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Self-reported physical activity in community-dwelling adults with diabetes and its association with diabetes complications

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ABSTRACT

Aims: To describe the physical activity levels of an Australian community-based adult population with diabetes, and investigate the interaction between diabetes complications and physical activity.
Methods: Anthropometric, demographic, biochemical and self-reported physical activity measures (IPAQ) were performed. Associations and multiple regression analyses were undertaken between physical activity, known risk factors for diabetes complications, and history of cardiovascular disease (CVD), neuropathy and foot ulceration obtained from medical records.
Results: 240 participants were recruited (96% type 2 diabetes; age 68.7 ± 10.5 y; 58% men; diabetes duration 14.3 ± 11.4 y). Sixty seven percent of participants reported undertaking moderate or vigorous intensity exercise to recommended levels, and 29% reported no moderate-vigorous exercise. In addition to being associated with known demographic and biochemical risk factors and other complications, diabetes complications were also associated with different physical activity behaviours. Individuals with a history of CVD were more likely to participate in moderate-vigorous exercise and meet exercise guidelines, individuals with neuropathy undertook less walking and moderate intensity exercise, and those with a history of foot ulceration sat more and participated less in vigorous exercise.
Conclusions: In Australian adults, the presence of diabetes complications may influence physical activity participation, and associate with characteristic physical activity approaches.

1. Introduction

The increasing prevalence of diabetes, particularly type 2 diabetes, has led to epidemic levels of adults with diabetes complications. The individual with diabetes is at significantly higher risk of cardiovascular disease,[1] peripheral neuropathy and microvascular complications, which can contribute to foot pathology (e.g. ulceration[2]), eye[3] and kidney[4] disease. These complications are strongly associated with factors such as increasing age, HbA1c and diabetes duration[5,6] and together contribute significantly to morbidity and economic burden of the disease. For instance, in Australia type 2 diabetes is the second leading cause of disability-adjusted life years lost[7] and in those people with micro- and macrovascular complications the individual cost is estimated at $5400 to $10,000 annually.[8]

Due to the disease prevalence and burden, there is an increasing need for efficacious therapies to manage diabetes and its complications at a population level. Lifestyle intervention involving physical activity is a cornerstone of therapy for diabetes,[9] particularly for its beneficial effect on glycaemic control.[10] Although less is known about the effect of physical activity on the pathophysiology underlying neuropathy and microvascular complications, a significant body of research involving randomised controlled trials has demonstrated that regular moderate to vigorous exercise reduces HbA1c,[10] and also improves CVD risk factors (e.g. lipids, hypertension)[11] and cardiovascular function[12] in diabetes cohorts. This has led to current exercise guidelines that advocate the promotion of moderate-to-vigorous intensity structured exercise.[9]

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However, CVD, neuropathy, foot ulceration, retinopathy and nephropathy can present a challenge to achieving recommended exercise targets[9] and physical activity participation may therefore be influenced by their presence. For instance, vigorous exercise may increase the risk of cardiovascular event,[9] and it is conceivable that individuals with a history of CVD might avoid such approaches. Despite some evidence suggesting that active people are less likely to prospectively experience foot ulceration,[13] there is concern about the effect of high impact activity[9] and weight-bearing activity[14] on the risk of foot trauma in people with peripheral neuropathy and limb vessel disease. Similarly avoidance of activities that result in Valsalva effects is promoted for individuals with retinopathy, and lower intensity activity (such as walking) may be preferred, particularly given its benefit for the management of associated obesity.[9] In this context sitting time has recently emerged as a predictor of CVD risk and mortality,[15] and small experimental studies have suggested that interventions involving reduced sitting may improve glycaemic control.[16]

There has been no investigation of physical activity participation with respect to diabetes complications, in community-dwelling adults. Understanding how the presence of complications may influence physical activity participation/behaviour in a community setting may help inform physical activity recommendations and approaches to achieve adherence to recommended exercise targets.

The aim of this study was to describe self-reported physical activity participation of community-dwelling Australian adults with diabetes. The study also sought to investigate whether diabetes complications are associated with self-reported physical activity behaviours, including meeting exercise guidelines, and participation in the physical activity domains: walking (low to moderate intensity), moderate intensity exercise, vigorous intensity exercise, and sitting time.

2. Subjects, materials and methods

2.1. Participants

Participants were recruited until December 2017 on a volunteer basis from a population attending two University community Podiatry clinics in New South Wales. The research conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by The University of Newcastle Human Research Ethics Committee. Participants provided written informed consent prior to their participation. Inclusion criteria were: diagnosis of type 1 or type 2 diabetes confirmed by medical records. Volunteers were excluded if they had current foot ulceration or reported undertaking hormone replacement therapy or a recent history of corticosteroid use. At the commencement of the testing session demographic and anthropometric data were documented including age, gender, height, weight, smoking history and physical activity participation. Full medical records were retrieved for all participants from their general medical practitioner. Medical history data extracted included duration of diabetes and most recent glycated haemoglobin [HbA1c], as well as history of CVD (coronary artery disease, stroke, heart failure/cardiomyopathy, arrhythmia etc. consistent with the definition of the World Health Organisation[17]), previous foot ulceration, nephropathy and retinopathy.[18] Diagnosis of overt nephropathy from blood chemistry testing was made by an estimated glomerular filtration rate <60 mL/min/1.73m^2, urinary albumin-to-creatinine ratio >25 mg/mmol for men and >35 mg/mmol for women.[19] Retinopathy was considered present if proliferative or non-proliferative changes were present at screening.[19]

2.2. Measurements

2.2.1. Anthropometry

Stature was recorded (SECA model 220 Telescopic Height Rod, Hamburg, Germany) and weight was measured in light clothing (Tanita BC-418 Body Composition Analyzer; Tanita Corporation, Tokyo, Japan). Waist circumference was measured in duplicate at the horizontal plane, midway between the inferior margin of the ribs and the superior border of the iliac crest during expiration, with the average reported.

2.2.2. Neuropathy

Neurological assessment was performed using a combination of two tests including a four-site monofilament test using a Semmes Weinstein 5.07/10 g monofilament and measurement of vibration perception threshold by neurothesiometer at the hallux. For the monofilament testing three or less sites in the four-site test was considered abnormal, as was a vibration perception threshold of >25 mV. Tests were performed bilaterally. One or more abnormal test results were considered indicative of neuropathy.[20]

2.2.3. Self-reported Physical Activity (IPAQ)

Self-reported physical activity participation was quantified by International Physical Activity Questionnaire Short Form (IPAQ-SF), which assesses physical activity levels during the last 7 days.[21] The questionnaire was completed during the same testing session as the previously described measures, and with the assistance of researchers. Participation in physical activity domains (walking, moderate intensity, vigorous intensity and sitting) was subsequently quantified using the IPAQ-SF scoring system, with the total number of days and minutes of physical activity and sitting time calculated for each participant as recommended.[22] In addition to derivation of weekly volumes, participants were also categorised nominally (yes or no) as “participating in (any) moderate exercise”, “participating in (any) vigorous exercise” and “meeting exercise guidelines” (≥150 min moderate and/or ≥90 min vigorous exercise per week[9]).

2.3. Statistical analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS; Release 24.0; SPSS Inc.). Data are reported as the mean values with their standard deviations from the mean or frequencies as appropriate. Pearson coefficients (R) were used for correlations between continuous variables and where one of the variables was dichotomous categorical data and the other continuous. Associations between categorical variables were assessed by chi-square test for independence (with Yates Continuity Correction where appropriate) with the phi coefficient determined for the strength of association. To further determine whether physical activity behaviours could characterise individuals according to their diabetes complication hierarchical regression analyses were used to examine the contribution of variables, including physical activity variables, to diabetes complications (cardiovascular disease, neuropathy, ulceration, other “microvascular” [considered as retinopathy and/or nephropathy]). To do this simple anthropometric, demographic and biochemical variables (age, gender, body weight, years since diagnosis and most recent HbA1c) were first entered into block 1 of the regression analysis and self-reported physical activity participation variables (weekly walking volume; weekly moderate intensity exercise volume, weekly sitting time and meeting exercise guidelines) were then entered into the regression in block 2. Only variables that were found to be significantly associated were entered into the regression analyses. Significance was set at $P < 0.05$.

3. Results

3.1. Participants

A total of 240 eligible volunteers (58% male) participated in the study. Participant characteristics are summarised in Table 1. Study participants were aged 68.7 ± 10.5 years (range: 25–92 years), with BMI of 33.3 ± 6.8 kg/m^2 (range: 19.9–63.1 kg/m^2). Twenty four percent had cardiovascular disease, 41% had neuropathy, 13% of the study population had a history of foot ulceration and 10% had a history of retinopathy

Table 1
Baseline characteristics of the study sample ($n = 240$). All values are means (standard deviations) unless otherwise stated.

Characteristic	Mean	SD
Demographic/anthropometric		
Diabetes type (% type 2)	96	
Diabetes duration (years)	14.3	(11.4)
HbA1c (% NGSP units)	7.2	(1.3)
Gender (%M)	58	
Age (y)	68.7	(10.5)
Weight (kg)	95.0	(20.4)
Height (cm)	169.2	(9.6)
BMI ($kg \cdot m^2$)	33.3	(6.8)
Waist (cm)[a]	114.9	(15.6)
Complications history		
History neuropathy (%)	41	
History CVD (%)	24	
History (ret/kid) (%)	10	
History ulcer (%)	13	
Self-reported physical activity		
Walking (min/wk)	271.9	(393.3)
Vigorous (min/wk)	34.5	(97.7)
Moderate (min/wk)	306.9	(380.2)
Sitting (min/wk)[b]	339.5	(179.9)
Does vigorous exercise (%)	17	
Does moderate exercise (%)	65	
Does no moderate or vigorous exercise (%)	29	
Meets exercise recommendations (%)	67	

Data are Mean (SD). BMI, body mass index; M, male; F, female; CVD, cardiovascular disease.
[a] n = 123.
[b] $n = 225$.

and/or overt nephropathy. A history of retinopathy or nephropathy was grouped together (and termed "microvascular") due to the low incidence. Smoking status data ($n = 106$) and waist circumference measurements ($n = 123$) were obtained in a sub-set of the population. As a result, smoking status was not entered into the regression analysis for CVD.

Self-reported physical activity levels from IPAQ-SF are shown in Table 1. All participants provided data for items relating to walking levels and participation in moderate exercise and vigorous exercise, however 15 individuals responded "unsure" or "did not know" to the item concerning sitting time. Overall, a majority of the population (67%) reported undertaking moderate-vigorous exercise to levels which met current guidelines; whereas 29% ($n = 69$) reported undertaking no moderate or vigorous exercise. Only 17% of individuals participated in self-reported vigorous exercise. A majority of participants (80%) reported undertaking walking activities with a weekly mean walking volume of 271.9 ± 393.3 min. Mean self-reported daily sitting time was 5.7 ± 3.0 h.

3.2. Bivariate correlations/associations

Associations between diabetes complications, demographic, anthropometric, biochemical variables and physical activity are summarised in Tables 2a and 2b. A history of CVD was associated with increasing age, being male, longer diabetes duration, smoking and the presence of other complications (neuropathy, foot ulceration and microvascular) (Table 2a). A history of CVD was also significantly positively associated with undertaking moderate intensity exercise and meeting exercise guidelines (Table 2b). Similarly, neuropathy was associated with increasing age, being male, longer diabetes duration, and the presence of other complications (CVD and microvascular disease) in addition to increased body weight (Table 2a). However, neuropathy was significantly associated with decreased weekly walking volume and decreased moderate intensity exercise volume (Table 2b). A history of foot ulceration was associated with the presence of other complications (CVD and microvascular disease) (Table 2a), with increased sitting time, and with not participating in vigorous exercise (Table 2b). Microvascular complications (retinopathy and/or nephropathy) were associated with longer diabetes duration and the presence of other complications (CVD, neuropathy and foot ulceration) (Table 2a) but not with any physical activity variable (Table 2b).

3.3. Hierarchical multiple regression analysis

Demographic, anthropometric variables (age, gender and diabetes duration) and the presence of other diabetes complications (neuropathy, foot ulcer and microvascular) accounted for 18% of the variance in history of CVD ($P < 0.001$; Table 3a), although only age and microvascular disease were statistically significant predictors of CVD. The addition of physical activity variables (participation in moderate exercise and meeting exercise guidelines) significantly raised the total variance explained by the model to 22% ($P = 0.003$, Table 3a).

Demographic, anthropometric variables (age, gender, diabetes duration and body weight) and the presence of other diabetes complications (CVD and microvascular) accounted for 17% of the variance in presence of neuropathy ($P < 0.001$; Table 3b). The addition of physical activity variables (decreased walking volume, decreased moderate exercise time), accounted for a further 4% of the variance in presence of neuropathy. ($P = 0.010$, Table 3b).

The presence of other diabetes complications (CVD and microvascular disease) accounted for 8% of the variance in history of foot ulceration ($P < 0.001$; Table 3c), and the addition of increased sitting time and non-participation in vigorous exercise accounted for a further 3% of the variance in foot ulceration history ($P = 0.026$).

4. Discussion

This study sought to describe the physical activity levels of a community-dwelling adult population with diabetes. Further we aimed to examine the possible association between the presence of diabetes complications and self-reported physical activity behaviour. Overall a majority of this older, obese Australian population reported undertaking moderate-vigorous exercise to levels which meet current guidelines, but approximately one third reported undertaking no moderate or vigorous exercise. A majority of participants reported

Table 2a
Correlations between anthropometric, demographic variables and history of complications.

	CVD	Neuropathy	Ulceration	Microvascular complications	Age	Gender	Duration	Weight	Smoking
Neuropathy	0.213**								
Ulceration	0.160*	0.126							
Microvascular complications	0.246**	0.132*	0.297**						
Age	0.253**	0.222**	0.017	0.109					
Gender	−0.247**	−0.245**	−0.077	−0.048	−0.037				
Duration	0.128*	0.154*	0.037	0.346**	0.069	0.040			
Weight	0.113	0.180**	0.003	−0.003	−0.179**	−0.243**	−0.078		
Smoking	0.247*	0.125	0.052	0.107	0.074	−0.267*	−0.024	0.113	
HbA1c	0.003	0.072	−0.014	0.054	−0.185**	−0.009	0.101	0.094	0.002

* Correlation/association is significant at the 0.05 level (2-tailed).
** Correlation/association is significant at the 0.01 level (2-tailed).

Table 2b
Correlations between anthropometric, demographic variables and history of complications and physical activity domain (IPAQ).

	CVD	Neuropathy	Ulceration	Microvascular complications	Age	Gender	Duration	Weight	Smoking	HbA1c
Walking time (/wk)	−0.022	**−0.148**[a]	−0.002	−0.058	**−0.282**[b]	**−0.141**[a]	−0.045	−0.091	0.132	−0.004
Moderate exercise time (/wk)	0.090	0−0.160[a]	−0.018	−0.006	0.076	−0.026	−0.058	−0.086	−0.058	−0.062
Vigorous exercise time (/wk)	0.004	−0.120	−0.087	−0.076	−0.068	0.029	0.019	−0.049	−0.008	−0.061
sitting time (/wk)	0.070	0.018	**0.168**[a]	0.092	−0.088	−0.012	−0.054	**0.217**[b]	0.037	0.103
Does moderate exercise	**0.149**[a]	−0.074	0.074	−0.028	0.044	−0.065	−0.043	0.019	0.152	−0.073
Does vigorous exercise	−0.049	−0.121	**−0.142**[a]	−0.073	−0.062	0.039	0.015	−0.042	−0.083	−0.095
Meets PA guidelines	**0.195**[b]	−0.062	−0.093	−0.061	0.058	−0.062	−0.033	0.009	0.089	−0.041

CVD, cardiovascular disease; "microvascular complications", history of nephropathy and/or retinopathy; "does moderate exercise", participates in (any) moderate exercise; "does vigorous exercise", participates in (any) vigorous exercise; "meets PA guidelines", meeting physical activity guidelines" (>150 min moderate and/or >90 min vigorous exercise per week); n = 240 except for associations with smoking (n = 106) and sitting time (n = 225).
[a] Correlation/association is significant at the 0.05 level (2-tailed).
[b] Correlation/association is significant at the 0.01 level (2-tailed).

undertaking walking as exercise. The results also suggested that the presence of diabetes complications influences physical activity participation because we observed significant associations between specific diabetes complications and participation in physical activity domains of the IPAQ-SF.

Specifically, in addition to being older, male and having longer diabetes duration, individuals with a history of CVD were characterised as participating in more structured moderate-vigorous exercise and meeting exercise guidelines. In contrast, in addition to being more likely to being older, male, overweight/obese and having longer diabetes duration, those with neuropathy were characterised as undertaking less walking and moderate intensity exercise, and those with a history of foot ulceration reported sitting more and not participating in vigorous exercise. There was no significant interaction between physical activity and other microvascular disease history (nephropathy and/or retinopathy), although the prevalence of these was relatively low.

Understanding the physical activity habits of adults with diabetes may better help clinicians identify individuals at risk and implement targeted lifestyle interventions aimed at improving health outcomes. For instance, whilst it is well known that regular moderate to vigorous exercise improves glycaemic control in type 2 diabetes,[10] overall exercise participation in Australian adults is typically low[23] and this has partly led to increasing interest in the efficacy and utility of low intensity physical activity and less sitting time for the management of health and disease.[15,16] Furthermore, there is little published information concerning physical activity participation in adults with diabetes complications. Peripheral neuropathy, retinopathy, nephropathy and foot ulceration can be barriers to achieving recommended exercise levels.[9] Unexpectedly, we found that adults with a past history of CVD were more likely to participate in regular moderate-to-vigorous exercise than those without CVD, perhaps reflecting increased awareness of the importance of exercise for managing health and future risk. Related to this, it is possible (although cannot be determined from these data) that these individuals had a history of engagement in structured cardiac rehabilitation programs, which may have subsequently increased their long-term physical activity levels. However, we observed that individuals with neuropathy undertook less walking and moderate intensity exercise, which possibly reflects increased discomfort, reduced sensation and/or fear of precipitation of foot ulceration associated with ambulation. This may imply an increased need for supported approaches in these patients, such as resistance exercise training which have proven efficacy for cardiovascular and glycaemic benefits,[9] as well as upper body exercises, and lower limb exercises which are less likely to cause sheer stress such as stationary bike cycling or swimming. Similarly those with a history of foot ulceration appeared to sit more and participate less in vigorous exercise, highlighting a need for strategies to achieve the beneficial cardiovascular and metabolic effects of exercise in these individuals. These may include exercise alternatives such as replacing sitting with "physical activity breaks".[16]

The findings that people with neuropathy or foot ulceration are less likely to undertake the recommended amount of exercise is particularly important when considering that cardiovascular mortality in people with diabetes who have these diabetes complications is markedly increased compared with people who have diabetes but no such peripheral neuropathy or foot related complications.[24,25] A recent study in type 2 diabetes in Australian adults has also shown that people with neuropathy were, by self-report, less likely to undertake exercise,[26] and it reflects studies undertaken in China.[27] Moreover, an increasing body of data supports the concept that exercise may improve symptoms and objective nerve function measures in people with diabetes who have peripheral neuropathy,[28,29] thus supporting the concept that targeted, regular exercise may help to address both lower limb and cardiovascular diabetes complications.

Table 3a
Hierarchical Regression examining the association between CVD and demographic/anthropometric variables, physical activity *n* = 240.

	History of CVD			
	Standardized beta	R^2	*F* Change	*P*
Block 1				
		0.180	8.401	0.000
Age	0.207*			
Gender	−0.207			
Diabetes duration	0.051			
Neuropathy	0.081			
Ulcer	0.078			
Microvascular	0.160*			
Block 2				
		0.220	5.844	0.003
Does moderate exercise	−0.051			
Meets exercise guidelines	0.240*			

* $p < 0.05$.

Table 3b
Hierarchical regression examining the association between neuropathy and demographic/anthropometric variables, physical activity n = 240.

	History of neuropathy			
	Standardized beta	R^2	*F* change	*P*
Block 1				
		0.173	8.028	0.000
Age	0.216*			
Gender	−0.187*			
Diabetes duration	0.140*			
Body weight	0.190*			
CVD	0.068			
Microvascular	0.038			
Block 2				
		0.206	4.677	0.010
Walking time	−0.081			
Moderate exercise time	−0.155*			

* $p < 0.05$.

Table 3c
Hierarchical Regression examining the association between history of foot ulceration and demographic/anthropometric variables, physical activity n = 240.

	History of foot ulceration			
	Standardized beta	R^2	*F* change	*P*
Block 1				
		0.082	9.859	0.000
CVD	0.105			
Microvascular	0.240[a]			
Block 2				
		0.111	3.693	0.026
Sitting time	0.122[b]			
Does vigorous exercise	−0.104			

[a] $p < 0.05$.
[b] $p < 0.062$.

The findings of this study, based on self-report, should be viewed with some caution because it is well acknowledged that, when compared with objective quantification, adults tend to over-report their physical activity levels using tools like the IPAQ-SF.[21,30] Thus, several validation studies of the IPAQ show differing results, but on the basis of systematic review in which IPAQ was compared with an objective physical activity and/or fitness measure, overall the absolute correlation between reported and actual physical activity is weak.[21] This is reflected in our finding that the majority of our sample population reported meeting current recommended exercise levels despite national data demonstrating that most Australians fail to meet these levels.[23] This inaccuracy of IPAQ-quantified physical activity levels also potentially limits the strength of associations found in the present study between physical activity domains and disease history. Despite this limitation, which affects all subjective physical activity tools, questionnaires like the IPAQ-SF offer a widely used, inexpensive, reliable way of characterising population-level physical activity habits.[21] Most importantly, the aforementioned limitations concerning *absolute* physical activity levels do not alter the major finding of the current study that physical activity *patterns* differ between adults with a documented history of CVD, foot complications, nephropathy/retinopathy and neuropathy.

It should also be noted that whilst being significantly correlated with the presence of diabetes complications, and significantly improving the statistical power of the regression model for predicting which diabetes complications individuals had, physical activity only explained a small amount of the variance in complication presence when compared with well-known risk factors such as age, sex and diabetes duration. Also, for the relationship of foot ulceration and neuropathy we observed only a near-significant interaction (*P* value of 0.08). Neuropathy has been well established as a risk factor for the development of diabetic foot ulcer and the lack of association in this present study is surprising. It is likely that this may have occurred as a result of lack of classification of foot ulcer type (i.e. arterial, neuropathic or mixed) and reliance of medical records data which is likely to have used a variety of definitions of an ulceration. Interestingly history of foot ulcer was significantly correlated with other microvascular complications which is consistent with previous research.[31] In addition participants in this study were classified as neuropathic if either VPT or monofilament testing were abnormal, consistent with current international guidelines. As neuropathic foot ulcer is linked to loss of protective sensations (determined by monofilament), increased VPT alone, while indicative of neuropathy, is less likely to be associated with foot ulcer.[32,33]

In conclusion, by comparing self-reported physical activity with anthropometric/demographic data and medical records we have shown that Australian adults with a history of CVD appear to participate in more structured moderate-vigorous exercise and meet exercise guidelines than individuals without CVD. Furthermore, individuals with neuropathy may undertake less walking and moderate intensity exercise, and those with a history of foot ulceration may sit more and participate less in vigorous exercise. These observations suggest a need for individualised strategies, which account for the presence of complications, when implementing physical activity in adults with diabetes.

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