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Abstract

Purpose: Profiling activity behaviours in young children is important to understand changes in weight status over time. The purpose of this study is to identify activity profiles from self- and parental-reported Physical Activity (PA) and Sedentary Behaviour (SB) variables by gender, and determine if the identified profiles are predictive of weight change from age 9 to 13 years. **Methods:** Cluster analysis was used to generate activity profiles for the National Longitudinal Study of 8570 9-year-old children (Growing Up in Ireland). **Results:** 5.4% of boys were found to be obese. Four cohesive activity profiles were identified for boys, with 7.3% of boys in the least active group identified as obese compared to 4.1% in the most active group. The odds of a normal weight 9-year-old boy in the least active profile becoming overweight or obese at age 13 were over twice those in most active profile (OR = 2.5, 95% CI: 1.9, 3.5). No coherent activity profiles were identified for girls. **Conclusions:** This study suggests that self- and parental-reported data can identify meaningful activity profiles for boys, which are predictive of weight changes over time. Future research should consider potential gender differences in self- and parental-reported PA and SB variables.

Keywords: Physical activity, sedentary behaviour, biostatistics, overweight, obesity

Introduction

Levels of childhood overweight and obesity are at epidemic proportions, with 43 million children estimated to be overweight or obese globally (39). The World Health Organisation (WHO) has identified obesity as one of the most serious public health challenges of the 21st century (43). Overweight and obese children are at a significantly increased risk of becoming overweight and obese adults (33) and therefore, of developing a range of health consequences in adulthood, including diabetes, cardiovascular disease and site specific cancers (9).

Physical activity plays a critical role in physical and mental health, as well as weight management in children and adolescent populations (30), with current WHO guidelines recommending children and adolescents participate daily in at least 60 minutes of moderate-to-vigorous intensity physical activity (43). However, studies indicate that the majority of children do not achieve the recommended amount of physical activity (24, 35), with increased participation in sedentary behaviours having a large negative impact on the weight profiles of children throughout the developed world (34). To develop efficient and effective strategies to positively impact children's participation in physical activity and sedentary behaviours, it is necessary for us to develop a better understanding of these behaviours.

Cluster analysis is a multivariate exploratory analysis tool which aims to group individuals into clusters or profiles, based on similarities found in the observed data (14). An advantage of using cluster analysis when analysing the associations between activity patterns and weight status is that a combined view of both physical activity and sedentary behaviour variables is established compared to using single activity variables only. Leech et al. (17) recently reviewed the profiling of diet, physical activity and sedentary behaviour in children and adolescents, using cluster analysis. Leech identified eight studies which focused specifically on the profiling of physical activity and sedentary behaviour, with five studies

generating profiles for boys and girls separately. All but one study found either a difference in proportion of activity levels for boys and girls, or different activity profiles, with boys generally having higher levels of physical activity. Three of these eight studies investigated the associations between activity profiles and weight status (11, 20, 32); however no study investigated these associations longitudinally. It is evident from this review that although previous research has used cluster analysis to examine activity profiles, few studies have considered activity profiles and the associations with body mass index (BMI) for pre-adolescent children, with even fewer studies using longitudinal data to establish the relationship between activity profiles and weight status over time. Furthermore, Leech recommends that future research use longitudinal data of younger children to track how profiles and their associations to overweight and obesity develop over time (17).

Previous studies have shown evidence of gender disparities in organised sports participation, with girls having lower levels of participation than boys (27, 38). Similarly it has been suggested that gender influences sedentary behaviours, with boys more likely than girls to accumulate excessive screen time (TV viewing and computer use) (21). A recent review by Ferrar et al. (8) of adolescent time-use clusters and associated correlates identified six studies which explored gender-specific clustering to analyse how adolescents spend their time. Two of these six studies focused more specifically on clustering physical activity and sedentary behaviours of adolescents, with different cluster patterns identified for boys and girls (10, 32). Te Velde's gender-specific clusters identified different levels of activity for boys and girls (32), while Gorely et al. found that boys were more likely to have higher computer use and girls were more likely to spend time in paid work or doing chores (10). It is therefore appropriate to investigate physical activity and sedentary behaviours for boys and girls separately.

The aims of this study are to 1) explore activity profiles using cluster analysis in a nationally representative sample of 9-year-old children based on self- and parental-reported physical activity and sedentary behaviours, for both boys and girls, 2) examine whether weight status at 9-years-old and 13-years-old differs across the activity profiles identified at age 9, controlling for socio-demographic variables and parental weight status, and 3) examine if the activity profiles are predictive of weight change from normal weight at age 9 to overweight or obese at age 13.

Methods

Study Population:

The Growing Up in Ireland (GUI) study is a nationally representative study which aims to track the development of children in the Republic of Ireland. The children were selected for this study through a two-stage sampling method within the primary school system. In the first stage, 910 randomly selected primary schools were successfully recruited to take part in the survey. In the second stage, a random sample of children was selected from within each school. At school level, a response rate of 82% was achieved, with 57% of the families agreeing to participate in the study (42). In the first wave of GUI, data for 8570 nine-year-old children were collected from the study child, their family and their teachers. This sample represents approximately 14% of all nine-year old children in the Republic of Ireland. The second wave of the study was carried out in 2011/12 when the children were aged 13 with an 87% follow up (n=7,423). Computer-assisted personal interviews were administered to the study child and primary caregiver by a trained researcher.

Measures:

Height, Weight and Body Mass Index

The interviewers were responsible for measuring the height and weight of both the child and the parent during the household interview. Height was recorded to the nearest millimetre using a Leicester portable height stick and weight was recorded using a SECA 761 flat mechanic scales (Seca Ltd., Birmingham, United Kingdom) to the nearest 0.5 kilogram (16). BMI was calculated using the standard calculation (weight in kilograms/(height in metres)^2). The International Obesity Task Force (IOTF) guidelines were used to categorise BMI in the children at age 9 and 13 years (6). The IOTF defined study participants as normal weight, overweight or obese based on the IOTF age and gender specific BMI cut-points. Parental weight status was classified according to the World Health Organization classifications as normal weight (<25 kg/m2), overweight (≥25 and <30 kg/m2) or obese (≥30 kg/m2) (44).

Self- and Parental-Reported Physical Activity and Sedentary Behaviour

The questions relating to physical activity and sedentary behaviours asked of the child and primary caregiver are outlined in Table 1.

The study child's self-reported favourite hobby variable has previously been used as an indicator of physical activity levels (4) and was recoded as active or inactive for the purpose of this study. For example, if the study child reported that their favourite hobby was basketball or swimming, then these activities were grouped into the active category, whereas if the child answered reading or painting, then these activities were categorised as inactive. How the study child usually travels to and from school was recoded as 'active' for walk or bike and 'inactive' for public transport, school bus or car. Travel to school has previously

been identified as an important source of information on physical activity (19) and was included in the GUI study to investigate its relationship with current and future health (22). Screen and reading time have previously been used as surrogate measures of sitting time or sedentary behaviours (13, 20). The questions asked in the GUI study were based on items from the Millennium Cohort Study from the UK (31) and The National Survey of Children's Health from the USA (2). For this study total sedentary time was recoded for each child by summing the responses to the four variables; 'watching TV', 'using the computer', 'time spent playing video games' and 'reading time', where the midpoint of a time interval was used to represent each response to these three variables (see Table 1).

Socio-Demographics

The study child was asked if they had siblings (yes, no). Household class was created using the occupations of the caregivers; professional workers, managerial and technical, non-manual, skilled manual, semi-skilled and unskilled and unclassified class, where the higher social class was assigned to a family where two parents were both economically active but in different classes (16). Equivalised household annual income was self-reported by the primary caregiver and reported in quintiles. Family type was classified as two parent or single parent households. The primary caregiver's age was recoded and categorised as <30, 30-39, 40-49 or 50+. The primary caregiver's level of education was classified as tertiary level education, secondary education or primary education or less.

Statistical Analysis:

All frequencies and percentages reported in this study are based on statistically reweighted data. The data were statistically adjusted using 2006 census information to be more representative of the whole population. Characteristics such as family structure, social class, economic and disadvantaged status were accounted for in the weights (42).

A Two Step Cluster Analysis (TSCA) was performed using the log-likelihood distance measure. TSCA was considered an appropriate clustering method as it can handle both continuous and categorical variables and is computationally efficient in large datasets. TSCA also provides the option to specify the desired number of clusters prior to carrying out the analysis. TSCA consists of two steps; pre-clustering the cases and using hierarchical clustering to cluster the pre-cluster cases.

TSCA was applied to the self- and parental-reported physical activity and sedentary variables, for both boys and girls separately. Multiple iterations of the cluster analysis were carried out with the optimal cluster solution chosen based on the Akaike information criterion (AIC), the Bayesian information criterion (BIC) and the ratio of distance measured values. Chiu and colleagues proposed that the combined use of the AIC or BIC and the ratio of distance measured was a more accurate means of determining the optimal solution than using a single criterion selection and stated that a large jump in the ratio distance suggested the merger of two clusters which should not be combined (5). The silhouette coefficient was also used to test the strength of the cluster solution, where the silhouette coefficient measures the cohesion and separation of the clusters and a clustering solution which produces a silhouette coefficient of 0.5 or above is considered to be a strong cluster solution (15). Thus the optimal cluster solution was chosen based on the largest resultant ratio of distance measured and largest silhouette coefficient. An issue with cluster analysis is the problem of pattern stability when clustering is applied to real world applications (1). The stability of the cluster solution was tested by randomly splitting the sample in half and performing separate cluster analyses on each. Evidence of the reliability of the cluster solution was provided through descriptive comparisons of the resultant solutions.

The cluster membership variable was used to examine the association between activity levels and BMI categories. Pearson's Chi-square test was used to test for significant

associations between categorical variables. A 5% level of significance was used for all statistical tests. The Cramer's V coefficient was used to measure the strength of the association between nominal categorical variables, where ≥0.1, ≥0.3 and ≥0.5 represent a low, moderate or high association respectively. Kendall's Tau b was used to measure the strength of the association between the ordinal categorical variables, with a range from -1 (perfect negative relationship) to +1 (perfect positive relationship). The Cohen's D coefficient was used to measure the strength of the association for continuous variables. Binary logistic regression was used to model the study child being overweight or obese versus normal weight at 9-years-old and 13-years-old, using activity profiles as a predictor variable and controlling for socio-demographic and parental weight status. All statistical analysis was undertaken using IBM® SPSS® Statistics V21.

Results

Descriptive Statistics and Preliminary Analysis

The body mass index (BMI) of 8090 9-year-old children was recorded; 4150 (51.3%) were boys and 3940 (48.7%) were girls. Results found 3236 boys had a normal BMI (78.0%), 690 were overweight (16.6%) and 224 were obese (5.4%). In comparison 2758 girls were classified as having a normal BMI (70.0%), 875 were overweight (22.2%) and 307 girls were obese (7.8%). Of the boys followed up at age 13 who provided BMI information, 2835 were found to have a normal BMI (77.0%), 679 overweight (18.5%) and 168 obese (4.6%). 2403 girls aged 13 had a normal BMI (69.4%), 810 were overweight (23.4%) and 251 were obese (7.2%).

Descriptive statistics for physical activity and sedentary variables are presented by gender in Table 2. The results suggest gender differences for sports participation. The most common response to how often sport is played for boys was 'almost every day' (55.5%),

whereas the most common response for girls was '1-2 times a week' (40.0%). The largest effect size for the physical activity and sedentary behaviour variables by gender was found for this variable (Table 2). Gender differences were less evident when looking at variables relating to exercise. For the self-reported exercise variable, the majority of boys (60.6%) and girls (52.0%) exercised 'almost every day'.

A descriptive analysis of the association between the physical activity and sedentary behaviour variables and weight status at 9-years-old and 13-years-old was undertaken to explore if individual variables were predictive of weight status, by gender (Supplementary Tables 1 and 2). Differences in weight status were evident for some variables, for example; at 9-years-old 57.3% of males with a normal weight status played sport almost every day compared to 50.9% of males who were overweight or obese. However some activity variables were less predictive of weight status, for example; at 9-years-old 30.6% of males with a normal weight status actively travelled to school compared to 32.3% of males who were overweight or obese. Thus cluster analysis was applied to determine if a combined view of physical activity and sedentary behaviour was predictive of weight status.

Physical Activity Clusters by Gender

Based on the AIC, BIC and ratio of distance measured values (see Supplementary Table 3), a four cluster solution was identified for activity profiles in boys, with an average silhouette value of 0.7, representing good cohesion and separation between clusters. The following physical activity and sedentary variables were included in the final cluster solution for boys; (1) favourite hobby (active or inactive), (2) travel to and from school (active or inactive), (3) plays sport (0-2 days a week or 3-7 days a week) and (4) total sedentary time. The categorical variables were of equal importance in predicting the cluster solution, with a variable importance value of 1.0. Table 3 displays the descriptive data for the four activity

profiles for boys. The profiles are ordered by level of activity, with 43.9% of 9-year-old boys assigned to profile 1, 18.4% to profile 2, 13.2% to profile 3 and 22.6% to profile 4.

Profile 1 has high physical activity levels (100% report having an active hobby and playing sport 3-7 days a week) and lowest levels of sedentary behaviour (mean sedentary time of 4.03 hours). Profile 2 can be characterised as having high levels of physical activity (100% report having an active hobby, active travel to school and playing sport 3-7 days a week), but increased sedentary behaviour compared to profile 1 (mean sedentary time of 4.24 hours). Profile 3 shows low levels of physical activity (100% playing sport 0-2 days a week) and high levels of sedentary behaviour (mean sedentary time of 4.57 hours), however reports having an active hobby. Profile 4 has low levels of physical activity (43.2% reported playing sport 0-2 times a week and 100% reported their preferred hobby was inactive), and the high levels of sedentary behaviour (mean sedentary time of 4.39 hours).

No coherent profiles could be found using the physical activity and sedentary behaviour variables for girls at age 9. Consequently, no further analysis was conducted on the girls at age 9 years and the remaining results focus on examining the relationship between the boys' activity profiles and weight status at age 9 and age 13.

Associations between Activity Profiles and Weight Status for Boys

Activity profiles were predictive of weight status in boys at age 9 and age 13. Highest levels (80.6%) of normal BMI at age 9 were observed in profile 1, the most active group, whilst the lowest levels of normal BMI (73.7%) were found in profile 4, the least active group. High levels of obesity at age 9 were identified in profile 4 (7.3%), compared to 4.1% in the most active group. Similarly, patterns emerged between the activity profiles and weight status at age 13. Profile 1 showed the highest rates of normal BMI (81.3% compared to

70.1% in profile 4) and the low levels of obesity in 13-year-old boys (3.6% compared to 6.8% in profile 4) (Table 4).

The relationship between the activity profiles and overweight or obese status at age 9 and 13, controlling for socio-demographic variables and parental weight status, was investigated for boys (Supplementary Table 4). The odds of being overweight or obese for boys in profile 4 were significantly higher than those in profile 1 at age 9 (OR = 1.4, 95% CI = 1.2, 1.8) and age 13 (OR = 1.9, 95% CI = 1.6, 2.4), when controlling for socio-demographics and parental weight.

Associations between Activity Profiles and Change in Weight Status from 9-years to 13-years for Boys

An association was found between cluster membership and weight change in boys belonging to the normal BMI category at age 9. In the least active profile, 16.0% of boys with a normal BMI status at 9-years-old were found to be overweight or obese at age 13, compared to 6.9% in the most active group (Table 5). The odds of boys in profile 4 changing from normal weight at 9 years to overweight or obese at 13 years were over twice the odds of those in profile 1 (unadjusted OR = 2.5, 95% CI: 1.9, 3.5).

Discussion

To our knowledge this is the first study to examine how profiles of physical activity and sedentary behaviour relate to weight status in pre-adolescent children and how these associations track over time. Cluster analysis was utilised to identify activity profiles from self- and parental-reported physical activity and sedentary behaviour variables provided in GUI. Leech and colleagues noted that clustering is developed from the idea that lifestyle behaviours are influenced by a number of multivariate factors (17). Thus, a benefit of using cluster analysis over traditional single behaviour approaches is the ability to capture the

multiple activity and sedentary behaviours which pre-adolescents participate in. For this study, the use of cluster analysis allows for the associations between weight status and the combined view of physical activity and sedentary behaviour to be investigated. Cohesive physical activity and sedentary behaviour profiles for boys were identified at age 9, with evidence of a clear relationship to weight status. Profile 1, the most active group, had the lowest levels of overweight or obesity at both age 9 and at age 13; whereas profile 4, the least active group, had a greater risk of being overweight or obese at age 9 and at age 13.

The self- and parental-reported physical activity and sedentary behaviour variables used to generate the activity profiles in this study relate to similar variables previously explored in adolescent youths using cluster analysis (18, 20, 23). However, no cohesive clusters could be found for girls using these variables. Similar to the analysis presented here, Gorely et al. (10) applied cluster analysis to the activity and sedentary patterns of adolescents aged 13 to 17 for girls and boys separately. Profiles were generated for both boys and girls; however the variable selection differed, with the boys' profiles including a variable describing the amount of time spent using the computer and the girls' profiles included a variable describing the amount of time spent working (paid work and chores). This suggests that using the same self-reported physical activity and sedentary behaviour variables when clustering girls and boys may not be appropriate, as differences in free-living activity behaviours due to gender (i.e. typical behaviours, hobbies, etc.) are likely to be evident. The review by Ferrar and colleagues (8) highlights that combinations of behaviours, such as sleep, physical activities, sedentary behaviours and cognitive activity, have an effect on adolescent health. The review highlights studies which incorporate a wider range of daily activities into their analysis of time-use clusters, thus resolving some issues which emerge from clustering selective physical activity and sedentary behaviour variables. Similarly the study conducted

by Hunt et al. used latent class analysis to group late adolescents into gender-specific time-use profiles and investigated the associations with health-related quality of life (12).

In addition to gender differences in free-living activities, previous research has also suggested that the differences between male and female participation in organised sports may be responsible for some gender disparities in physical activity levels (3, 37, 38). Our findings may suggest that the questions presented to the girls in this study do not measure their physical activity behaviours adequately. Table 2 highlights these gender differences in participation in sport. Over half (55.5%) of the boys play sport every day compared to 32.7% of the girls, yet the differences in exercising every day are much smaller (60.6% of boys compared to 52% of girls). As highlighted by both Ferrar et al. (8) and Hunt et al. (12), using a larger selection of time-use variables may account for gender differences in physical activity behaviours and optimally measure activity levels over a 24 hour day.

This study relies solely on self- and proxy-reported data for physical activity and sedentary behaviours, despite increasing evidence that objectively measured physical activity is considerably more valid than self- or proxy-reported data alone (26, 36, 40, 41). Dhurandhar, Schoeller et al. (7) suggest that physical activity includes multiple activities such as exercise; sports; and occupational, leisure-time and household activities; which collectively make it difficult to recall and self-report these behaviours. It was recommended that the reliance on self-reported physical activity behaviours be reduced and that more accurate and objective measures of physical activity (i.e. accelerometry, heart rate monitoring) be used instead (7). Past reviews have also questioned the use of self-reported measurement of physical activity (28, 29) stating that physical activity questionnaires offer limited reliability and validity. Shephard and Aoyagi (29) noted that many questionnaires fail to take into account low intensity activities, again leading to a distorted view of the activity levels of the sample. These reviews also highlighted that physical activity questions that offer

interval responses may prompt higher frequencies than open ended questions. This may be the case in our study as, for example, the sport and exercise variables offered the response options: never, 1-2 days, 3-5 days, 6-8 days or more than 9 days. Similar issues may arise with interval response sedentary behaviour variables. For example, TV viewing, computer, and video game use offer the response options: none, less than an hour, 1 to less than 3 hours, 3 to less than 5 hours, 5 to less than 7 hours, and 7 hours or more. It is now widely accepted that children should not exceed more than 2 hours of total screen time per day, (25) however the response categories to these sedentary behaviour variables are broad, and made it impossible to take into account the current screen time guidelines of less than 2 hours for children. If future studies intend to use self-reported measures of sedentary time, response options could be broken down into smaller intervals, for example 30 minute intervals. This would allow items to be analysed within the recommended guidelines, as well as potentially providing the opportunity for researchers to combine these scores for a total sedentary score.

Limitations of this study include the use of self- and proxy-reported physical activity and sedentary behaviours which may be less valid and reliable than alternative objective measures. Secondly, the questions utilised in this study may have limited the amount of information on alternative physical activity behaviours (i.e. light intensity physical activities) that could be collected from the study children and their primary caregivers. This may have impacted on the ability to identify cohesive activity profiles for girls at age 9, and relate to current or future weight status. A known advantage of the clustering method used (TSCA) is its ability to handle both categorical and continuous variables; however the categorical variables often show higher variable importance statistics, strongly influencing the cluster patterns produced, which can influence cluster pattern stability. The stability of the cluster solution was tested by applying the cluster analyses to 50% randomly split sample. However it was not possible to examine the temporal stability of the clusters, that is whether the

children remain in clusters for a meaningful amount of time, as the data was collected only once at 9 years and again at 13 years. Besides these limitations, a strength of this study is the use of a multivariate approach to identify activity profiles in a large cohort (n=8,570) of pre-adolescent children at age 9, which represents 14% of all 9-year-old children nationally over the study period. In addition the availability of longitudinal data, allows for the boys' activity profiles at age 9 to predict current weight status, while also enabling us to track how 9-year-old activity profiles predict future weight status.

Conclusion:

In summary, this present study provides important insights into profiling physical activity and sedentary behaviours of pre-adolescent boys. It also allows for a better understanding of how these activity profiles in 9-year-old boys relate to current weight status; as well predict future weight status. This study has also highlighted gender differences in the physical activity and sedentary behaviours which are used to characterise activity levels. Future research should look to include a wider range of questions examining activity behaviours common in both young boys and girls, which would allow for a better insight into activities relating to daily living. Furthermore, methods, such as accelerometers, should be exploited to objectively quantify physical activity and sedentary behaviours in young children.

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Table 1: Physical activity and sedentary behaviours questions asked to the study child and primary caregiver

Self-reported Variables:	Question	Response Categories
Child's favourite hobby	What is your favourite hobby or activity?	Open question
How often Study Child plays sport	How often do you play sport?	Never 1-2 times a week 3-4 times a week Almost every day
How often Study Child takes exercise	How often do you take exercise (i.e. running, cycling, swim) for 20 minutes or more?	Never 1-2 times a week 3-4 times a week Almost every day
Physically active	Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. Physical activity can be done in sports, school activities, playing with friends or walking to school. Some examples of physical activity are running, brisk walking, rollerblading, biking, dancing, skate-boarding, swimming, soccer, basketball, football and surfing. For this next section add up all the time you spent in physical activity each day. Over the past 7 days on how many days were you physically active for a total of at least 60 minutes per day?	No days 1 day 2 days 3 days 4 days 5 days 6 days 7 days
Parental-reported Variables:		
Travels to or from school	How does the Study Child usually (a) go to school and (b) come home from school?	He/she walks By public transport School bus/coach

Self-reported Variables:	Question	Response Categories
		By car Rides a bicycle Other
Last 14 days no. times hard exercise	How many times in the past 14 days has the Study Child done at least 20 minutes of exercise hard enough to make him/her breathe heavily and make his/her heart beat faster? (Hard exercise includes, for example, playing football, jogging, or fast cycling). Include time in physical education class.	None 1-2 days 3-5 days 6-8 days 9 or more days
Last 14 days no. times light exercise	How many times in the past 14 days has the Study Child done at least 20 minutes of light exercise that was not hard enough to make him / her breathe heavily and make his / her heart beat fast? (Light exercise includes, walking or slow cycling) Include time in physical education class.	None 1-2 days 3-5 days 6-8 days 9 or more days
Total sedentary time	On a normal weekday during term time, how many hours does the Study Child spend watching television, videos or DVDs? Please remember to include time before school as well as time after school? On a normal weekday, during term-time, about how much time does the Study Child spend using the computer? Please include time before school as well as time after school. DO NOT include time spent using computers in school. On a normal weekday, during term-time, about how much time does the Study Child spend playing video games such as, Playstation, X-box, Nintendo, etc.? Please include time before school as well as time after school. DO NOT include time spent using computers in school. On a normal weekday during term time, about how many hours does the Study	None Less than an hour 1 to less than 3 hours 3 to less than 5 hours 5 to less than 7 hours 7 hours or more

Self-reported Variables:	Question	Response Categories
	Child spend reading for pleasure [NOT during school hours]? Include time when the child reads to themselves or is read to by someone else. Do not include time spent listening to books on audio tapes, records, cds or a computer.	

Table 2: Descriptive statistics for physical and sedentary variables by gender

		Male (n=4381) Count (%)	Female (n=4187) Count (%)	P-value	Effect Size
Self-reported Variables:					
Child's favourite hobby	Inactive	989 (23.0)	1058 (25.9)	0.002	0.03
	Active	3312 (77.0)	3027 (74.1)		
How often Study Child plays sport	Never	89 (2.0)	133 (3.2)	<0.001	-0.23
	1-2 times a week	932 (21.4)	1659 (40.0)		
	3-4 times a week	914 (21.0)	1003 (24.1)		
	Almost every day	2416 (55.5)	1357 (32.7)		
How often Study Child takes exercise	Never	38 (0.9)	43 (1.0)	<0.001	-0.09
	1-2 times a week	715 (16.4)	915 (22.0)		
	3-4 times a week	963 (22.1)	1037 (25.0)		
	Almost every day	2636 (60.6)	2157 (52.0)		
Past week no. days physically active for at least 60min p/day?	No days	184 (4.2)	186 (4.5)	<0.001	-0.11
	1 day	218 (5.0)	370 (8.9)		
	2 days	424 (9.8)	557 (13.4)		
	3 days	601 (13.8)	681 (16.4)		
	4 days	628 (14.4)	597 (14.4)		
	5 days	556 (12.8)	546 (13.2)		
	6 days	462 (10.6)	330 (8.0)		
	7 days	1274 (29.3)	881 (21.2)		
Parental-reported Variables:					
Travels to or from school	Inactive	3025 (69.0)	2822 (67.5)	0.12	0.02
	Active	1356 (31.0)	1359 (32.5)		
Last 14 days no. times hard exercise	none	75 (1.7)	135 (3.2)	<0.001	0.14
	1 to 2 days	204 (4.7)	293 (7.0)		
	3 to 5 days	681 (15.5)	862 (20.6)		

		Male (n=4381) Count (%)	Female (n=4187) Count (%)	P-value	Effect Size
	6 to 8 days	757 (17.3)	901 (21.5)		
	9 or more days	2663 (60.8)	1994 (47.6)		
Last 14 days no. times light exercise	none	74 (1.7)	41 (1.0)	<0.001	0.07
	1 to 2 days	160 (3.7)	204 (4.9)		
	3 to 5 days	490 (11.2)	534 (12.8)		
	6 to 8 days	504 (11.5)	620 (14.8)		
	9 or more days	3152 (72.0)	2787 (66.6)		
		Mean (SD)	**Mean (SD)**		
Total sedentary time (hours)		4.2 (2.5)	4.1 (2.3)	0.057	0.04

Table 3: Comparison of activity level clusters in 9-year-old boys (n=4298)*

	Profile 1 (n = 1924, 43.9%)	Profile 2 (n = 807, 18.4%)	Profile 3 (n = 578, 13.2%)	Profile 4 (n = 989, 22.6%)
Favourite hobby	Active: 1924 (100%)	Active: 807 (100%)	Active: 578 (100%)	Inactive: 989 (100%)
Travel to school	Inactive: 1927 (100%)	Active: 807 (100%)	Active: 180 (31.1%)	Active: 337 (34.1%)
			Inactive: 398 (68.9%)	Inactive: 652 (65.9%)
Number of days plays sport in a week	3-7 days a week: 1924 (100%)	3-7 days a week: 807 (100%)	0-2 days a week: 578 (100%)	0-2 days a week: 427 (43.2%)
				3-7 days a week: 561 (56.8%)
Mean sedentary time (hours)	4.03	4.24	4.57	4.39

* 83 cases were excluded due to missing data on one or more of the above variables

Table 4: Prevalence of Activity Clusters by BMI at age 9 and 13 for Boys

	Profile 1 (n = 1924)	Profile 2 (n = 807)	Profile 3 (n = 578)	Profile 4 (n = 989)
	Count (%)	**Count (%)**	**Count (%)**	**Count (%)**
Boys BMI at 9				
- Normal	1489 (80.6)	602 (78.2)	417 (75.8)	685 (73.7)
- Overweight	283 (15.3)	130 (17.1)	91 (16.5)	177 (19.0)
- Obese	76 (4.1)	36 (4.7)	42 (7.6)	68 (7.3)
Boys BMI at 13				
- Normal	1363 (81.3)	497 (76.8)	358 (73.1)	570 (70.1)
- Overweight	254 (15.1)	131 (20.2)	99 (20.2)	188 (23.1)
- Obese	60 (3.6)	19 (2.9)	33 (6.7)	55 (6.8)

Table 5: Prevalence of Activity Clusters by normal weight status change from age 9 to 13 for boys

	Profile 1 (n = 1295)	Profile 2 (n = 488)	Profile 3 (n = 356)	Profile 4 (n =583)
	Count (%)	**Count (%)**	**Count (%)**	**Count (%)**
Boys' normal BMI change from 9 to 13				
- Normal at 9 and 13	435 (93.1)	435 (89.1)	319 (89.6)	490 (84.0)
- Normal at 9, overweight/obese at 13	53 (6.9)	53 (10.9)	37 (10.4)	93 (16.0)

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Supplementary Table 1 and 2:

The association between the physical activity, sedentary behaviour variables and weight status at 9-years and 13-years is displayed in Supplementary Tables 1 and 2, for males and females separately.

Supplementary Table 1: Descriptive statistics for physical and sedentary variables by weight status at 9-years-old

		Male (n=4381) Count (%)		Female (n=4187) Count (%)	
Self-reported Variables:		**Normal**	**Overweight / Obese**	**Normal**	**Overweight / Obese**
Child's favourite hobby	Inactive	685 (21.4)	244 (27.0)	693 (25.7)	308 (26.4)
	Active	2511 (78.6)	660 (73.0)	2003 (74.3)	859 (73.6)
How often Study Child plays sport	Never	56 (1.7)	28 (3.1)	97 (3.5)	27 (2.3)
	1-2 times a week	661 (20.5)	219 (24.0)	1047 (38.1)	500 (42.5)
	3-4 times a week	662 (20.5)	201 (22.0)	699 (25.5)	248 (21.1)
	Almost every day	1849 (57.3)	465 (50.9)	902 (32.9)	401 (34.1)
How often Study Child takes exercise	Never	24 (0.7)	12 (1.3)	20 (0.7)	19 (1.6)
	1-2 times a week	506 (15.7)	175 (19.2)	588 (21.4)	260 (22.1)
	3-4 times a week	699 (21.60	203 (22.3)	670 (24.4)	314 (26.7)
	Almost every day	2001 (62.0)	521 (57.2)	1467 (53.4)	582 (49.5)
Past week no. days physically active for at least 60min p/day?	No days	130 (4.0)	50 (5.5)	126 (4.6)	52 (4.4)
	1 day	161 (5.0)	46 (5.0)	229 (8.3)	119 (10.2)
	2 days	308 (9.6)	95 (10.5)	369 (13.4)	152 (13.0)

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Supplementary Table 1: Descriptive statistics for physical and sedentary variables by weight status at 9-years-old

		Male (n=4381) Count (%)		Female (n=4187) Count (%)	
	3 days	437 (13.6)	141 (15.4)	459 (16.7)	197 (16.8)
	4 days	447 (13.9)	140 (15.3)	380 (13.8)	179 (15.3)
	5 days	404 (12.5)	122 (13.3)	344 (12.5)	164 (14.0)
	6 days	355 (11.0)	79 (8.6)	235 (8.6)	72 (6.1)
	7 days	981 (30.4)	240 (26.3)	602 (21.9)	237 (20.2)
Parental-reported Variables:					
Travels to or from school	Inactive	2246 (69.4)	619 (67.7)	1903 (69.1)	771 (65.4)
	Active	990 (30.6)	295 (32.3)	852 (30.9)	408 (34.6)
Last 14 days no. times hard exercise	none	41 (1.3)	21 (2.3)	74 (2.7)	32 (4.4)
	1 to 2 days	145 (4.5)	50 (5.5)	171 (6.2)	96 (8.1)
	3 to 5 days	470 (14.5)	164 (17.9)	498 (18.1)	313 (26.5)
	6 to 8 days	556 (17.2)	157 (17.2)	611 (22.1)	245 (20.7)
	9 or more days	2023 (62.5)	522 (57.1)	1405 (50.9)	476 (40.3)
Last 14 days no. times light exercise	none	46 (1.4)	13 (1.4)	20 (0.7)	17 (1.4)
	1 to 2 days	109 (3.4)	42 (4.6)	96 (3.5)	93 (7.9)
	3 to 5 days	334 (10.3)	118 (12.9)	305 (11.1)	190 (16.1)
	6 to 8 days	364 (11.3)	107 (11.7)	403 (14.6)	173 (14.6)
	9 or more days	2386 (73.6)	635 (69.4)	1933 (70.1)	709 (60.0)
		Mean (SD)		**Mean (SD)**	
Total sedentary time (hours)		4.14 (2.48)	4.54 (2.61)	4.07 (2.32)	4.28 (2.40)

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Supplementary Table 1: Descriptive statistics for physical and sedentary variables by weight status at 9-years-old

	Male (n=4381) Count (%)	Female (n=4187) Count (%)

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Supplementary Table 2: Descriptive statistics for physical and sedentary variables by weight status at 13-years-old

		Male (n=4381) Count (%)		Female (n=4187) Count (%)	
Self-reported Variables:		**Normal**	**Overweight / Obese**	**Normal**	**Overweight / Obese**
Child's favourite hobby	Inactive	570 (20.4)	242 (28.9)	617 (26.3)	288 (27.5)
	Active	2220 (79.6)	595 (71.1)	1725 (73.7)	760 (72.5)
How often Study Child plays sport	Never	46 (1.6)	33 (3.9)	80 (3.4)	31 (2.9)
	1-2 times a week	562 (19.9)	219 (26.0)	930 (39.0)	447 (42.4)
	3-4 times a week	601 (21.3)	166 (19.7)	603 (25.3)	230 (21.8)
	Almost every day	1616 (57.2)	425 (50.4)	774 (32.4)	347 (32.9)
How often Study Child takes exercise	Never	22 (0.8)	10 (1.2)	15 (0.6)	11 (1.0)
	1-2 times a week	448 (15.9)	147 (17.4)	536 (22.4)	227 (21.5)
	3-4 times a week	628 (22.2)	188 (22.3)	576 (24.1)	263 (25.0)
	Almost every day	1727 (61.1)	498 (59.1)	1261 (52.8)	553 (52.5)
Past week no. days physically active for at least 60min p/day?	No days	90 (3.2)	48 (5.7)	95 (4.0)	49 (4.7)
	1 day	143 (5.1)	51 (6.1)	182 (7.6)	131 (12.4)
	2 days	283 (10.0)	73 (8.7)	323 (13.5)	140 (13.3)
	3 days	395 (14.0)	140 (16.6)	386 (16.2)	157 (14.9)
	4 days	416 (14.7)	120 (14.3)	349 (14.6)	161 (15.3)
	5 days	352 (12.5)	97 (11.5)	321 (13.5)	130 (12.3)

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Supplementary Table 2: Descriptive statistics for physical and sedentary variables by weight status at 13-years-old

		Male (n=4381)		Female (n=4187)	
		Count (%)		Count (%)	
	6 days	316 (11.12	93 (11.0)	210 (8.8)	71 (6.7)
	7 days	829 (29.4)	220 (26.1)	520 (21.8)	214 (20.3)
Parental-reported Variables:					
Travels to or from school	Inactive	2007 (70.8)	572 (67.5)	1682 (70.1)	676 (63.7)
	Active	828 (29.2)	275 (32.5)	718 (29.9)	385 (36.3)
Last 14 days no. times hard exercise	none	31 (1.1)	20 (2.4)	59 (2.5)	42 (4.0)
	1 to 2 days	115 (4.1)	53 (6.3)	152 (6.3)	82 (7.7)
	3 to 5 days	423 (14.9)	149 (17.6)	430 (17.9)	271 (25.5)
	6 to 8 days	474 (16.7)	152 (17.9)	556 (23.1)	219 (20.6)
	9 or more days	1790 (63.2)	473 (55.8)	1206 (50.2)	447 (42.1)
Last 14 days no. times light exercise	none	40 (1.4)	21 (2.5)	15 (0.6)	15 (1.4)
	1 to 2 days	97 (3.4)	40 (4.7)	106 (4.4)	61 (5.7)
	3 to 5 days	294 (10.4)	111 (13.1)	267 (11.1)	162 (15.3)
	6 to 8 days	322 (11.4)	103 (12.1)	371 (15.4)	158 (14.9)
	9 or more days	2083 (73.4)	573 (67.6)	1644 (68.4)	665 (62.7)
		Mean (SD)		**Mean (SD)**	
Total sedentary time (hours)		4.18 (2.47)	4.46 (2.41)	4.01 (2.24)	4.27 (2.39)

Supplementary Table 3: The AIC, BIC and ratio of distance measures were used to identify the optimal cluster solution for boys. The values produced for these statistics have been presented in Supplementary Table 3 for one to ten cluster solutions.

Supplementary Table 3: Indicators of fit for models with one through ten cluster groups

Number of cluster groups	AIC	BIC	Ratio of distance measures
1	16657.1	16688.7	
2	11911.3	11974.4	1.6
3	8936.0	9030.7	1.1
4	6344.8	6471.1	2.2
5	5162.4	5320.3	1.4
6	4332.1	4521.6	1.0
7	3507.5	3728.6	1.2
8	2849.3	3101.9	1.6
9	2430.4	2714.6	1.1
10	2031.9	2347.7	1.8

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Supplementary Table 4: The relationship between the activity profiles and overweight or obese status at age 9 and 13, controlling for socio-demographic variables and parental weight status was investigated for boys in Supplementary Table 4.

Supplementary Table 4: Boys Binary Logistic Regression Model

	Boys age 9		Boys age 13	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Activity Cluster				
- Profile 1	1	0.003	1	<0.001
- Profile 2	1.2 (0.9 - 1.4)	0.18	1.3 (1.0 – 1.6)	0.03
- Profile 3	1.2 (1.0 - 1.6)	0.09	1.6 (1.2 – 2.0)	<0.001
- Profile 4	1.4 (1.2 - 1.8)	<0.001	1.9 (1.6 – 2.4)	<0.001
Family Type				
- 2 Parents	1		1	
- Single Parent	1.2 (0.8 - 1.7)	0.36	1.1 (0.8 – 1.6)	0.51
Siblings				
- Yes	1	0.04	1	0.002
- No	1.4 (1.1 - 1.8)	0.02	1.5 (1.1 – 2.0)	0.006
- Missing	1.2 (0.7 - 2.0)	0.44	1.8 (1.1 – 2.9)	0.01
Primary Caregiver's Age				
- 50+	1	0.22	1	0.11
- 40-49	1.1 (0.7 - 1.8)	0.70	0.7 (0.5 – 1.2)	0.21
- 30-39	1.1 (0.7 - 1.8)	0.64	0.7 (0.5 – 1.2)	0.19
- <30	1.5 (0.9 - 2.7)	0.12	1.1 (0.6 – 1.9)	0.82
Household Class				
- Professional workers	1	0.002	1	<0.001
- Managerial and Technical	1.1 (0.8 - 1.5)	0.52	1.3 (0.9 – 1.8)	0.12
- Non-Manual	1.1 (0.8 - 1.5)	0.72	1.6 (1.1 – 2.3)	0.01
- Skilled Manual	1.3 (0.9 - 1.8)	0.14	1.9 (1.3 – 2.7)	0.001
- Semi-skilled & unskilled	1.6 (1.1 - 2.3)	0.02	1.8 (1.2 – 2.7)	0.004
- Unclassified	0.7 (0.5 - 1.1)	0.16	0.9 (0.6 – 1.5)	0.71
Equivalised Household Annual Income (in quintiles)				
- Highest	1	0.07	1	0.39
- 4th	0.8 (0.7 - 1.1)	0.20	0.9 (0.7 – 1.2)	0.64
- 3rd	0.9 (0.7 - 1.2)	0.52	0.8 (0.6 – 1.1)	0.15
- 2nd	0.7 (0.6 - 1.0)	0.03	0.9 (0.7 – 1.3)	0.70
- Lowest	0.7 (0.5 - 0.9)	0.007	0.8 (0.6 – 1.1)	0.27
- Missing	1.0 (0.7 - 1.4)	0.82	1.2 (0.8 – 1.7)	0.40
Primary Caregivers Education				
- 3rd Level Education	1	0.13	1	0.01
- Secondary Education	1.2 (1.0 - 1.5)	0.03	1.3 (1.1 – 1.6)	0.004
- Primary Education (or lower)	0.8 (0.6 - 1.2)	0.27	1.0 (0.7 – 1.6)	0.85
Mother's measured BMI Classification				
- Normal	1	<0.001	1	<0.001
- Overweight	2.2 (1.8 - 2.6)	<0.001	1.7 (1.4 – 2.1)	<0.001
- Obese	3.5 (2.8 - 4.3)	<0.001	2.5 (2.0 – 3.1)	<0.001

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Supplementary Table 4: Boys Binary Logistic Regression Model

	Boys age 9		Boys age 13	
	OR (95% CI)	*P*	OR (95% CI)	*P*
- Missing	2.3 (1.6 - 3.2)	<0.001	1.9 (1.4 – 2.6)	<0.001
Father's measured BMI Classification				
- Normal	1	<0.001	1	<0.001
- Overweight	1.1 (0.8 - 1.3)	0.69	1.5 (1.1 – 1.9)	0.009
- Obese	2.0 (1.6 - 2.6)	<0.001	2.8 (2.1 – 3.8)	<0.001
- Missing	1.3 (1.0 – 1.9)	0.11	2.0 (1.4 – 2.9)	<0.001