Seasonal Variation in the Distribution of Daily Stepping in 11-13 Year Old School Children

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ABSTRACT

International Journal of Exercise Science 8(4): 358-371, 2015. Seasonality studies in adolescent's physical activity (PA) tend to report total PA (e.g. steps/day) rather than more specific detail such as steps/hour. This study compared the detailed changes in PA between seasons. Thirty three adolescents (baseline age 12.2 ± 0.3y) wore the activPAL activity monitor for 8 days on two occasions. Steps/day were higher in summer (Mdn = 12,879) than winter (Mdn = 10,512), $p<.001$. Steps/hour were significantly higher in summer compared to winter between 17:00 and 21:00 ($p<.044$). No steps/day differences were found between boys and girls at either time point ($p>.05$), however, boys had significantly higher step counts in summer between '13:00-14:00' ($p=.023$), '19:00-20:00' ($p=.032$) and '20:00-21:00' ($p=.023$). Total steps/day masked sex differences within specific hours of the day, particularly evening times. Detailed daily patterns of PA are required to fully understand differences between sexes and across seasons.

KEY WORDS: Physical Activity, Adolescent, Accelerometers, Seasons

INTRODUCTION

Physical activity (PA) levels in children have received a considerable amount of attention from the scientific community, particularly in response to the concerning and growing trends in childhood obesity (29, 17). There is a negative association between levels of PA and obesity (30), and the decline in average daily energy expenditure has been cited as the likely underlying cause of the current epidemic (3). The latest Scottish Health Survey (17) identifies 20% of boys and 14% of girls (ages 2-15 years) as either obese or morbidly obese.

In the adolescent population, benefits of PA include weight/adiposity management (20), improved bone health (30), increased physical fitness (20), and increased self-esteem (19), with long-term benefits including the reduced risk of breast cancer (19). As a result, PA guidelines have been developed nationally and internationally to maximise the benefits of PA. In Scotland, at least 60 minutes per day of moderate intensity PA have been recommended for children under between 5 and 18 years of

age, with the incorporation of vigorous intensity activities at least 3 times per week (9); identical to the international recommendations developed by the World Health Organisation (33). In Scottish adolescents, 66% of 11-12 year old girls and 72% of similar aged boys are currently meeting the guidelines set by the Scottish Government. With increasing age these proportions decrease dramatically, particularly in girls: Only 45% of 13-15 year old girls and 65% of boys currently meet the Scottish guidelines (5).

The determinants of PA behaviour are complex and interrelated, and include a range of individual, biological, social, and environmental factors (2). One area that has received limited attention regarding PA behaviour, particularly in Scotland, has been the effects of both season and weather (22). Carson and Spence (6), in their review of PA in children and adolescents, found evidence for seasonal differences in 83% of the 35 reviewed studies, across a number of different, although predominantly developed, countries. Seasonal differences were generally characterised by higher PA levels in the spring/summer and lower PA levels in the autumn/winter (e.g. 12, 24). Seasonal variation was more apparent in children 8-10 years (79% of studies reporting variation) and adolescents >12 years old (83% reporting variation) than in younger children <6 years old (50% reporting variation) (6).

Whilst data has been presented regarding the seasonal variation of PA in children and adolescents in several countries (10, 24, 25, 26), this has tended to involve organising data into 'average' daily outcomes, such as steps/day. Although this knowledge is informative for overall daily activity levels, it does not provide detailed 'time of day' information to understand the nature of the variation and to allow targeted interventions to increase PA engagement. The distribution of PA throughout the day has received very limited attention: A British (26) and Norwegian study (21), as far as the authors are aware, being the exceptions. Unlike the current study however, both used cross-sectional data, and only the Norwegian study investigated the hourly distribution of PA as a function of season.

Within the present study, PA patterns in terms of steps taken were recorded, on two seasonally distinct time-points, for a group of Scottish adolescents with a baseline age of 11-12 years old. It was hypothesised that summer step counts would be significantly higher than winter step counts and that boys would have significantly greater activity levels than girls at both time-points. In addressing these hypotheses, the detailed patterns of step distribution throughout the day are investigated, developing a greater understanding of the patterns of PA in this population.

METHODS

Measurement was split into two seasonally distinct time-points: November/December 2009 and May/June 2010. These two periods are referred to as 'winter' and 'summer' hereafter. The protocol was the same for both periods.

Participants
Participants were recruited in October 2009 from a Scottish state high school located within a small rural town in the west of

Scotland. A convenience sample of two first year classes, containing a total of 56 pupils were invited, although excluded from analysis if functionally dependent or suffering impairments in mobility. Ethical approval for the study was obtained from Glasgow Caledonian University Ethics committee, North Ayrshire Educational Authority and the participating school.

The participating school was located in a town with a population ≈ 7,320 (14), and a catchment area that incorporated two neighbouring towns (populations' ≈ 5,700 and 6,170) (14). The children included had an average commuting distance of 5.8 km and used a variety of transport including walking, car and bus.

The school day started at 09:00 and finished at 15:25 with a morning break from 11:00 to 11:15 and a lunch break from 13:00 to 13:40.

Steps were objectively monitored with the *activ*PAL™ professional activity monitor (PAL Technologies Ltd., Glasgow, UK). This is a small (5 x 3.5 x 0.7 cm, 20 grams), anterior mid thigh mounted device incorporating a uniaxial accelerometer which uses proprietary algorithms to detect the postural elements of PA (sitting/lying and quiet standing) as well as stepping (*activ*PAL Professional Research Edition, v5.8.3.5). The monitor had a recording capacity of 8 days and was attached using hydrogel pads (PAL*stickies*™). The *activ*PAL has been shown to be an accurate, valid and reliable device to measure free living PA and postural related movement in a variety of populations (Healthy adults (8, 15), Older adults (16), Chronic Low Back Pain (27).

Protocol

Each class received a 10 minute verbal description of the study from the researcher within a Person and Social Education (PSE) class, as well as being given information sheets and consent forms to be taken home to be signed by the parent/guardian. The following week, within the same class (55 minutes in total), consenting participants filled out a demographic questionnaire and were given a 15 minute tutorial concerning monitor application, removal and re-application. Each participant was given a monitor, a bag of 10 PAL*stickies*™, and a tubigrip bandage (elasticated bandage) to offer greater support.

Those involved were instructed to wear the monitor for 8 consecutive days (24 hours a day), only removing it for water based events (e.g. shower, swimming etc) or activities such as sports deemed a potential risk for the wearer (forceful contact in sports such as rugby or falling in skiing/snowboarding) or the monitor.

The participants were also given a tutorial regarding the completion of an adapted version of the Previous Day Physical Activity Recall (PDPAR) diary (32). This questionnaire was completed at registration (10 minute class at the beginning of the day) during the assessment period. The results were used to provide context to the PA behaviour of the participants, and not for comparison to the objective PA data.

The researcher, plus 4 senior pupils, returned to the school every morning of the study period to assist with the completion of the PDPAR diaries.

Weight and height were taken at the beginning of each measurement period and Body Mass Index (BMI) scores were calculated.

The UK's National Weather Service, the MET office, was used to collect details of daily maximum temperature (Celsius), cumulative rainfall (mm), sunshine (hrs) and daylight hours (hrs) for each day of the measurement period(s).

Statistical Analysis

The first day was used to account for possible 'reactivity' (6) to wearing the monitor and was not used in the analysis. Data outputs from the activPAL software were used to identify periods of non-compliance with monitor wear. The full day was removed from analysis if the data seemed inconsistent with standard school days. Inconsistencies between monitor and PDPAR data were classified as missing, and excluded from analysis. Where both PDPAR and activPAL identified longer sedentary pursuits, the raw acceleration signal was analysed for variation. If there was no change in the signal units (A/D units) for 1 hour, the data was classified as non-wearing time, and the full day removed from the analysis.

For the purposes of this study, 4 full week days (from 00:00-23:59) at both measurement points were used for analysis. The average step count for each hour of the day, across 4 days for each participant was calculated using customised software. This data reduction allowed investigation of PA patterns throughout the day of each participant, as well as average patterns across the sample.

Normality testing, consisting of histogram inspection and Kolmogorov-Smirnov tests, was carried out across the distributions of all analysed variables. The use of either Dependent samples t-tests or Wilcoxon Signed Rank tests, to analyse the differences between winter and summer, were inferred from the results of the normality tests, with Independent samples t-tests or Kolmogorov-Smirnov Z tests being utilised when analysing between sex differences. Kolmogorov-Smirnov Z tests can be used as a non-parametric equivalent to the independent t-test when sample sizes are <25 per group; this test tends to offer greater power than the Mann Whitney test (11). The parametric tests were used unless otherwise stated.

One tailed tests were used where there was an expectation of increased stepping and Bonferroni correction was applied as appropriate. For all data the mean and standard deviations (SD) are reported and effect sizes for each significant difference are presented as 'mean differences' between conditions. Estimates of the error associated with those differences are presented using 95% Confidence Intervals (95% CI's). All statistical analysis was carried out in SPSS (v. 17).

RESULTS

Maximum temperature (Celsius), cumulative rainfall (mm), sunshine (hrs) and daylight hours (hrs) are reported in Table 1 as *mean daily* figures as a function of the 7-day measurement periods.

Fifty-six pupils were invited to take part in the study. Twelve declined consent, 10 failed to meet the measurement

requirements of 4 monitoring days in both winter and summer, and 1 failed to meet the inclusion criteria. If five complete week days had been used instead of four, 16 participants would have been included in the analysis; three days would have resulted in 37 participants being included.

TABLE 1. Recorded weather data at both time-points Mean (SD).

Weather Variables (mean ± SD)	Winter	Summer	Mean Difference (95% CI of difference)
Daily maximum temperature (Celsius)	8.6 (4.0)	19.2 (2.9)*	10.6 (8.1 to 13.1)
Cumulative rainfall (mm/day)	5.8 (7.5)	0.4 (1.0)*	-5.4 (-9.4 to -1.4)
Sunshine (hrs/day)	1.1 (1.3)	7.4 (4.4)†	6.3 (3.9 to 8.7)
Daylight hours (hrs/day)	8.2 (1.1)	17.11 (0.42)*	9.0 (8.3 to 9.6)

*p<.001, †p<.015

The final sample (n = 33) included 18 females and 15 males, with a mean age of 12.2yrs (SD = 0.3) at study onset. The 33 participants who completed the study were not statistically different (baseline age, weight and height) from those who failed to complete the study (p>.05). There were no significant differences between males and females across any descriptive variable at either measurement point. The descriptive data for participants at both time points can be seen in Table 2.

Participants daily step count was higher in the summer compared to winter (Summer *Mdn* = 12,879, Winter *Mdn* = 10,512; p <.001). When separated into school (09:00-15:25) and evening (16:00 – 23:00) periods (see Table 3), significantly greater evening steps were observed in summer compared

to winter (summer mean = 5,652, winter mean = 3,503; p<.001), but there was no difference in school steps (p >0.10). As a result, the distribution of steps during the 'evening period' was explored in more detail.

Figure 1 highlights the differences between winter and summer stepping activity, represented by the hourly distribution of mean number of steps from '07:00 – 24:00'. Significantly more steps were taken in summer compared to winter between the hours of '17:00-18:00' (p= .028), '18:00-19:00' (p= .044), '19:00-20:00' (p= .036) and '20:00-21:00' (p=.004) – all one tailed (Bonferroni corrected).

In relation to sex differences, both boys and girls mean daily steps (Table 3) were higher in summer than winter (boys, p= .015, girls, p= 0.003), however there were no significant differences *between* males and females (p>.05) at either time point. Significant between sex differences were evident however, in the hourly breakdown of summer stepping, between the hours of '19:00-20:00' (p=.032, 1-tailed) and '20:00-21:00' (p=.023, K-S Z test, 1-tailed) – boys having significantly higher step counts during this time (Figure 2). Also evident was a significantly higher step count for boys between '13:00-14:00' (p=.023, KS Z test, 1-tailed), again, only for the summer measurement (summer measurement - boys v girls).

The inter-individual variation in evening steps, between winter and summer, can be seen in Figure 3 and 4. Each line represents the mean step count of an individual person, throughout each hour of the displayed times. When focussing on the

evening period, it is clearly visible that not only are the steps counts greater in the summer, as indicated within the inferential statistics presented in Table 3, but the variation in step counts during the summer evening period are also greater (which can also be seen from the standard deviations in Table 3).

TABLE 2. Descriptive characteristics for the sample at both time-points – Mean (SD).

Mean (SD)	Males (n = 15)		Females (n = 18)		All (n = 33)	
	Winter	Summer	Winter	Summer	Winter	Summer
Age (yrs)	12.2 (0.25)	12.7 (0.26)*	12.2 (0.36)	12.8 (0.24)*	12.2 (0.3)	12.7 (0.25)*
Height (cm)*	152.7 (7.7)	156.3 (8.8)*	153.6 (7.6)	156.9 (6.6)*	153.2 (7.5)	156.6 (7.6)*
Weight (kg)	46.0 (9.7)	49.1 (10.0)*	47.6 (11.3)	50.1 (11.0)*	46.9 (10.5)	49.7 (10.4)
BMI (kg/m²)	19.8 (4.3)	20.2 (4.1)	20.1 (3.9)	20.3 (3.9)	19.9 (4.1)	20.2 (4.0)*

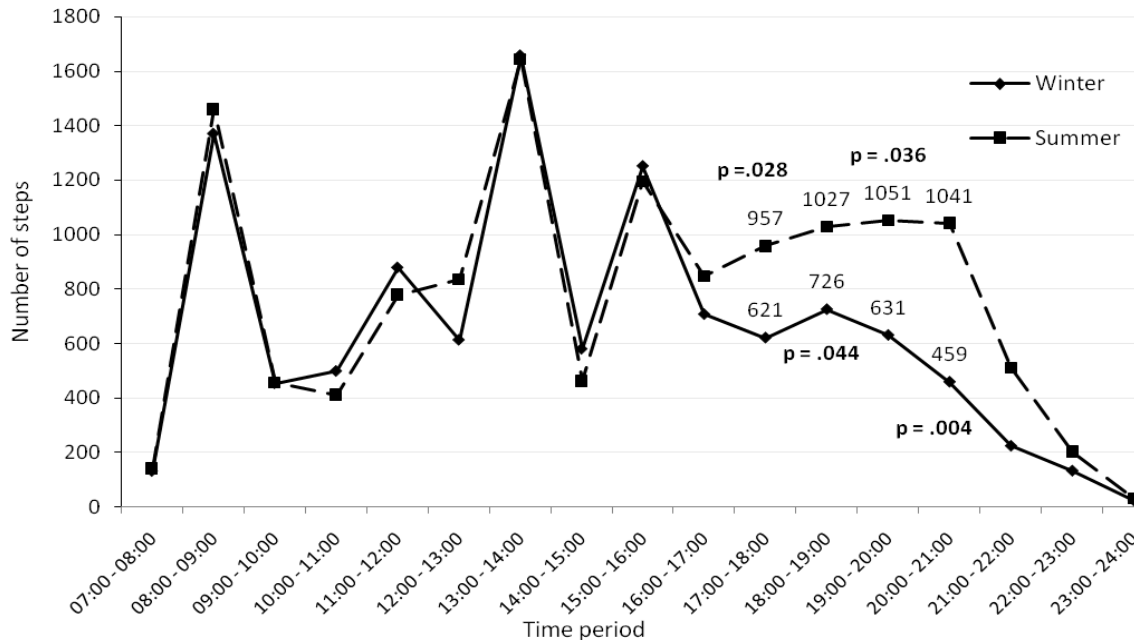*$p<.001$ (paired differences; BMI significant at combined level only)

TABLE 3. School and evening steps/day between seasons (mean ± SD; Bonferroni corrected; significant differences emboldened)

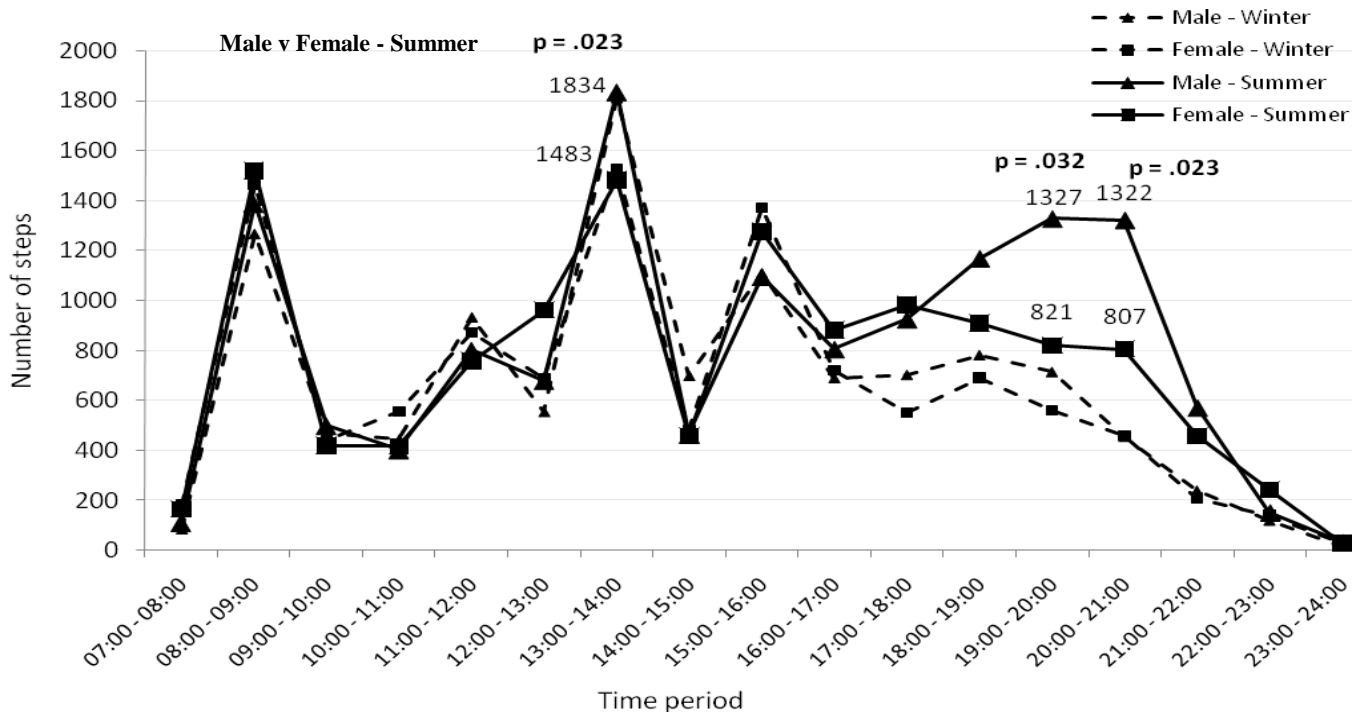| Step variables	Winter	Summer	95% CI of difference
Overall daily steps, all	**10976 (2562)**	**13069 (3208)*†**	1094 to 3092
Overall daily steps, male	**11099 (2686)**	**13585 (3481) §**	571 to 4402
Overall daily steps, female	**10873 (2528)**	**12638 (2994) ‡**	673 to 2857
School steps , all (9am-3.25pm)	4871 (993)	4641 (1125)	-550 to 89
School steps, male	5106 (973)	4807 (1226)	-916 to 319
School steps, female	4676 (993)	4502 (1049)	-525 to 177
Evening steps, all (4pm-11pm)	**3503 (1420)**	**5652 (2749) †**	1250 to 3048
Evening steps, male	**3704 (1466)**	**6271 (2807) ‡**	999 to 4136
Evening steps, female	**3337 (1400)**	**5137 (2667) ‡**	664 to 2937

* Wilcoxon Signed Ranks Test
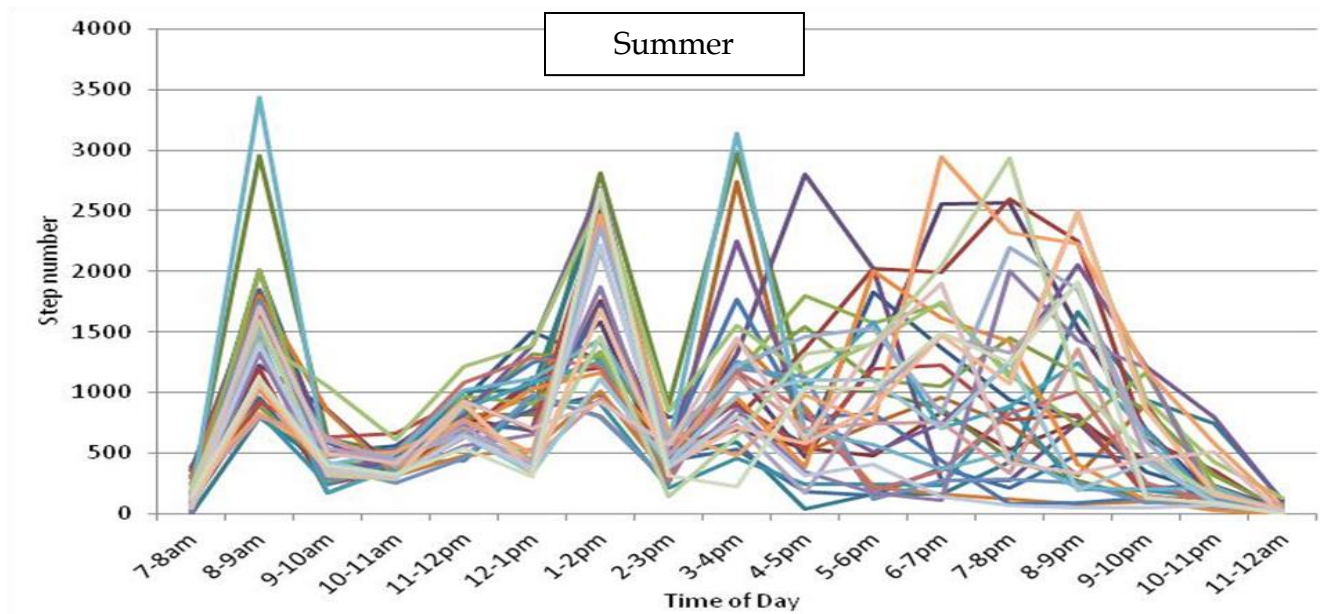†$p<.001$, ‡$p<.02$, §$p<.05$

Figure 1. Distribution of number of steps taken throughout an average day for winter and summer data collection points. Each point is calculated as the average of the mean steps of all participants within each hour of the day.
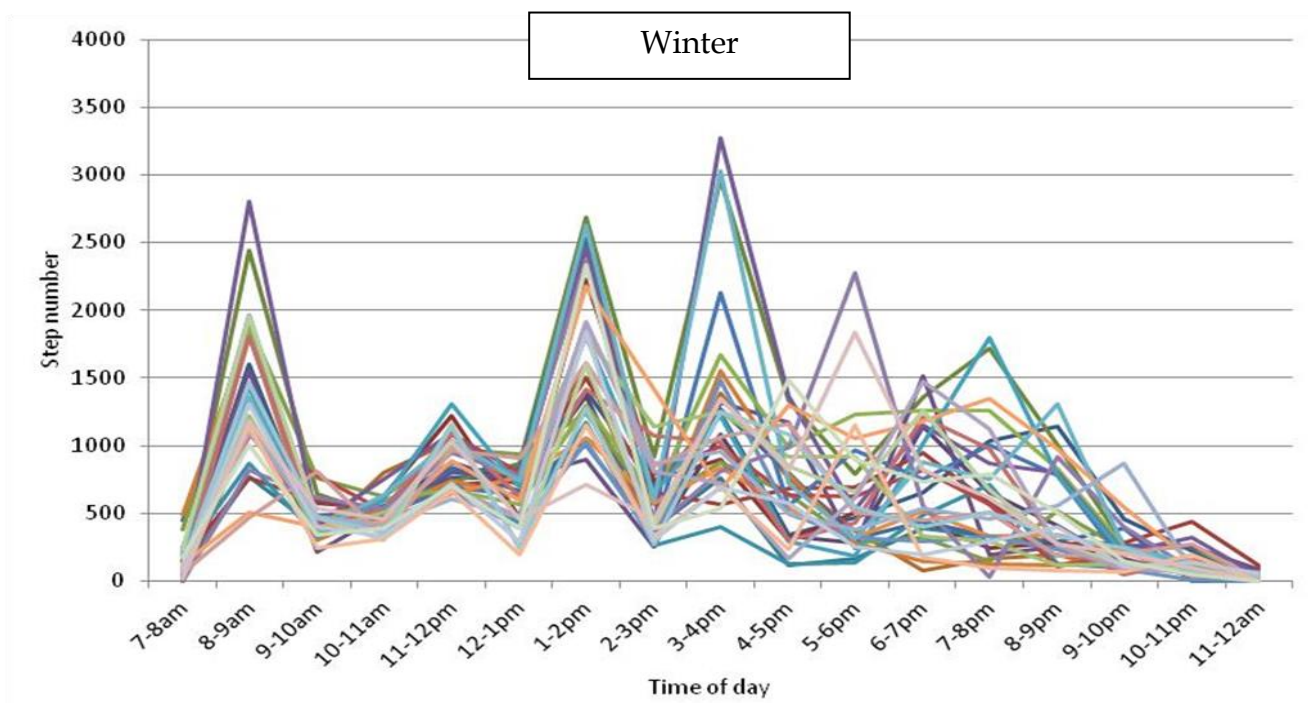

Figure 2. Seasonal differences in mean step distribution by sex. Each point is calculated as the average of the mean steps of the group members within each hour of the day

Figure 3. Inter-individual variation for hourly summer steps between 07:00-00:00: Each line represents one participant.

Figure 4. Inter-individual variation for hourly winter steps between 07:00-00:00: Each line represents one participant.

DISCUSSION

This study used objective activity monitoring to examine the seasonal differences in weekday stepping in Scottish 11-13 year old adolescents. Participants' mean daily steps (weekday) were 19% higher in summer compared to winter (10,975 and 13,069 steps respectively). The observed difference is consistent with previously published work (6, 12, 22, 24, 25). In an English sample of 11/12 year olds (26), accelerometry data (MTI Actigraph, 7164) highlighted a difference of '108 counts/min' between winter and summer, with summer being the most active season. Furthermore, differences of '188 counts/min' for girls and '121 counts/min' for boys (MTI Actigraph 7164) have been reported in a Norwegian sample of 9 year olds (21). In relation to step count, a study conducted in Cyprus (24) grouped their 11-13 year old sample into rural and urban residents. Compared to the winter measurement, the rural participants had a 33% higher step count in summer, with urban participants 6% higher in summer. The current study's location provides data representing a Scottish 'rural' sample, and although incomparable geographically with the Cypriot study, a similar large difference between seasons (19% higher in summer) was highlighted. Although studies have reported inconsistent or contrary findings to the seasonal differences highlighted above (6), it would seem that there is mounting evidence to suggest that seasons do have an effect on the activity levels of children and young adolescents. As such, it is imperative that more than one measurement assessment be taken to characterise adolescents' PA levels (6, 10, 25).

Examination of the 'evening step count' and 'step count per hour' highlighted detailed seasonal differences not apparent in average daily step counts. The evening analysis (16:00 – 23:00) located the general time period where seasonal differences were apparent, as well as highlighting greater variation in stepping compared to the school day (Table 3). More specifically, the hours between 17:00 – 21:00 (excluding 18:00 – 19:00) in the summer had significantly higher step counts than the same hours during the winter, contributing significantly to the differences seen in the overall steps/day between winter and summer. This type of analysis is seldom reported in the PA measurement literature, and very rarely in the seasonal variation context. For example, Riddoch and colleagues (26), although segmenting their cross sectional data into hourly points (n = 5,595; MTI Actigraph), did not present this as a function of season. Importantly however, the authors did highlight the after school/early evening period as the time period with the greatest variation between participants, a finding similar to the present study. A Norwegian study (21) however, also using the MTI Actigraph, successfully grouped their cross sectional data (9 and 15 year olds: n= 1,127 and n = 697 respectively) into hours and seasons. The 9 year old group illustrated a similar seasonal pattern as the present study: the spring period having higher counts/min than winter, with marked differences in the evening period. The older group had no identifiable seasonal differences at any period of the day. The 11-13 year old age group in the present study can be placed in between the year groups investigated by Kolle and colleagues (21), continuing the

pattern evident in the 9 year old age group. It is possible that unidentified changes following the first year of high school negates any seasonal effects, however further investigation would be needed to identify where these differences cease to be evident. Even though both of the aforementioned studies used cross sectional data, different measurement devices and metrics, the current study's repeated measures approach identified similar patterns, particularly regarding the observed evening effects.

There were no significant differences in mean daily step counts between boys and girls at either the winter (11,099 ± 2,686 v 10,873 ± 2,528 steps) or summer (13,585 ± 3,481 v 12,638 ± 2,994 steps) measurements. However, both groups had significantly higher steps in summer than winter. Importantly, when broken down into hourly data points (Figure 2), boys had significantly higher steps than girls during the evenings with strong trends for higher activity between 19:00 - 21:00, but only in the summer measurement. A similar pattern for the 13:00 - 14:00 period was visible for both summer and winter measurements (significant during summer measurement only), indicating a consistent male/female difference for this period, 40 minutes of which was accounted for by a 'lunch break'. The opportunities to be active at lunch were high, with the school grounds offering large green-space; indicating boys were more inclined to use the time and space for PA than girls. Although both boys and girls were inclined to take more steps during summer evenings, boys' accumulated approximately 1,000 steps more than girls between 19:00 and 21:00 in the summer, demonstrating

that boys were also using this summer evening period more than their female counterparts.

The non-significant differences in overall daily step count between the male and female participants (see above) are contrary to other published studies with similar ages (e.g. 5, 13, 21, 22, 23, 31). For example, Flohr and colleagues (13) found a significant difference of approximately 2000 steps/day in a sample of 7th grade adolescents (boys = 12,490 ± 3,910, girls = 10,557 ± 4,142). The outcomes of the present study may be a reflection of small group sizes, as although non-significant, boys did have higher daily steps counts on average than girls at both measurement occasions. Conversely, the differences seen in the evening during summer may indicate the beginnings of a gender gap which is reported to widen in later adolescence (5).

The overall trend observed in the current study contradicts the opinion that PA levels decrease through adolescence (5). As the study was conducted with the same participants on two separate occasions during their school year (winter and then summer), we may have expected a decline in activity from the first to second measurement, and not an increase like the one we have identified. It is clear from the results presented here that observations of change with age may be confounded by differences in PA across seasons. Belanger and colleagues (1), although reporting a similar pattern of seasonal variation to the current study (higher PA in summer than winter, baseline age = 12/13yrs old), highlighted an overall annual decrease in PA of 7% across a 5-year span – attributable to yearly lows in the winter months. The

longitudinal nature of the aforementioned study might provide evidence to explain the observed results in the present study. Additionally, it may be more important to focus our attention on increasing PA levels in the winter months, as this period may contribute to the overall decline seen in PA across the adolescent years (1). Increasing activity in the winter months, especially in the early evening period, may require different approaches compared to summer. Reduction in daylight hours and colder temperatures in winter may limit the efficacy of promoting outdoor activity in the evening time; parents may not be as enthusiastic to allow their children to be outdoors when it's dark. Therefore, winter intervention programs may require an 'indoor' centred approach if targeting evening activity. Additionally, winter programs may benefit from a family centred approach. Compared to the summer, where parents may allow their children to stay outside for longer in response to increased daylight, encouraging parents to take an active interest in their children's activity during the winter may offer successful avenues to increasing PA in winter.

The relationship between the weather and PA is understandably complex: the relationships between weather constructs are inherently linked, and identifying the independent contributions requires complex statistical analyses. Unfortunately, the limited sample size in the present study, combined with the number of possible predictor variables would render any calculation insufficiently powered and was therefore not carried out. Adequately powered studies have attempted to identify the effects of specific weather variables and

PA levels. A study from Auckland, New Zealand (10) illustrated that a 10°C increase in ambient temperature corresponded to an increase of 1,700 (90% CI: ± 1300) weekday steps in boys and 2,300 (90% CI: ±1000) steps in girls. The effects of moderate rainfall (1.1-4.9mm) had a negative effect on both boys (-1700, 90% CI: ±460) and girls (-1180, 90% CI: ±360) weekday daily step count. The results presented here indicate considerable extension of the active period in the evenings with extension of daylight. However, the accumulation of multiple data sets at similar times of year with different weather conditions would be necessary to fully explore the dependence of activity on constructs such as temperature, rainfall and daylight hours.

There were some limitations to the reported study. The participants were sampled (out of a total n = 190) via convenience from one school, chosen by teachers who assisted with implementing the protocol. Therefore, the generalisation of the results to the wider population of Scottish adolescents must be treated with caution. The group sizes of 15 (males) and 18 (females) may have also reduced the study's ability to detect effects.

When considering targeted interventions, this study emphasises the importance of investigating detailed patterns of PA throughout the day and across season, for both males and females. From the present study, the school day seems to be fairly consistent between seasons, with its rigid structure and timetable. It may be possible to intervene at recreation times such as break or lunch; however the largest variation in PA levels occurred after school, into the early evening, an observation highlighted in previous seasonal variation

studies (21, 26). Accordingly, it may be more effective to target PA levels in the early evening, when the structure apparent in school is removed.

Understanding the contributing and determining factors that impose on the PA levels of adolescents is of major importance. At a time where activity levels begin to drop dramatically, and fail to recover into adulthood, the years surrounding early adolescence may hold the key to increasing PA in adulthood. Through the detailed analysis of daily stepping this study has confirmed a seasonal effect of PA in the Scottish adolescent population. Importantly, the early evening period was identified as the major contributor to the higher stepping observed during the summer measurement. Additionally, the hourly analysis revealed significant sex differences not evident when looking at overall steps/day: males having higher steps between 19:00 and 21:00 in the summer evening period.

Seasonal variation in physical activity behaviour has been conducted in multiple countries, including the UK. However, prior work in Scotland has investigated the seasonal differences in young children (12) and adult males (18); the present study is the first to objectively measure the seasonal variation of PA steps in a sample of Scottish adolescents.

This study provides evidence of PA distribution that may be used to inform intervention studies aimed at increasing PA in adolescents or at least reducing the decline commonly observed throughout the adolescent years. In particular, many research papers investigating PA levels of a population will concentrate on total/daily PA, however, this work emphasizes the importance of establishing detailed PA patterns throughout the day, as significant information may be lost by focusing on 'overall daily' data.

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CONFLICT-OF-INTEREST STATEMENT

For full disclosure, Professor Malcolm Granat is a co-inventor of the activPAL physical activity monitor and a director of PAL Technologies Ltd. However, Professor Granat was not involved in data collection or the statistical analysis of the results. The remaining authors declare no competing interests.

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