Physical activity and sedentary behaviour in Scottish youth with type 1 diabetes

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Abstract

The purpose of this study was to objectively measure physical activity and sedentary behaviour, across week and weekend days, in Scottish children and adolescents with type 1 diabetes mellitus. Forty patients aged 7–9 years (n=20) or 12–14 years (n=20) wore accelerometers for seven days. Validated cut-points categorised sedentary behaviour, <100cpm, and moderate to vigorous physical activity (MVPA), ≥3200cpm. Differences in behaviour based on age, gender, and diabetes treatment therapy, and patterns in behaviour were explored.

The average sedentary time was 10.2±1.7 hours/day and MVPA was 43.2±23.8 minutes/day. Two participants achieved 60 minutes MVPA on each accelerometer wear day and 19/40 did not achieve 60 minutes of MVPA on any day. Adolescents (11.5±1.2 hours) were more sedentary than younger children (8.9±1.0 hours), (Cohen’s D, [d] = 2.36, p<0.001). MVPA and sedentary behaviour were similar for insulin injection and pump users. MVPA was lower on Saturdays (32.3±27.7 minutes, d=0.56) and Sundays (34.5±33.7 minutes, d=0.40) than weekdays (44.1±14.2 minutes), p<0.05.

It was concluded that physical activity was below the recommendations for health and sedentary behaviour was high, confirming the need for intervention in youth with type 1 diabetes. Particular focus should be made to: minimise sedentary behaviour in adolescents; increase MVPA in adolescent girls; and increase MVPA in children and adolescents at weekends. Copyright © 2014 John Wiley & Sons.

Key words

physical activity; sedentary behaviour; accelerometer; children; adolescents

Introduction

Physical activity is recommended as part of diabetes management. Guidance on safe physical activity participation has been published for youth with type 1 diabetes mellitus. For any young person, regular physical activity can result in health benefit. The potential benefits are especially pertinent for those with type 1 diabetes who can have poorer health, and are at an increased risk of developing cardiovascular disease, compared to peers without diabetes. Physical activity recommendations for youth, inclusive of those with and without type 1 diabetes, are to achieve a minimum of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day.

Previous studies have found conflicting results in whether youth with type 1 diabetes meet these guidelines, and if they are less active than peers without diabetes. Inconsistent findings could be due to differences in data collection and/or analysis.

A review found that sedentary behaviour (sitting time) negatively affects health in youth, and that decreasing sedentary behaviour can improve BMI. A large longitudinal study did not find an association between sedentary behaviour and cardiovascular disease risk in youth. Studies measuring sedentary behaviour are important to investigate inconsistencies in the literature. Research on sedentary behaviour in youth with type 1 diabetes is limited. Initial studies indicate poorer glycaemic control is linked with greater levels of self-reported sitting time in samples of youth with type 1 diabetes.

The study aimed to: (1) determine daily physical activity and sedentary time in Scottish youth with type 1 diabetes; and (2) explore variation between weekdays and weekend days (e.g. identifying when patients are most/least active and sedentary), and population subgroups (based on age and gender). The study advances the research area by objectively monitoring

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physical activity and sedentary behaviour across a range of ages (child and adolescent aged youth). Emerging evidence indicates better glycaemic control in children using pump compared to injection therapy. In a sub-sample analysis, the hypothesis was tested that pump therapy would support greater physical activity participation, through better glycaemic control.

Patients and methods
National Health Service and university ethical approvals were granted. A comparison group of youth without diabetes were not included as published information using similar methodology was available (see Appendix 1 [available in Practical Diabetes online at www.practicaldiabetes.com]). Written informed consent (or assent from those aged <12 years) was obtained from participants and their parents.

Participants
Figure 1 details recruitment and participant flow through the study. Inclusion criteria were: diagnosed type 1 diabetes for >12 months, and aged 7–9 or 12–14 years. Exclusion criteria were: unable to understand study requirements, or contraindicated medical reason (severe cardiac problems and severe physical or learning disabilities). Twenty children (7–9 years) and 20 adolescents (12–14 years) were recruited, allowing comparisons between primary (elementary) and secondary age groups. The representativeness of the sample of the clinic population in terms of gender, age and Scottish Index of Multiple Deprivation (SIMD) is presented in Figure 1.

Data collection
Two visits, at least eight days apart, were made to the participant’s home, clinic or another suitable location. At visit 1, informed consent/assent and demographic questionnaires were completed and participants were given instruction on accelerometer wear and accelerometer wear diary completion. Participants were asked to continue with normal physical activity participation. At visit 2, the researcher collected the accelerometer and wear diary. Physical activity/
sedentary behaviour questionnaires were completed.

**Outcome measures**

**Descriptive characteristics.** Socio-economic status was determined using the SIMD categorised from home postcode data for each participant. BMI z-score (age and gender specific), blood pressure, HbA1c (%) and diabetes duration data were collected from the clinic database as descriptors of the population. BMI z-score and HbA1c are measured every three months, and blood pressure yearly at the clinic. Measurements were taken at the clinic nearest to the participant joining the study. Demographic questionnaires captured information on diabetes therapy (insulin pump versus insulin injection).

**Accelerometry.** Participants were given an accelerometer (Actigraph Model GT3X+; Actigraph, LLC. Pensacola, FL, USA). Accelerometers were worn around the waist using belts during waking hours for seven days excluding water-based activities. An accelerometer wear diary was given to record attachment and removal. Accelerometer data were downloaded to Actilife software (version 6.4.3). In line with previous studies of youth, a minimum wear time for a valid day was defined as 10 hours/day, with three days of data required for analysis inclusion,\(^\text{15}\) using a 15s epoch.

The primary outcome measures of daily time spent in MVPA and sedentary behaviour were determined using cut-points validated in paediatric studies: sedentary behaviour (<100cpm)\(^\text{24}\) and MVPA (≥3200cpm).\(^\text{25}\) Wear diaries identified any non-wear periods, which were removed\(^\text{26}\) using the Actilife software wear diary processing facility. To ensure that sleep data were not included in analysis, only data recorded between 6.00am and 12.00am and corresponding to reported wear time recorded in diaries, were included in analyses. Periods of consecutive zeros, other than that recorded in wear diaries as sleep time or non-wear, were kept in the data. Additional days were included in analysis if participants wore the accelerometer for more than seven full days. As wear time differed across participants (Table 1), adjustments were made to time in sedentary behaviour and MVPA. The absolute maximum wear time across all participants and all days of wear (1004.25 minutes/day or 16.7 hours/day) was used as a standardised wear value to adjust sedentary behaviour and MVPA time, as previously described.\(^\text{27}\) If, for example, a participant achieved 30 minutes of MVPA on a given day and had worn the monitor for 840 minutes, then MVPA was adjusted as follows: (30/1004.25)/840=35.9 minutes in MVPA.

**Type of physical activity and sedentary behaviour.** Participants, aided by their parent/s, completed a physical activity and sedentary behaviour questionnaire developed based on the findings of a previously conducted survey study.\(^\text{28}\) The questionnaire explored the type and frequency of behaviours from the participant’s previous week.

**Analysis**

Data were analysed using SPSS version 21.0.0 (IBM Corp., Armonk, NY). Normality of all data was assessed using Kolmogorov-Smirnov tests. Non-normally distributed data were successfully transformed using a square root transformation (MVPA time data for gender and age-gender comparisons) before analysis using parametric tests. Non-parametric tests were conducted to compare with parametric results for analyses including transformed variables (results available from corresponding author). Pearson correlation coefficients were determined to identify associations between time spent in MVPA or sedentary behaviour with HbA1c.

Differences in sedentary behaviour and MVPA when data were grouped by age (adolescent or younger patient) or gender (boy or girl) were explored using independent t-tests. Data were also explored when grouped by age-gen- der (1 = adolescent boy; 2 = adolescent girl; 3 = younger boy; 4 = younger girl), using one-way ANOVA (with age-gender group as a factor), followed with Fisher’s least significant difference (LSD) post-hoc tests. Nine participants had insulin pumps and the remaining participants were on insulin injection therapy (n=31). To create similar groups for comparisons between participants administering insulin injection therapy (n=9) or using insulin pump therapy (n=9), patients of the same age and gender were selected. Differences in sedentary and MVPA time between participants were determined using independent t-tests.

Table 2 details the number of days of data and number of participants with data for those types of day. Patterns in average daily sedentary and MVPA time were examined using repeated measures ANOVA followed by Fisher’s LSD post-hoc tests (weekday versus Saturday). Significance was set at \(p<0.05\).

Effect sizes for ANOVA and t-tests were calculated using partial eta squared \((\eta^2_p)\), where 0.01 = a small effect, 0.06 = a medium effect and 0.14 = a large effect, and Cohen’s D \((d)\), where 0.2 = a small effect, 0.5 = a medium effect and 0.8 = a large effect, respectively.\(^\text{29}\) Correlation coefficients of \(|r| >0.1 = a\ small\ effect,\ |r| >0.3 = a\ medium\ effect\ and\ |r| >0.5 = a\ large\ effect\ were\ used.\(^\text{29}\)

**Results**

**Accelerometer data**

All participants (n=40) had at least 10 hours of data each day on three days and were included in analyses. Mean duration of accelerometer wear was 6.1±1.2 days (range 4–9 days) and 12.9±1.0 hours/day. Table 1 includes accelerometer wear time for the total sample and for age-gender groups.

A sensitivity analysis was undertaken to determine if addition of MVPA time, when the accelerometer had been removed and activity undertaken, would significantly affect the results. When sufficient information (e.g. indicators of duration and intensity of activity) were provided in wear diaries, regarding physical activity performed when the accelerometer was removed, minutes in MVPA were added to that individual’s data. A total of 743 minutes of activity was reported in diaries to have been undertaken while
Accelerometers were not worn (a combined total of 328 minutes of light physical activity and 415 minutes of MVPA were added to total daily light physical activity and MVPA data for six participants). Of the six participants one removed the accelerometer during football, and five during water-based activity (swimming [n=4]; playing in a pool [n=1]); one of the five removed the accelerometer during swimming and also while playing rugby. Replacement of missing data with estimated MVPA did not significantly affect overall mean MVPA (difference of 1.4 minutes/day), or the percentage of participants meeting the physical activity recommendations. As MVPA data were not significantly affected, analyses do not include the addition of MVPA for activities undertaken during accelerometer non-wear.

**MVPA and sedentary behaviour**

Table 1 shows time in MVPA and sedentary behaviour as well as descriptive characteristics for the total sample and for age-gender groups. For the full sample, average daily MVPA time was 43.2±23.8 minutes/day and sedentary time was 10.2±1.7 hours/day (78.9±10.4% of wear time).

Two participants (5%), achieved ≥60 minutes MVPA every day that they wore the accelerometer and 19/40 (47.5%) participants did not meet the guidelines on any wear day. HbA1c was not associated with time in MVPA (r=-0.158; p=0.330), but was positively associated with sedentary time (r=0.462; p<0.005). Gender, age and therapy comparisons

Adolescents spent more time being sedentary (11.5±1.2 hours) than did younger patients (8.9±1.0 hours); t(38)=7.36, p<0.001, d=2.36. An overall effect of age-gender group was found for sedentary time; F(3,36)=19.11, p<0.001, ηp²=0.614. Sedentary time was greater in adolescent boys compared to younger boys, d=2.94, and younger girls, d=2.00, (p<0.001 for

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**Table 1. Descriptive characteristics of the full sample (n=40) and for age-gender groups. (Unless otherwise stated, data are given as mean ± SD [range])**

<table>
<thead>
<tr>
<th></th>
<th>Full sample (n=40)</th>
<th>Adolescent boys (n=11)</th>
<th>Adolescent girls (n=9)</th>
<th>Younger boys (n=9)</th>
<th>Younger girls (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range (yrs)</td>
<td>11.1±2.7 (7.0–14.9)</td>
<td>13.8±0.8 (12.2–14.9)</td>
<td>13.4±0.7 (12.6–14.4)</td>
<td>8.5±1.0 (7.0–9.7)</td>
<td>8.6±0.9 (7.3–9.5)</td>
</tr>
<tr>
<td>BMI z-score</td>
<td>0.07±1.07 (-2.3–2.1)</td>
<td>0.38±0.83 (-1.05–1.41)</td>
<td>0.78±1.18 (-1.29–2.07)</td>
<td>-0.29±0.94 (-1.35–1.30)</td>
<td>-0.53±0.93 (-2.30–0.47)</td>
</tr>
<tr>
<td>Diabetes duration (yrs)</td>
<td>5.5±2.8 (2.1–13.4)</td>
<td>7.7±3.6 (2.4–13.4)</td>
<td>4.8±2.7 (2.1–10.0)</td>
<td>4.8±1.7 (2.1–7.7)</td>
<td>4.5±1.7 (2.4–6.8)</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>8.2±0.9 (6.8–11.1)</td>
<td>8.5±1.2 (7.1–11.1)</td>
<td>8.4±0.9 (7.3–9.7)</td>
<td>7.8±0.5 (7.2–8.7)</td>
<td>7.9±0.8 (6.8–9.1)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>64±7 (49–79)</td>
<td>66±8 (49–77)</td>
<td>66±8 (59–79)</td>
<td>63±6 (54–72)</td>
<td>61±6 (51–72)</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>113±9 (89–140)</td>
<td>116±11 (98–140)</td>
<td>118±8 (109–135)</td>
<td>109±7 (99–120)</td>
<td>110±8 (89–117)</td>
</tr>
<tr>
<td>Average daily accelerometer (cpm)</td>
<td>741±345 (230–2034)</td>
<td>619±203 (297–1090)</td>
<td>429±130 (230–628)</td>
<td>897±144 (685–1129)</td>
<td>992±445 (603–2034)</td>
</tr>
<tr>
<td>Average daily MVPA time (mins)</td>
<td>43.2±23.8 (7.6–123.3)</td>
<td>48.8±26.0 (13.2–117.5)</td>
<td>27.5±13.5 (7.6–52.0)</td>
<td>48.2±11.7 (25.6–65.5)</td>
<td>46.6±31.5 (23.2–123.3)</td>
</tr>
<tr>
<td>Average daily sedentary time (hrs)</td>
<td>10.2±1.7 (7.0–14.6)</td>
<td>11.2±1.0 (9.7–12.9)</td>
<td>11.8±1.4 (10.1–14.6)</td>
<td>8.7±0.7 (7.6–9.5)</td>
<td>9.1±1.1 (7.0–10.6)</td>
</tr>
<tr>
<td>Average daily wear time (hrs)</td>
<td>12.9±1.0 (10.7–15.0)</td>
<td>13.5±0.6 (12.4–14.5)</td>
<td>13.8±1.1 (11.6–15.0)</td>
<td>12.4±0.6 (11.8–13.5)</td>
<td>12.0±0.7 (10.7–13.1)</td>
</tr>
<tr>
<td>% meeting the MVPA recs on all days</td>
<td>2/40 (5%)</td>
<td>1/40 (2.5%)</td>
<td>0</td>
<td>0</td>
<td>1/40 (2.5%)</td>
</tr>
<tr>
<td>% not meeting the MVPA recs on any day</td>
<td>47.5% (19/40)</td>
<td>36.4% (4/11)</td>
<td>77.8% (7/9)</td>
<td>22.2% (2/9)</td>
<td>54.5% (6/11)</td>
</tr>
<tr>
<td>Diabetes treatment therapy</td>
<td>31 injection; 9 pump</td>
<td>9 injection; 2 pump</td>
<td>7 injection; 2 pump</td>
<td>7 injection; 2 pump</td>
<td>8 injection; 3 pump</td>
</tr>
</tbody>
</table>

*a(adolescent boys vs younger boys); b(adolescent boys vs younger girls); c(adolescent girls vs younger boys); and d(adolescent girls vs younger girls) = significant difference between groups (p<0.05); recs = recommendations.

Median and interquartile range data available upon request from the lead author.
both comparisons). Likewise, adolescent girls were more sedentary than younger boys, $d=2.95$, and younger girls, $d=2.16$, ($p<0.001$ for both comparisons). No other differences in sedentary time between gender or age/gender groups were found ($d$ ranged from 0.12–0.51). No differences between age, $d=0.34$, or gender, $d=0.45$, or age/gender groups, $\eta^2=0.177$, were found for MVPA time. Daily MVPA time and sedentary behaviour did not differ between participants administering insulin pump therapy (MVPA = 36.2±16.3 minutes; sedentary time = 10.0±1.2 hours) compared to participants administering injection therapy (MVPA = 43.8±31.4 minutes; sedentary time = 10.0±1.9 hours), ($d=0.32$ for MVPA and $d=0.00$ for sedentary behaviour; $p<0.05$ for both).

Patterns across days

Twenty-five participants had sufficient data for inclusion in comparisons of weekdays versus Saturdays versus Sundays. No differences for sedentary behaviour between weekdays, Saturdays and Sundays, $\eta^2=0.002$, were found.

MVPA time differed between weekdays, Saturdays and Sundays, $F(2,48)=3.80$, $p<0.05$, $\eta^2=0.137$.

MVPA time was greater on weekdays ($44.1±14.2$ minutes) than on Saturdays ($32.3±27.7$ minutes, $d=0.56$) and on Sundays ($34.5±33.7$ minutes, $d=0.40$), ($p<0.05$ for both comparisons).

MVPA time did not differ between Saturdays and Sundays ($d=0.07$).

Table 2. Summary of the amount of total accelerometer data collected and when split by type of day (weekday versus Saturday or Sunday)

<table>
<thead>
<tr>
<th>Days of data (n) / total days of data (n)</th>
<th>All days</th>
<th>Weekdays</th>
<th>Saturdays</th>
<th>Sundays</th>
</tr>
</thead>
<tbody>
<tr>
<td>242/242</td>
<td>180/242</td>
<td>34/242</td>
<td>28/242</td>
<td></td>
</tr>
</tbody>
</table>

Patients with data (n) / total patients (n)

| 40/40 | 40/40 | 33/40 | 28/40 |

Patients with data (n) for X days

- 9 days, n=1
- 8 days, n=0
- 7 days, n=16
- 6 days, n=13
- 5 days, n=3
- 4 days, n=7
- 6 days, n=2
- 5 days, n=25
- 4 days, n=6
- 3 days, n=5
- 2 days, n=2
- 2 days, n=1
- 1 day, n=32
- 0 days, n=7
- 2 days, n=28
- 0 days, n=12

Type of physical activity and sedentary behaviour

Playground games and active transport (such as cycling, walking, scooter, skateboarding and skating) were the most performed activities; n=12/40 and n=11/40 participants reporting taking part in these activities ≥7 times in the previous week, respectively. Television/DVD watching followed by talking/texting on the phone then computer/internet use and reading (not for school) were the most reported sedentary activities, with n=13/40, n=8/40, n=6/40 and n=6/40 participants respectively taking part in these behaviours ≥7 times in the past week.

Discussion

MVPA and sedentary behaviour levels

This study supports the need for physical activity and sedentary behaviour intervention in youth with type 1 diabetes as: (1) average MVPA time was lower than recommended for health benefits (only two participants met minimum guidelines for physical activity on every day of monitor wear, and less than half of participants did not meet recommendations on any day); and (2) a large proportion of the day was spent in sedentary behaviour. HbA1c was moderately, positively associated with sedentary behaviour but not MVPA. Older patients participated in more sedentary behaviour compared to younger patients; therefore diabetes professionals should make these patients a priority target for intervention. Type of diabetes therapy (pump versus injection) was not associated with different MVPA or sedentary behaviour levels. Comparisons across days of data collection identified patients were least active at weekends.

Participants in the current study were not any less active than youth without diabetes of similar ages from the majority of previously published studies conducted in the UK (Appendix 1 summarises studies). Average daily sedentary behaviour in the current study was greater than in a previously conducted study of adolescent girls with type 1 diabetes (7.4±1 hours/day), and in the majority of studies of youth without diabetes (Appendix 1). Exploration into the reasons why youth with type 1 diabetes might spend more time sedentary is required. Glycaemic control may be an important mediator or effect of sedentary behaviour, as supported by the fact that an association was found between sedentary behaviour and HbA1c in this study. Experimental research is necessary to identify which variable is the cause or effect in this relationship.

Although comparisons with previously collected data provide support that MVPA levels are not greatly different, and that sedentary behaviour may be greater in Scottish youth with type 1 diabetes compared to those without diabetes, differences between studies need highlighting. The studies in Appendix 1 varied in terms of the following data decisions: epoch sampling value; the number of hours and days of data constituting a valid data set; MVPA and sedentary behaviour cut-points; and inclusion or exclusion of a non-wear criteria. An example of how choice of cut-point could potentially affect conclusions is that studies using lower MVPA cut-points than the ≥3200cpm criterion used in the current study reported greater MVPA levels than in this study. The differences in MVPA could be largely due to the different cut-points employed rather than actual differences in MVPA levels.

MVPA levels were slightly greater in the current study than in a study including 8–16 year olds with type 1 diabetes professionals should make these patients a priority target for intervention. Type of diabetes therapy (pump versus injection) was not associated with different MVPA or sedentary behaviour levels. Comparisons across days of data collection identified patients were least active at weekends.
Physical activity is recommended for diabetes management, and regular participation can have significant positive effects on short- and long-term health outcomes in children and adolescents with type 1 diabetes. This study indicates that Scottish youth with type 1 diabetes are not meeting the physical activity recommendations and that they are spending large proportions of their day in sedentary pursuits. Adolescents were spending more time in sedentary behaviour than younger children, highlighting the importance of developing support to minimise sedentary behaviour in adolescence. Adolescent girls had particularly low physical activity levels and should be a priority target group for physical activity intervention. Interventions should prioritise maximising physical activity at weekends, as time spent being physically active was less on weekend days than during weekdays.

**MVPA and sedentary behaviour patterns**

Physical activity was significantly lower on Saturdays and Sundays compared to weekdays indicating that, for youth with type 1 diabetes, physical activity at weekends is an important target. Unlike the MVPA findings in the current study, van Sluijs et al.\(^7\) found no differences in MVPA between weekdays and weekend days in youth without diabetes. Playground games and active travel appear to be popular activities for this group and should be encouraged. Television/DVD watching was the most common sedentary pursuit for this population and interventions should discourage their prolonged participation.

**Study strengths, limitations and future directions**

This study used an objective measurement and all participants’ accelerometer data were used in analysis, confirming viability of this measure in this population. No consensus currently exists as to the most accurate accelerometer MVPA and sedentary behaviour cut-points for research with youth.\(^1\) The present study used cut-points that have been extensively used in youth research. Other accelerometer cut-points may have produced different findings.

A primary and secondary school aged sample of youth were recruited to allow comparisons of different age and gender groups. An age and gender-matched comparison group without diabetes was not recruited due to study constraints. However, there were already sufficient data using methodology similar to that of the present study, to allow comparison (detailed in Appendix 1).

Evidence exists supporting seasonal differences in physical activity of youth in the UK, with lower participation during winter months.\(^2\) Data were collected in this study between February and August, with most participants having a measurement period in April (n=10) or May (n=10). Based on the previous review, physical activity would have been less had data collection occurred during winter.

Small effect sizes indicate a lack of power to detect differences in some comparisons. Readers should be cautious regarding their interpretation of non-significant results of small–medium effect size. Significant differences with large effect sizes were identified for some comparisons. Parametric tests were used for consistency in analysis, with transformations used to normalise distribution where necessary. Using a parametric test, MVPA was not found to differ between age–gender groups. From observation of mean MVPA data across age–gender groups and comparison with non-parametric findings (available from the author), it appears that adolescent girls with type 1 diabetes were the least active. Research with larger samples is now warranted to further explore differences in behaviour between age–gender groups.

Physical inactivity\(^3\) and high sedentary behaviour\(^4\) over the long-term significantly increase the risk of cardiovascular disease and overall mortality. Immediate effects of walking, compared to sitting, include significant reductions in post-prandial glucose, through increased post-prandial glycaemic excursion, in adults with and without diabetes type 1 diabetes.\(^5\) This finding highlights the immediate impact that substituting sedentary behaviour with even light physical activity can have on glycaemic control. Although MVPA and sedentary behaviour levels appear to be similar between youth with diabetes and youth without diabetes from previous studies, with effective support and guidance, youth with type 1 diabetes have the potential to gain greater health benefits than those without diabetes, due to initial poorer health. Diabetes professionals involved in the care of youth with type 1 diabetes should consider how to emphasise physical activity and minimise sedentary behaviour as part of the ongoing management of type 1 diabetes.

**Acknowledgements**

We thank the diabetes team and patients who participated in this study. We also thank Professor John Reilly and Dr David Rowe for their guidance.

**Declaration of interests**

This study was undertaken as part fulfilment of a PhD funded by the Scottish Funding Council and the University of Strathclyde.

There are no conflicts of interest declared.

**References**

References are available in Practical Diabetes online at www.practicaldiabetes.com.
References

Table 1. Summary of studies conducted in the UK measuring physical activity and sedentary behaviour in youth using Actigraph accelerometers. Data are median (IQR) or mean±SD. (Continued on next page)

<table>
<thead>
<tr>
<th>Lead author, year, type of study; study name</th>
<th>Actigraph accelerometer methodology</th>
<th>No., gender and age of participants, study location and data collection period</th>
<th>Main MVPA and sedentary behaviour findings for total sample and differences between gender, age or country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisher (2011)14 Baseline measurement from an intervention study</td>
<td>Epoch: 60-s Valid data set: ≥3 days Valid day: ≥9 hours between 7am–11pm Cut-points: sedentary ≤1100cpm; MVPA ≥3200cpm</td>
<td>No. 64; 33M, 31F Age: 6.2±0.3 years Location: Glasgow, Scotland Data collection period: winter</td>
<td>Proportion of habitual time in MVPA was 3(2–5)%; Proportion of habitual time in sedentary behaviour was 78(74–81)%</td>
</tr>
<tr>
<td>Basterfield (2011)15 Longitudinal study; Gateshead Millennium Study</td>
<td>Epoch: 15-s Valid data set: any ≥3 days Valid day: ≥6 hours Cut-points: sedentary ≤1100cpm; MVPA ≥3200cpm</td>
<td>No. 405; 198M, 207F Age: 7 years &amp; again at 9 years Location: North East England Data collection period: all seasons</td>
<td>Time in MVPA/day was 26(18–37) mins and 24(15–37) mins at 7 and 9 years of age, respectively. In boys, time in MVPA/day was 28(19–43) and 28(20–43) mins at 7 and 9 years, respectively. In girls, time in MVPA/day was 24(17–34) and 21(13–30) mins at 7 and 9 years, respectively</td>
</tr>
<tr>
<td>Riddoch (2007)16 Cross-sectional study (Avon Longitudinal Study of Parents and Children)</td>
<td>Epoch: 60-s Valid data set: any ≥3 days Valid day: 10 hours Cut-points: sedentary &lt;200cpm; MVPA ≥3600cpm</td>
<td>No. 5595; 2662M, 2933F Age: 11.8 (11.6–11.9) years Location: Avon, England Data collection period: all seasons</td>
<td>Sedentary time/day was 430(384–474) mins. Time in MVPA/day was 20(12–31) mins. The proportion of participants meeting ≥60 mins of MVPA/day was 2.5(2.1–2.9). Sedentary time/day was 420(373–464) mins in boys and 440(394–482) mins in girls. Time in MVPA/day was 25(16–38) mins in boys and 16(10–25) mins in girls. The proportion of participants meeting ≥60 mins of MVPA/day was 5.1(4.3–6.0) in boys and 0.4(0.2–0.7) in girls. Participants were most physically active in the summer</td>
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<tr>
<td>Van Sluijs (2008)17 Cross-sectional study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people)</td>
<td>Epoch: 5-s Valid data set: any ≥3 days Valid day: ≥8.3 hours between 6am–11pm Cut-points: MVPA &gt;2000cpm Non-wear: ≥10 minutes of continuous zero counts</td>
<td>No. 1868; 822M, 1046F Age: 9–10 years Location: Norfolk, England Data collection period: spring and early summer</td>
<td>Time in MVPA/day was 74.1±24.9 mins. The proportion of participants meeting ≥60 mins of MVPA/day was 69.1%. Time in MVPA/day was greater in boys, 84.1±38.5 mins, than girls, 66.1±20.8 mins. Time in MVPA was similar on weekend and weekdays</td>
</tr>
<tr>
<td>Owen (2010)18 Cross-sectional study (Child Heart and health Study in England)</td>
<td>Epoch: 5-s Valid data set: ≥1 day Valid day: ≥10 hours Cut-points: not reported Non-wear: ≥10 minutes of continuous zero counts</td>
<td>No. 2049; 979M, 1070F Age: 9–10 years Location: London, Birmingham, Leicester Data collection period: all seasons</td>
<td>Sedentary time was 575.2(87.5) mins in boys and 584.7(82.0) mins in girls. MVPA time was 77.0(19.0) mins in boys and 60.4(14.9) mins in girls</td>
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<tr>
<td>McMinn (2012)19 Baseline data from an intervention study (Travelling Green Study)</td>
<td>Epoch: 5-s Valid data set/valid day: no wear criteria Cut-points used: MVPA = age-adjusted cut points (ranging from 1632–2052 cpmp)</td>
<td>No. 166 children; n=79 in the intervention group (45M, 34F) and n=87 in the comparison group (54M, 33F) Age: 8–9 years; 8.7±0.51 years in the intervention group and 8.6±0.48 years in the comparison group Location: Scotland Data collection period: autumn</td>
<td>Time in MVPA/day was 84.3±27.4 mins in the intervention group and 97.1±27.7 mins in the comparison group at baseline</td>
</tr>
<tr>
<td>Lead author, year, type of study; study name</td>
<td>Actigraph accelerometer methodology</td>
<td>No., gender and age of participants, study location and data collection period</td>
<td>Main MVPA and sedentary behaviour findings for total sample and differences between gender, age or country</td>
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<td>Jago (2010)&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Epoch: 10-s</td>
<td>No. 340; Age: 10–11 years (11.0±0.4 years)</td>
<td>Time in MVPA/day was 35.3±16.7 mins. Sedentary time/day was 552.3±103.1 mins</td>
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<tr>
<td>Cross-sectional data from a longitudinal study (Personal and Environmental Associations with Children’s Health project)</td>
<td>Valid data set: ≥3 days</td>
<td>Location: England Data collection period: all seasons</td>
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<td>Valid day: ≥8.3 hours</td>
<td>Non-wear: ≥60 minutes of continuous zero counts</td>
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<td>Cut-points used: sedentary &lt;727cpm; MVPA ≥2912cpm</td>
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<td>Epoch: 10-s</td>
<td>No. 629; 320M, 309F Age: 10–11 years Location: England Data collection period: all seasons</td>
<td>Sedentary time was 449±97.96 mins/day</td>
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<td>Pulsford (2013)&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Valid data set: ≥1 weekday and 1 weekend day</td>
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<tr>
<td>Cross-sectional data from a longitudinal study (Personal and Environmental Associations with Children’s Health project)</td>
<td>Valid day: ≥10 hours</td>
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<td>Cut-points: sedentary &lt;100cpm</td>
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<td>Non-wear: ≥60 minutes of continuous zero counts</td>
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<td>Epoch: 10-s</td>
<td>No. 176; 87M, 89F (n=98 were younger and n=78 were older dichotomising at the mean age) Age: 12–16 years (mean 14.4 years) Location: East Midlands, England Data collection period: all seasons</td>
<td>A greater proportion of boys (27.6%) were achieving ≥60 mins of MVPA/day compared to girls (16.8%). A greater proportion of younger adolescents (30.6%) were achieving ≥60 mins of MVPA/day compared to older adolescents (11.5%)</td>
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<tr>
<td>Pearson (2009)&lt;sup&gt;22&lt;/sup&gt;</td>
<td>Valid data set: between 10 000 and 20 million</td>
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<td>Cross-sectional study</td>
<td>Cut-points: age-specific cut-points (range not reported)</td>
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<td>Epoch: 15-s</td>
<td>No. 6497; 3176M, 3321F Age: 7–8 years Location: UK wide (all 4 countries) Data collection period: all seasons</td>
<td>Time in MVPA/day was 60(47–76) mins. Sedentary time/day was 6.4(6–7) hours. The proportion of participants achieving ≥60 mins of MVPA/day was 51%. When using a cut-point of &gt;2000 for MVPA, 80.4% of boys and 59.4% of girls achieved ≥60 mins of MVPA/day. Using a cut-point of &gt;3000cpm for MVPA, 13.7% of boys and 0.4% of girls achieved ≥60 mins of MVPA/day.</td>
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<td>Griffiths (2013)&lt;sup&gt;23&lt;/sup&gt;</td>
<td>Valid data set: ≥2 days</td>
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<td>Cross-sectional data taken from a longitudinal study (Millennium Cohort Study)</td>
<td>Valid day: daily counts between 7am–10pm</td>
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<td>Cut-points: sedentary &lt;100cpm; MVPA &gt;2241cpm</td>
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<td>Non-wear: ≥20 minutes of continuous zero counts</td>
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</table>

Appendix 1. Summary of studies conducted in the UK measuring physical activity and sedentary behaviour in youth using Actigraph accelerometers. Data are median (IQR) or mean±SD. (Continued from previous page)