MEASUREMENT

Effect of physical activity measurement type on the association between walking activity and glucose regulation in a high-risk population recruited from primary care

Thomas Yates,1,2* Joe Henson,1,2 Kamlesh Khunti,1,2 Danielle H Morris,1,2 Charlotte Edwardson,1,2 Emer Brady1,3 and Melanie J Davies1,2

1National Institute for Health Research Leicester–Loughborough Diet, Lifestyle and Physical Activity Biomedical Research Unit, University Hospitals of Leicester and University of Leicester, Leicester, UK, 2Diabetes Research Unit, Leicester General Hospital, College of Medicine, Biological Sciences and Psychology, University of Leicester, Leicester, UK and 3Leicester Diabetes Centre, Leicester General Hospital, University Hospitals of Leicester NHS Trust, Leicester UK

*Corresponding author. Leicester Diabetes Centre, Leicester General Hospital, Leicester, LE5 4PW, UK. E-mail: Ty20@le.ac.uk

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Background  We investigate associations of self-reported and objectively assessed walking activity with measures of glucose regulation in a multi-ethnic population at high risk of type 2 diabetes.

Methods  This study reports data from a 2009–2011 screening programme for impaired glucose regulation (IGR) within a high-risk primary care population in Leicestershire, UK; 2532 participants (38% women, 8% South Asian) with a mean age of 64 ± 8 years and an average BMI of 32.1 ± 5.6 kg/m² were included. Walking activity was measured by self-report (International Physical Activity Questionnaire) and objectively (pedometer). Glucose regulation assessments included 2h post-challenge glucose, fasting glucose and HbA1c.

Results  Higher levels of self-reported walking activity and pedometer steps were associated with lower 2h post-challenge glucose after controlling for several known confounding variables, including BMI. Similarly, when categorized in tertiles, both measures were associated with a lower odds of having any form of IGR; odds ratio for lowest vs highest tertile was 0.64 (0.51–0.80) for self-report and 0.69 (0.55–0.87) for pedometer steps. There was no significant difference between self-reported and objective measures in the strength of associations with glucose regulation; associations with self-report were maintained when further adjusted for pedometer steps. Stronger associations between self-reported walking activity and glucose regulation were observed in South Asians compared with White Europeans.

Conclusions  Self-reported and objectively measured walking activity were equally associated with indices of glucose regulation. Associations with self-reported walking activity were maintained when further adjusted for pedometer steps, suggesting that self-reported walking activity measurement type has minimal impact on the association between walking activity and glucose regulation in a high-risk population recruits from primary care.
activity may measure facets of physical activity that are beyond total volume.

Keywords Asian continental ancestry group, diabetes mellitus, epidemiological measurements, exercise, glucose, prediabetic state

Introduction

Walking is the preferred choice of physical activity in the general population and high-risk groups,\(^1\) and is associated with reduced mortality and morbidity.\(^1,4,5\) Studies investigating the relationship between walking activity and health have relied on self-reported instruments (questionnaires) which in general have poor validity and are susceptible to response bias. These limitations become more pronounced when measuring common non-vigorous daily activities such as walking.\(^6\) Therefore, due to measurement error, it can be expected that observational evidence has historically underestimated the true strength of the association between walking and health.\(^7\) In order to overcome this limitation, the use of objective measures of physical activity has been recommended. For example, pedometers provide an accurate assessment of overall ambulatory activity and have been shown to correlate reasonably with objectively assessed total moderate-to-vigorous physical activity (MVPA).\(^8\) Therefore pedometers have a higher order of accuracy than self-report measures, particularly when quantifying walking activity.\(^9\) Indeed, studies commonly employ pedometers as a criterion measure in the validation of self-reported instruments.\(^10\)–\(^12\)

Several studies have investigated differences in the association of physical activity with markers of health status when using self-reported and objective methods. These studies have tended to investigate total MVPA and have reported superior effects for objective measures in some\(^13,14\) but not all publications.\(^15\) However, data are lacking for comparison between measures of common daily activities such as walking. In addition, it is not known whether these factors vary across different populations and ethnic groups. Such data are needed in order to inform the interpretation of epidemiological research and the selection of physical activity measurement instruments in future surveillance and cohort studies.

The aim of this paper is to establish, through a multi-ethnic cohort recruited from primary care, whether the strength of the association of walking activity with glucose regulation varies across two of the most widely used self-reported and objective measures: the International Physical Activity Questionnaire (IPAQ) and the pedometer. We hypothesized that associations would be stronger for pedometer data.

Methods

This analysis reports baseline data from the screening phase of the Let’s Prevent Diabetes study [Clinicaltrials.gov NCT00677937], described in detail elsewhere.\(^16\) Briefly, this two-staged project conducted within primary care includes screening for impaired glucose tolerance (IGT), impaired fasting glucose (IFG) or undiagnosed type 2 diabetes, followed by a diabetes prevention trial in those with IGT and/or IFG.

Participants

Forty-four family practices across Leicestershire, UK, were recruited to the study between 2009 and 2011. Participants were identified and invited for screening based on their calculated risk of having impaired glucose regulation through the Leicester Practice Risk Score.\(^17\) This automated risk score uses patient record data, based on weighted values assigned to six variables (age, sex, ethnicity BMI, family history of diabetes and antihypertensive medication), to rank individuals for their risk of having IFG, IGT or undiagnosed type 2 diabetes. The 10% of patients with the highest scores were invited for screening.

Physical activity

Sealed piezoelectric pedometers with a 7-day memory (NL-800, New-lifestyles, USA) were used to measure ambulatory activity. These pedometers assign a count to all steps undertaken above a specific threshold designed to distinguish between purposeful and more incidental walking activity. New-lifestyles pedometers have been shown to have excellent reliability and validity and are more accurate than traditional spring-levered pedometers for use on overweight and obese individuals.\(^18,19\) All participants were fitted with a pedometer (placed on their trunk along the right anterior axillary line) and instructed to wear it during waking hours for 7 consecutive days and to keep a daily log of the time the instrument was worn. Participants then returned the pedometers to the research centre, where the data were extracted. For the purposes of this study, at least 3 valid days of data were required; a valid day constituted at least 10 h of wear time. It has been shown that the average steps per day of any weekly 3-day combination are highly correlated (\(r>0.8\)) with the average steps per day taken over a full 7-day period.\(^20\) Consequently, three or more days of data provide an acceptable measure of habitual walking activity.
Total MVPA and walking activity were measured using the short last-7-days self-administered format of IPAQ.\textsuperscript{21} IPAQ measures the frequency and duration of any walking and other MVPA undertaken for more than 10 continuous minutes across all contexts (e.g., work, home and leisure) over a 7-day period. IPAQ enables the calculation of metabolic equivalents (MET-hours/week), by assigning standardized MET values for walking, other moderate-intensity physical activity and vigorous-intensity physical activity of 3.3, 4 and 8, respectively. IPAQ has been shown to have reasonable test-retest reliability and validity when compared with an accelerometer in an international study (UK data; test-retest validity \( r \sim 0.7 \), criterion validity \( r \sim 0.4 \)).\textsuperscript{21}

### Measures of glycaemia and impaired glucose regulation

All participants attending screening received a standard 75 g oral glucose tolerance test (OGTT). Participants were categorized according to World Health Organization (WHO) 1999 criteria.\textsuperscript{22} Diabetes was defined as a fasting blood glucose of \( \geq 7 \text{mmol/l} \) and/or 2-h plasma glucose of \( \geq 11.1 \text{mmol/l} \). Anyone who had an OGTT result in the diabetes range was recalled for a second, confirmatory test. IFG was defined as a fasting blood glucose concentration of between 6.1 and 6.9 mmol/l inclusive and IGT as a 2-h blood glucose concentration of between 7.8 and 11 mmol/l inclusive. HbA1c was also assessed. For the purposes of this study a composite measure of IGR was created, calculated as those found to have any of the following: screening detected type 2 diabetes as described above; an HbA1c of \( \geq 6.5\% \); IGT; or IFG. All glucose parameters were measured on fresh samples in the same laboratory located within Leicester Royal Infirmary, UK, using stable methodology standardized to external quality assurance reference values.

### Anthropometric and demographic variables

Body weight, waist circumference (midpoint between the lower costal margin and iliac crest) and height were measured to the nearest 0.1 kg and 0.5 cm, respectively.\textsuperscript{17} Smoking status (non-smokers, past smokers, or current smokers \( \geq 1 \) cigarette per day), medication status and family history of diabetes were gained through interview-administered protocol. Social deprivation was determined by assigning an Index of Multiple Deprivation (IMD) score to participant postcodes.\textsuperscript{24}

Participants classified themselves into one of 16 ethnic groups including three categories of White (British, Irish or other) and four categories of Asian or Asian British (Indian, Pakistani, Bangladeshi or other). Those classifying themselves as White were referred to as White Europeans (WEs) and those classifying themselves as Asian or Asian British were referred to as South Asians (SAs).

### Statistical analysis

Low, moderate and high categories of self-reported walking activity and steps/day were created using tertiles; where multiple identical values crossed a tertile cut-point, they were placed in the same interval. The lowest tertile of self-reported walking activity therefore solely comprised participants reporting 0 min of walking activity.

Spearman’s correlation coefficients were used to assess the strength of the relationship between self-reported walking and pedometer steps and Cohen’s kappa coefficient was used to access the degree of agreement between tertiles of activity derived from each measure.

Forced entry linear-regression models were used to analyse the associations of self-reported walking activity and pedometer steps with measures of glycaemic control (fasting glucose, 2 h post-challenge glucose and HbA1c). Due to their skewed distribution, 2 h post-challenge glucose and HbA1c were log-transformed. Analysis was conducted on two adjusted models. Model 1 was adjusted for measured variables known to influence glucose levels, including: age, sex, ethnicity, smoking, social deprivation, family history of type 2 diabetes (first degree) and beta-blocker and steroid medication status. Model 2 was adjusted for the same variables plus BMI to examine the extent to which adiposity may attenuate any observed findings. Given some dependent variables were log-transformed and to allow for direct comparison between measures and outcomes, results are reported as standardized regression coefficients \( \pm SE \).

In addition, further analysis was undertaken whereby both self-reported walking activity and pedometer steps were entered simultaneously into Model 1 in order to assess whether associations with self-report were ameliorated by the inclusion of pedometer data. Furthermore, an interaction term was fitted to assess whether the strength of the association differed between the two measures.

Interaction terms were also used to examine whether differences were present in the strength of associations of each physical activity measure with glucose parameters by sex and ethnicity. For the ethnicity interaction analysis, only those classified as WE or SA were included due to the low numbers in other groups.

Logistic regression modelling was used to assess the association between tertiles of self-reported walking and objectively assessed pedometer steps and the odds of having prevalent IGR. Models were adjusted for the same variables as above. Interaction terms assessing the effect of ethnicity were fitted across two categories (lowest tertile vs the combined middle and highest tertile) due to the limited numbers of IGR cases for SAs in the middle and highest tertiles of both physical activity measures. In this instance, the self-reported data was categorized as those reporting
no walking activity against those reporting some
walking activity.
As adjustment was not made for multiple compa-
risons, data were viewed with caution and in rela-
tion to the overall pattern of results.
All analyses were two sided and carried out on
PASW Statistics version 18 for Windows (SPSS,
Chicago, USA).

Results
In total 3450 participants were recruited to the study.
Of these 3071 (89%) completed IPAQ and 2820 (82%)
had valid pedometer data; in total 2532 (73%) had
complete IPAQ and pedometer data. This study
reports data from the cohort of 2532 individuals
with complete data. Those excluded from the analysis
were more likely to be: younger (62.1 ± 8.8 vs
63.6 ± 7.8 years); female (43% vs 38%); SA (19% vs
8%); and obese (BMI = 33.4 ± 5.9 vs 32.1 ± 5.6 kg/m²).
However, there was no difference between included
and excluded participants in fasting glucose, 2-h
post-challenge glucose, prevalence of IGR, level of
social deprivation or smoking status. Table 1 shows
the characteristics of the study cohort across tertiles
of self-reported walking activity and pedometer steps.
Levels of self-reported MVPA and walking activity
were weakly correlated with pedometer steps
(ρ = 0.24, P < 0.001; ρ = 0.18, P < 0.001, respectively).
The level of agreement between tertile-derived cate-
gories of self-reported walking activity and pedometer
steps were also low (κ = 0.07, P < 0.001).
Table 2 shows the strength of associations of
self-reported walking activity and pedometer steps
with 2h glucose, fasting glucose and HbA1c. Both
measures were associated with 2h glucose after ad-
justment for measured confounders and BMI.
Although the strength of the association was slightly
greater for pedometer steps, the difference (assessed
by an interaction term) was not statistically mean-
ingful (P = 0.29). Results and significance levels were un-
affected when further adjusted for self-reported
vigorous-intensity physical activity or if waist circum-
ference rather than BMI was used as a covariate (data
not shown).
When self-reported walking activity and pedometer
steps were entered into model 1 simultaneously, both
measures were independently associated with 2h glu-
cose (self-report walking β = −0.06 ± 0.02, P = 0.005;
pedometer steps β = −0.10 ± 0.02, P < 0.001).
Interaction analysis revealed the strength of the asso-
ciation between self-reported walking and measures
of glucose control were stronger for SAs compared
with WEs; results of stratified analysis are displayed in
Table 3. A similar pattern was observed with pedo-
meter steps, although the difference was not statisti-
cally meaningful (P = 0.51 for 2h glucose) (Table 3).
No interactions were observed for sex.
The odds of having any form of IGR were reduced in
the middle and highest teriles of self-reported walking
activity and pedometer steps compared with those in
the lowest terile (Table 4). Results were unaffected if
further controlled for self-reported vigorous-intensity
physical activity or if both measurement types were
entered into the model simultaneously (data not dis-
played).
When results were dichotomized into those report-
ing no walking activity (lowest terile) and those
reporting some walking activity (combined middle
and highest teriles) to assess interactions with ethni-
city, SAs had a greater reduction in their odds of IGR
compared with WEs (62% vs. 33% reduction) (Figure 1).
A similar pattern was observed for pedom-
eter steps (Figure 1).

Discussion
We were unable to confirm our a priori hypothesis
that objectively measured ambulatory activity would
result in stronger associations with markers of glucose
regulation than self-reported walking activity. Both
measures were similarly associated with IGR.
Furthermore, when entered simultaneously into the
same model, both self-reported walking activity and
pedometer steps were independently associated with
glucose regulation, suggesting that each construct
captures distinctive aspects of physical activity that
are important for health. In addition, self-reported
measures revealed important interactions between
ethnic groups, with SAs demonstrating stronger asso-
ciations with glucose regulation than WEs.
This study is broadly consistent with an Australian
study of younger adults that compared the long ver-
ion of IPAQ with pedometer data in associations
with markers of health15; several domains of the
IPAQ-long displayed stronger or similar associations
with insulin resistance and other markers of
metabolic health. However, others have reported su-
perior associations with health for objectively mea-
sured MVPA compared with self-report data.13,14
Nonetheless, one of these studies did find that self-
reported physical activity was associated with
some markers of metabolic health independently of
the objective measure.14
There are several possible explanations that may
account for the independent associations of self-
reported walking activity with glucose regulation in
our cohort. Firstly, IPAQ is designed to capture walk-
ing activity accumulated in bouts of at least 10 min,
whereas pedometers capture total steps taken.
However, others have shown that bout length may
not be an important factor in determining associ-
ations with health.14 It is also possible that by relying
on the recall of past activity, self-reported measures
may prioritize periods of volitional activity, whereas
more incidental bouts of walking activity may be re-
called with a lower degree of accuracy. In contrast,
Table 1  Unadjusted participant characteristics across tertiles of self-reported walking activity and objectively assessed pedometer steps

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tertiles of self-reported walking activity</th>
<th>Tertiles of pedometer steps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low ($n = 1055$)</td>
<td>Moderate ($n = 640$)</td>
</tr>
<tr>
<td>Self-reported walking (MET/h/wk)</td>
<td>0.0 (0.0–0.0)</td>
<td>6.7 (4.1–11.5)</td>
</tr>
<tr>
<td>Total self-reported MVPA (MET/h/wk)</td>
<td>0.0 (0.0–24.0)</td>
<td>13.2 (6.7–31.1)</td>
</tr>
<tr>
<td>Pedometer steps (steps/day)</td>
<td>5680 (2587)</td>
<td>6414 (2717)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>63.4 (7.9)</td>
<td>63.3 (7.8)</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>426 (40)</td>
<td>248 (39)</td>
</tr>
<tr>
<td>Social deprivation (IMD score)*</td>
<td>11.2 (7.0–22.1)</td>
<td>11.2 (7.5–21.8)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Asian</td>
<td>89 (8)</td>
<td>63 (10)</td>
</tr>
<tr>
<td>Other</td>
<td>27 (3)</td>
<td>11 (2)</td>
</tr>
<tr>
<td>Family history of type 2 diabetes in first-degree relative</td>
<td>381 (36)</td>
<td>224 (35)</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td>104 (10)</td>
<td>76 (8)</td>
</tr>
<tr>
<td>Past smoker</td>
<td>426 (42)</td>
<td>494 (48)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>32.7 (5.8)</td>
<td>32.3 (5.8)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>109.1 (13.1)</td>
<td>108.5 (13.2)</td>
</tr>
<tr>
<td>Fasting glucose (mmol/l)</td>
<td>5.4 (0.8)</td>
<td>5.3 (0.8)</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>5.9 (5.7–6.2)</td>
<td>5.9 (5.6–6.1)</td>
</tr>
<tr>
<td>2h glucose (mmol/l)</td>
<td>6.4 (5.1–8.4)</td>
<td>6.2 (5.1–7.7)</td>
</tr>
<tr>
<td>Impaired glucose regulation*</td>
<td>393 (37)</td>
<td>181 (28)</td>
</tr>
</tbody>
</table>

Categorical results as number (percentage), continuous parametric results as mean (SD) and continuous non-parametric results as median (interquartile range).

\*Higher values denote greater deprivation.\*Impaired glucose regulation refers to those who were found to have any of the following at screening: type 2 diabetes; HbA1c>6.5%; impaired glucose tolerance; impaired fasting glucose.
The inability to determine the specific facets within self-report, beyond total volume, which contribute to the independent associations with health has implications for the interpretation of such data in epidemiological research. This is likely to be particularly relevant when quantifying the amount of physical activity undertaken, regardless of volitional intent. It is feasible that purposeful physical activity may be associated with factors that influence psychological and physiological health independently of total activity volume, such as healthier dietary patterns, more leisure time and greater social support. This could be particularly relevant in an older primary care-based population.

The inability to determine the specific facets within self-report, beyond total volume, which contribute to the independent associations with health has implications for the interpretation of such data in epidemiological research. This is likely to be particularly relevant when quantifying the amount of physical activity needed to gain specific health benefits. In this study, the average difference between the highest and lowest tertile of self-reported walking activity was 34.7 MET-hours/wk (equivalent to 1 h 40 min of moderate-paced walking per day) and the difference between highest and lowest tertile of pedometer data was just over 6000 steps/day (approximately equivalent to 1 h per day of moderately paced walking activity).\(^\text{25}\) This finding is consistent with other studies,\(^\text{13}\) and suggests that self-reported activity may inflate levels of physical activity undertaken, and thus overestimate the amount needed to gain specific health benefits.

Uniquely, our study found that the strength of association of self-reported walking with glucose regulation was substantially stronger for SAs compared with WEs. Although the same pattern was observed for the pedometer data, differences were smaller. This suggests that factors other than total volume may be particularly important in influencing self-reported physical activity levels in minority populations and subsequent associations with health. For example, inter-cultural differences in how concepts like ‘moderate’ and ‘vigorous’ are interpreted and norms around the social acceptability of undertaking purposeful physical activity have been reported as factors that may contribute to differences in how physical activity is self-reported between WEs and SAs.\(^\text{26}\)

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Self-reported walking activity</th>
<th>Objectively assessed pedometer steps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1(^a)</td>
<td>Model 2(^b)</td>
</tr>
<tr>
<td></td>
<td>Standardized $\beta$</td>
<td>$P$</td>
</tr>
<tr>
<td>2-h glucose</td>
<td>$-0.08$ (0.02)</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Fasting glucose</td>
<td>$-0.02$ (0.02)</td>
<td>$0.41$</td>
</tr>
<tr>
<td>HbA1c</td>
<td>$-0.02$ (0.02)</td>
<td>$0.41$</td>
</tr>
</tbody>
</table>

Data displayed as standardized regression coefficients (SE).
\(^a\)Model 1 is adjusted for sex, age, ethnicity, family history of type 2 diabetes, social deprivation, smoking, and steroid and beta-blocker medication status.
\(^b\)Model 2 is adjusted for the above covariates plus BMI.

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>White European</th>
<th>South Asian</th>
<th>$P$ for interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$0.07$ (0.02)</td>
<td>$-0.21$ (0.07)</td>
<td>$0.023$</td>
</tr>
<tr>
<td></td>
<td>$-0.01$ (0.02)</td>
<td>$-0.11$ (0.07)</td>
<td>$0.10$</td>
</tr>
<tr>
<td></td>
<td>$-0.01$ (0.02)</td>
<td>$-0.10$ (0.07)</td>
<td>$0.10$</td>
</tr>
<tr>
<td></td>
<td>$-0.10$ (0.02)</td>
<td>$-0.15$ (0.08)</td>
<td>$0.51$</td>
</tr>
<tr>
<td></td>
<td>$-0.03$ (0.02)</td>
<td>$-0.00$ (0.09)</td>
<td>$0.90$</td>
</tr>
<tr>
<td></td>
<td>$-0.02$ (0.03)</td>
<td>$-0.08$ (0.07)</td>
<td>$0.18$</td>
</tr>
</tbody>
</table>

Data displayed as standardized regression coefficients (SE).
\(^a\)Model 1 is adjusted for sex, age, ethnicity, family history of type 2 diabetes, social deprivation, smoking, and steroid and beta-blocker medication status.

### Table 4

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>$P$ for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-reported walking activity</td>
<td>1</td>
<td>0.64</td>
<td>0.63</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Objectively assessed pedometer steps</td>
<td>1</td>
<td>0.82</td>
<td>0.65</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>

Data displayed as odds ratio (95% CI)
Model 1: adjusted for sex, age, ethnicity, family history of type 2 diabetes, social deprivation, smoking, and steroid, and beta-blocker medication status.
Model 2: adjusted for the above covariates plus BMI.
Ethnic group highlights the ongoing need to develop types in SAs and the high risk of IGR in this minority and metabolic health seen with both measurement the relatively strong association between walking activity (Graph A) and objectively assessed pedometer steps (Graph B), stratified by ethnic group Data adjusted for sex, age, family history of type 2 diabetes, social deprivation, smoking, and steroid, and beta-blocker medication status

These could in turn influence the strength of associations with markers of glucose regulation. However the relatively strong association between walking and metabolic health seen with both measurement types in SAs and the high risk of IGR in this minority ethnic group highlight the ongoing need to develop and evaluate culturally acceptable physical activity interventions in minority populations.

This study has several strengths and limitations. Strengths include the large primary care-based sample which enabled investigation of potential effect modifiers (ethnicity and sex) and that glucose regulation was rigorously measured using standardized procedures. Limitations include the fact that vigorous-intensity physical activity was not objectively measured and therefore higher levels of vigorous-intensity physical activity may have contributed to the association between walking activity and IGR seen in our study. However, adjustment for self-reported vigorous activity did not affect the pattern or strength of the results. Further, the prevalences of vigorous activity levels in industrialized countries are very low in similarly aged or overweight/obese adults (<5 min per day) when objective measures and cut-points are applied and are therefore unlikely to account for the size of effect demonstrated in this study. Another potential limitation is that this study was specifically conducted in a population recruited on the basis of a high risk of type 2 diabetes. Therefore results are not generalizable to the general population. Finally, limitations are inherent in the study design; unmeasured lifestyle factors may have affected the results and causality cannot be inferred.

In conclusion, this study provides evidence that self-reported walking activity and objectively measured ambulatory activity are both associated with IGR in a high-risk population, although each measure appears to capture different facets of physical activity behaviour. This finding supports the continued use of self-reported physical activity in epidemiological research, especially where resources are limited and physical activity forms a secondary outcome. However, given that both measures were independently associated with IGR, we endorse previous recommendations that, where possible, studies should employ both objective and subjective measures of physical activity.

**Funding**


**Conflict of interest:** None declared.

**References**