>β (95% CI)</td>
<td>β (95% CI)</td>
</tr>
<tr>
<td>Model 1</td>
<td>-9.46 (-13.02, -5.90)**</td>
<td>-3.21 (-4.82, -1.61)***</td>
<td>2.13 (1.23, 3.02)***</td>
<td>1.41 (0.85, 1.96)***</td>
<td>0.55 (0.22, 0.88)***</td>
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<tr>
<td>Model 2</td>
<td>-5.41 (-8.76, -2.06)**</td>
<td>-2.54 (-3.90, -1.17)***</td>
<td>0.71 (-0.13, 1.56)</td>
<td>0.46 (-0.05, 0.97)</td>
<td>0.35 (0.00, 0.71)</td>
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<tr>
<td>+ medications</td>
<td>-0.77 (-3.97, 2.43)</td>
<td>-1.07 (-2.40, 0.26)</td>
<td>-0.02 (-0.90, 0.85)</td>
<td>0.23 (-0.30, 0.76)</td>
<td>0.32 (0.01, 0.64)*</td>
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<tr>
<td>+ CV conditions</td>
<td>-4.57 (-7.87, -1.29)**</td>
<td>-2.28 (-3.65, -0.92)**</td>
<td>0.57 (-0.28, 1.42)</td>
<td>0.44 (-0.09, 0.96)</td>
<td>0.38 (0.04, 0.72)*</td>
</tr>
<tr>
<td>+ MoCA</td>
<td>-5.31 (-8.69, -1.94)**</td>
<td>-2.47 (-3.83, -1.10)***</td>
<td>0.70 (-0.15, 1.55)</td>
<td>0.45 (-0.07, 0.96)</td>
<td>0.38 (0.05, 0.70)*</td>
</tr>
<tr>
<td>+ CRT</td>
<td>-4.23 (-7.43, -1.03)*</td>
<td>-2.12 (-3.46, -0.77)**</td>
<td>0.39 (-0.47, 1.26)</td>
<td>0.52 (0.04, 0.99)*</td>
<td>0.43 (0.06, 0.79)*</td>
</tr>
<tr>
<td>+ CTT2</td>
<td>-5.38 (-8.53, -2.23)**</td>
<td>-2.49 (-3.76, -1.22)***</td>
<td>0.59 (-0.27, 1.46)</td>
<td>0.41 (0.12, 0.93)</td>
<td>0.35 (0.02, 0.68)*</td>
</tr>
<tr>
<td>+ CES-D</td>
<td>-4.72 (-8.01, -1.43)**</td>
<td>-2.27 (-3.63, -0.91)**</td>
<td>0.62 (-0.22, 1.48)</td>
<td>0.43 (-0.09, 0.95)</td>
<td>0.40 (0.05, 0.75)*</td>
</tr>
<tr>
<td>+ grip strength</td>
<td>-4.80 (-8.10, -1.50)**</td>
<td>-2.29 (-3.60, -0.97)**</td>
<td>0.57 (-0.24, 1.38)</td>
<td>0.43 (-0.08, 0.95)</td>
<td>0.36 (0.02, 0.70)*</td>
</tr>
<tr>
<td>+ smoking status</td>
<td>-5.01 (-8.30, -1.73)**</td>
<td>-2.41 (-3.77, -1.05)**</td>
<td>0.66 (-0.19, 1.51)</td>
<td>0.45 (-0.07, 0.97)</td>
<td>0.37 (-0.02, 0.76)</td>
</tr>
<tr>
<td>+ previous falls</td>
<td>-5.30 (-8.66, -1.95)**</td>
<td>-2.50 (-3.87, -1.13)***</td>
<td>0.72 (-0.12, 1.56)</td>
<td>0.47 (-0.05, 0.98)</td>
<td>0.46 (0.13, 0.79)**</td>
</tr>
<tr>
<td>+ fear of falling</td>
<td>-5.22 (-8.54, -1.90)**</td>
<td>-2.46 (-3.84, -1.09)***</td>
<td>0.68 (-0.14, 1.51)</td>
<td>0.44 (-0.07, 0.95)</td>
<td>0.34 (-0.01, 0.70)</td>
</tr>
<tr>
<td>+ unsteadiness</td>
<td>-4.18 (-7.20,-1.15)**</td>
<td>-2.06 (-3.29,-0.83)**</td>
<td>0.53 (-0.29,1.35)</td>
<td>0.37 (-0.15,0.89)</td>
<td>0.31 (0.04,0.59)</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Model 3^c</td>
<td>-0.79 (-3.68, 2.11)</td>
<td>-1.07 (-2.33,0.19)</td>
<td>-0.18 (-1.05,0.70)</td>
<td>0.30 (-0.22,0.82)</td>
<td>0.23 (-0.16,0.61)</td>
</tr>
<tr>
<td>N</td>
<td>2420-2560</td>
<td>2420-2560</td>
<td>2420-2560</td>
<td>2420-2560</td>
<td>2417-2557</td>
</tr>
</tbody>
</table>

Note. No Diabetes=Reference Category. Linear regression models used for gait speed, step length, double support phase and step width; quantile regression models used for step length variability; all analyses were weighted. CES-D, Centre for Epidemiological Studies Depression Scale; CRT, choice reaction time; CTT2, Colour Trails Test 2; CV, cardiovascular; MoCA, Montreal Cognitive Assessment.

^aModel 1 unadjusted.

^bModel 2 adjusted for age, sex, education, height, weight + the individual variables indicated.

^cModel 3 adjusted for age, sex, education, height, weight, number of medications, number of CV conditions, MoCA, CRT, CTT2, depressive symptoms (CES-D), grip strength, smoking status, previous falls, fear of falling, unsteadiness during walking.

*p<0.05, **p<0.01, ***p<0.001
Table 3: Incidence of recurrent and injurious falls, ADL and IADL difficulty occurring after 4 years follow-up by diabetes status.

<table>
<thead>
<tr>
<th></th>
<th>No diabetes</th>
<th>Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>Recurrent falls</td>
<td>422 (18.8)</td>
<td>59 (25.9)</td>
</tr>
<tr>
<td>Injurious falls</td>
<td>429 (19.1)</td>
<td>44 (19.3)</td>
</tr>
<tr>
<td>ADL difficulty</td>
<td>388 (17.3)</td>
<td>63 (27.6)</td>
</tr>
<tr>
<td>IADL difficulty</td>
<td>377 (16.8)</td>
<td>64 (28.1)</td>
</tr>
</tbody>
</table>

*In those who did not report these outcomes at baseline*

<table>
<thead>
<tr>
<th></th>
<th>No diabetes</th>
<th>Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>Recurrent falls a</td>
<td>257 (14.6)</td>
<td>30 (19.2)</td>
</tr>
<tr>
<td>Injurious falls a</td>
<td>280 (15.9)</td>
<td>21 (13.5)</td>
</tr>
<tr>
<td>ADL difficulty b</td>
<td>311 (15.1)</td>
<td>45 (23.0)</td>
</tr>
<tr>
<td>IADL difficulty c</td>
<td>315 (14.8)</td>
<td>50 (24.1)</td>
</tr>
</tbody>
</table>

Note. ADL, activities of daily living; IADL, instrumental activities of daily living.

- In those who did not report falls in year prior to baseline
- In those who did not report ADL difficulty at baseline
- In those who did not report IADL difficulty at baseline
Table 4. Associations of diabetes status with recurrent falls, difficulty in ADLs and IADLs at four year follow-up

<table>
<thead>
<tr>
<th></th>
<th>Recurrent falls IRR (95% CI)</th>
<th>ADL difficulty IRR (95% CI)</th>
<th>IADL difficulty IRR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1a</td>
<td>1.33 (1.01,1.76)*</td>
<td>1.43 (1.11,1.85)**</td>
<td>1.55 (1.20,1.99)**</td>
</tr>
<tr>
<td>Model 2b</td>
<td>1.25 (0.95,1.65)</td>
<td>1.40 (1.09,1.81)**</td>
<td>1.60 (1.26,2.03)**</td>
</tr>
<tr>
<td>+ medications</td>
<td>0.99 (0.73,1.34)</td>
<td>1.16 (0.88,1.53)</td>
<td>1.31 (1.01,1.69)*</td>
</tr>
<tr>
<td>+ CV conditions</td>
<td>1.17 (0.89,1.54)</td>
<td>1.36 (1.06,1.75)*</td>
<td>1.56 (1.23,1.98)**</td>
</tr>
<tr>
<td>+ MoCA</td>
<td>1.25 (0.95,1.65)</td>
<td>1.37 (1.05,1.78)*</td>
<td>1.55 (1.21,1.98)**</td>
</tr>
<tr>
<td>+ choice reaction time</td>
<td>1.25 (0.97,1.69)</td>
<td>1.46 (1.12,1.90)**</td>
<td>1.63 (1.26,2.10)**</td>
</tr>
</tbody>
</table>
+ colour trails 2  1.29 (0.97,1.71)  1.42 (1.08,1.87)*  1.61 (1.23,2.10)**
+ depressive symptoms  1.20 (0.92,1.57)  1.35 (1.05,1.75)*  1.57 (1.23,2.00)***
+ grip strength  1.23 (0.94,1.62)  1.39 (1.07,1.81)*  1.60 (1.25,2.05)***
+ smoking status  1.25 (0.95,1.65)  1.37 (1.06,1.76)*  1.59 (1.25,2.02)***
+ previous falls  1.16 (0.88,1.53)  1.36 (1.05,1.76)*  1.58 (1.24,2.01)***
+ fear of falling  1.24 (0.96,1.61)  1.41 (1.09,1.82)**  1.63 (1.28,2.07)***
+ unsteadiness  1.20 (0.91,1.58)  1.32 (1.01,1.71)*  1.48 (1.16,1.90)**
+ ADL difficulty  -  1.31 (1.00,1.70)*  -
+ IADL difficulty  -  -  1.41 (1.09,1.82)**
+ step length (dual task)  1.17 (0.88,1.57)  1.24 (0.92,1.65)  0.99 (0.68,1.42)
Model 3c  1.05 (0.78,1.41)  1.21 (0.88,1.67)  1.03 (0.71,1.50)
N  2293-2473  2293-2473  2293-2473

Note. No Diabetes=Reference Category. Generalised linear models with poisson regression used; all analyses were weighted. ADL, activities of daily living; CV, cardiovascular; IADL, instrumental activities of daily living; IRR, incidence rate ratio; MoCA, Montreal Cognitive Assessment.

aModel 1 unadjusted.
Model 2 adjusted for age, sex, education, height, weight, time between baseline health assessment and follow-up interview + the individual variables indicated.

Model 3 adjusted for age, sex, education, height, weight, time between baseline health assessment and follow-up interview, number of medications, number of CV conditions, MoCA, choice reaction time, Colour Trail Test 2, depressive symptoms, grip strength, smoking status, falls in the year prior to baseline, fear of falling, unsteadiness, ADL difficulty at baseline (ADL difficulty model only), IADL difficulty at baseline (IADL model only), step length (dual task).

*p<0.05, **p<0.01, ***p<0.001