Patterns of physical activity in 9 and 15 year-old children in Iceland

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ÁGRIP

Hreyfiatferli 9 og 15 ára barna á Íslandi.

Hreyfing er mikilvægur þáttur til að sporna við ofþyngd og offitu, sem herjar sífellt meira á bæði börn og fullorðna. Hreyfingarleysi er stór áhættuþáttur fyrir marga sjúkdóma og kvilla. Mikil minnkun á hreyfingu verður með aldrinum og er hún einna mest á unglingsárum. Einnig er almennt mikill munur á hreyfingu stúlkna og drengja, þar sem stúlkur stunda minni hreyfingu og af minni ákefð. Aukinn tími sem varið er fyrir framan sjónvarpið og tölvuna á unglingsárunum hefur hugsanlega einhver áhrif á þessa þróun. Markmið rannsóknarinnar var að kanna hreyfiatferli 9 og 15 ára barna í daglegu lífi og athuga tengsl milli þess við holdafar og þol þeirra. Einnig að kanna á hvern hátt tómstundaiðkun og skjátími (sjónvarpsskjá- og tölvuskjátími) hafa áhrif á hreyfiatferlið. Þátttakendur í rannsókninni voru 934 börn fædd 1988 og 1994, þá 9 og 15 ára gömul og voru mælingar teknar frá september 2003 til febrúar 2004. Hreyfingin var metin með hreyfimælum sem skráðu hreyfingu barnanna niður í þrjá til fimm daga. Alls skiluðu 338 þátttakendur inn gögnum sem uppfylltu uppgefin skilyrði, en 743 svöruðu spurningarlistum. Í rannsókninni voru skoðaðir mismunandi þættir hreyfiatferlisins. Helstu niðurstöður voru að daglegt hreyfimynstur var mismunandi bæði eftir aldri og kyni, en 9 ára börn (stúlkur= 528±166 kslög/dag (±SD), drengir= 620±186 kslög/dag) voru marktækt virkari en 15 ára unglingar (stúlkur= 425±130 kslög/dag, drengir= 543±195 kslög/dag; F= 37,2; df= 1;334; p<0,001). Einnig kom í ljós munur á hreyfimynstri milli helga og virkra daga (F= 27,4; df= 10,6;3535; p<0,001) og var þessi munur ekki sá sami fyrir aldurshópana tvo (F= 12,6; df= 10,6;3535; p<0,001) eða fyrir kyn (F= 2,30; df= 10,6;3535; p= 0,009). Sjö óháðir þættir (components), sem lýstu hreyfingunni best, voru reiknaðir með hjálp leitandi meginþáttagreiningar (Principal component analysis). Þrír af þessum þáttum

lýstu mismunandi hliðum hreyfingar af miðlungs ákefð eða meiri, en fjórir þættir hreyfingu af mjög mikilli ákefð. Tveir af þessum þremur þáttum (einn sem lýsti meðal lengd lota og annar fjölda lota á dag) höfðu sterkustu fylgnina við nokkrar af þeim breytum sem rannsakaðar voru. Þessar breytur voru aldur, kyn, þrjár breytur sem lýstu líkamssamsetningu, þol og tvær breytur sem lýstu lífsstíl. Af þessu má álykta að það sé aðallega lengd og fjöldi lota yfir ákveðnum þröskuldi, frekar en heildarhreyfing, sem hefur sterkustu tengslin við fitusöfnun og þol. Þetta gefur til kynna að hreyfing sé margþætt atferli og það sé mikilvægt að horfa ekki eingöngu á hefðbundnar breytur við mat á hreyfingu, heldur einnig að skoða mismunandi þætti hreyfimynstursins.

ABSTRACT

Patterns of physical activity in 9 and 15 year-old children in Iceland.

Physical activity is an important factor to prevent overweight and obesity, which is becoming more and more prevalent in both children and adults. Sedentary behaviour is a powerful predictor for many diseases and disorders. Physical activity declines with age, especially during adolescence. There are also differences between boys and girls, where girls are less physically active and their activity tends to be of lower intensity. Increased time in front of the television or computer during adolescence likely has an effect on this trend. The aim of this study was to examine the daily activity pattern of 9 and 15 year old (YO) children and explore the relationship between the activity pattern and body composition and fitness. A secondary aim was to explore how leisure- and screen time (TV, DVD, video and computer) is associated with different factors of the activity pattern. Participants in this study were 934 children born in 1988 and 1994, 9 and 15YO at that time. Measurements were taken from September 2003 to February 2004. The activity was assessed using an accelerometer which recorded the child´s activity for three to five days. Participants returning physical activity data which met the minimum criteria were 338 and 743 participants answered a questionnaire. The main findings were that the daily activity pattern varied considerably depending on both age and sex. 9YO children (girls= 528±166 kcounts/day (±SD), boys= 620±186 kcounts/day) were significantly more active than 15YO adolescents (girls= 425±130 kcounts/day, boys= 543±195 kcounts/day; $F= 37.2$; $df= 1.334$; $p<0.001$). Also, it was found that the activity pattern was not the same on weekends and weekdays ($F= 27.4$; $df= 10.6;3535$; $p<0.001$) and this difference depended on age ($F= 12.6$; $df= 10.6;3535$; $p<0.001$) and gender ($F= 2.30$; $df= 10.6,3535$; $p= 0.009$). Seven

independent components, were chosen which best described the nature and quality activity. These were calculated using Principal component analysis. Three of these components described activity of moderate intensity or more. Another four of the components described activity of very much intensity. Two components of the activity data were found to most strongly correlate with various subjects attributes (age, gender, three measures concerning body composition and fitness, and two concerning lifestyle). These components were described by the total number of bouts of activity over the day, and the average length of individual bouts. From this it can be concluded, that it is the length and number of bouts over certain intensity thresholds, rather than total activity, that is most strongly associated with fatness and fitness. This shows that physical activity is a complex behaviour and it is important not only to look at traditional variables of physical activity, but also to examine different components of the activity pattern.

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LIST OF ABBREVIATIONS

AB3M =	Average length of bouts over 3 METs
ACSM =	American College of Sports Medicine
adjW =	Adjusted waist circumference
AI8+M =	Average length of intervals between bouts over 8+METs
BMI =	Body max index
BMR =	Basal metabolic rate
CDC =	The Centers for Disease Control and Prevention
CVD =	Cardio vascular disease
DLW =	Doubly labelled water
DVD =	Digital video disc
HDL =	High-density lipoprotein
MET =	Metabolic equivalent
NB3M =	Number of bouts over 3 METs
NB9Mwd =	Number of bouts over 9 METs on a weekday
PCA =	Principal components analysis
RMR =	Resting metabolic rate
RPM =	Rounds per minute
STD =	Standard deviation
TI2+M =	Total time in intervals between bouts over 2+METs
TI9M10we =	Total time in intervals between bouts that lasted more than 10 min over 9 METs on weekends
TT2+M =	Total time over 2+METs
TT3M =	Total time over 3 METs
TT5+M =	Total time over 5+METs
TT6M =	Total time over 6 METs

TT8+M =	Total time over 8+METs
TT8+Mwe =	Total time over 8+METs on weekends
TT9M =	Total time over 9 METs
TT9M10 =	Total time that lasted more than 10 min over 9 METs
TV =	Television
VO_2max =	Maximal oxygen uptake
wd =	Weekday
we =	Weekend
YO =	Year-old

INTRODUCTION

The importance of physical activity

Obesity among children and adolescents has increased tremendously in recent years and is now a worldwide epidemic (62, 87), which places children and adolescents at increased risk of significant health problems (29, 48, 89). Childhood obesity is associated with several metabolic and endocrine disorders, such as glucose intolerance, hypertension and dyslipidemia, which are all risk factors for the development of cardiovascular diseases (CVD) and type 2 diabetes (28, 90). Evidence indicates, that regular physical activity in youth is inversely related to an array of negative health outcomes, such as elevated blood lipids, hypertension and cigarette smoking, and positively related to favourable health outcomes, such as increased cardio-respiratory fitness, elevated high-density lipoprotein (HDL) cholesterol, increased bone mass and improved psychological well-being (14, 59, 140). Obese children and adolescents are at increased risk for adult obesity (153), and limited physical activity at young age may predispose to sedentary lifestyle later in life (80). Adequate participation in physical activity during childhood and adolescence may be of critical importance in the primary prevention of chronic diseases (56, 80, 129, 140, 143, 153). Participation in physical activity at a young age is also considered essential for normal growth and development (140).

Overweight, obesity and physical activity

Prevalence of overweight and obesity has increased more rapidly in the last 10 to 15 years than in previous decades (13). A survey in three Australian states showed that overweight had increased by 60-70% from 1985 to 1997 (13). Also, studies conducted in the United States (45, 99, 135), Spain (88), Britain (22) and many European countries, consistently show that the prevalence of overweight and obesity in young people is increasing exponentially. This was found to be evident among preschool aged children as well as older children and adolescents (37, 93, 94, 99). Childhood obesity is multi factorial disease that involves genetic, social, cultural, and environmental components (10, 18, 37, 65).

Lack of physical activity is hypothesized to be an important contributing factor to the development and maintenance of childhood obesity (49, 79, 101, 134, 148), and negative associations between objectively measured physical activity and fatness in children and adolescents have been shown (37, 58, 104, 111, 113). Many studies have found out that obese or overweight children and adolescents are less active than their normal-weight peers, and spend more time in sedentary activities (19, 25, 30, 31, 35, 79, 83). Total activity counts and time spent in vigorous activity have been associated with a decreased likelihood of being overweight (19, 37, 101). Obese children appear to exhibit significantly lower daily accumulations of moderate and vigorous physical activity and participate in significantly fewer continuous bouts of moderate to vigorous activity (136). Some research indicates that the intensity of physical activity is more important factor to prevent obesity, rather than the duration of activity (1, 104) and several studies of American and European children agree (58, 67, 111, 113). In a study of normal weight North American adolescents (58), who spent only a few minutes a day in vigorous physical activity, a significant positive association with body fat was observed and this has been confirmed by others (113). In a study in which obese children took part in a physical training program for four months, the total mass increased less in children who took part in physical training sessions more frequently (8). This is further supported by a longitudinal study that showed that young children who were more active, were less likely to increase their body fat than their less active friends (86). In addition, a cross-sectional study showed that regular physical activity was associated with a greater percentage of fat free mass and a lower percentage fat mass in 10YO (year old) children (26).

Sedentary behaviour

Past decades have seen changes, both environmental and behavioural, in the lives of children. Some studies have shown increased sedentary activity to be related to less physical activity (60, 146). Sedentary activities, like TV (including DVD and video) - and the computer viewing, has increased. TV viewing is usually self-reported, and the subjects are asked about TV viewing before and after school on an average weekday. It is difficult to assess the validity of these self-reports, though it seems to be the only way to assess this kind of behaviour (36). Excessive TV viewing has been linked to obesity (11, 30, 81, 108, 141) and a study done by Gordon-Larsen (50) showed that the odds of being overweight were nearly 50% greater with more TV viewing for white adolescents. Another study done by Butte (19) showed that a sedentary lifestyle and excessive TV viewing were significantly associated with being overweight. Likewise, Tremblay and Williams (130) found out that excessive TV viewing and videogames are risk factors for being overweight (17 to 44% increased risk) or obese (10 to 61% increased risk). Similar results have been reported in other studies (32, 36, 53, 61, 145). Other researchers have found TV viewing to be associated with obesity and some metabolic-risk factors (11, 30, 53, 61, 81, 108, 155).

Not all studies however have come to the same conclusion. Some studies indicate only a weak or no relationship between overweight /obesity and watching TV (44, 54, 69, 109). Ekelund and co-workers (36) found a negligible association between TV viewing and physical activity, and the association between TV viewing and adiposity was independent of physical activity.

Some studies indicate that the relationship between sedentary time and obesity is more complex, confined to specific periods of the day, such as before or after school and taking into account weekdays and weekends (32). Research done by Hager (60) showed that boys who watch TV after school are less likely to be physically active than those who did not watch TV at that time. This was consistent with previous research which showed that the TV - activity relationship is strongest during periods of time when children have the greatest opportunity to be active or watch TV (32). For girls, the pattern appears less clear which may be because girls have overall less or more varied activity, regardless of whether or not they are watching TV. That is, girls engage in sedentary behaviours other than TV viewing (e.g., talking on the phone, doing homework, reading, etc.) more than boys (60).

Because of these possible effects of excessive TV-, DVD-, video viewing and the popularity of videogames, sedentary activities should be limited to two hours a day, to increase physical activity and to prevent weight gain, either directly or indirectly (124). The American Academy of Pediatrics agrees on this point, and suggests that TV viewing should be limited to one to two hours a day in children, but suggests that less than one hour is even better (61).

TV viewing is thought to promote weight gaining, not only by possibly displacing physical activity, but also by increasing energy intake (42, 107). Eating between meals is consistently associated with TV viewing, and snacking while watching TV is associated with increased total energy intake, especially energy dense food (36, 51, 52, 73). This suggests that TV viewing is associated with increased energy intake, which may affect energy balance and subsequent weight gain in children, and might be a stronger effector than the amount of physical activity. However, it is also possible that increased TV time is a result of being more overweight (36, 114). Furthermore, advertisements on TV could affect the children´s dietary choices (34). US and British children are exposed to about ten food commercials per hour of their TV time, and most of them contain unhealthy food like fast food, candy, soft drinks and sugar-sweetened breakfast cereal (74, 77, 127). Exposure to 30 second commercials increases the likelihood that 3 to 5YO would later select an advertised food when presented with options (15).

Fitness

Aerobic fitness has usually been reported to have low to moderate association with physical activity in children (68, 97, 124). However, a strong relationship exists between aerobic fitness and favourable lipid profiles, which are correlated to childhood adiposity (33, 59). A correlation has been found between aerobic fitness, BMI, skinfold thickness and adjusted waist circumference (adjW), physical activity and gender, but the relationship was found to be different for 9 and 15YO, where body composition variables are a good predictor for both age groups. For 15YO skinfold thickness represented fitness better than BMI and adjW, but for the 9YO these variables predicted equally for aerobic fitness (125). A study of young Norwegian men showed that VO_2max, relative to body weight, had decreased by 8% over the last two decades (33). At the same time body weight had increased by 7%. Reduced VO_2max, combined with increased body weight, is probably a result of decreased physical activity (33, 113).

Activity pattern

Most previous studies show boys to be more active than girls in all age groups (112, 115, 138). Time spent on both moderate and vigorous activity has been found to be higher in boys in all grade groups, and most studies agree on a strong age-related decline in physical activity (98, 115, 117). The greatest decline in physical activity has been reported to occur during middle adolescence, at the time when children leave middle school and go to high school, and this decline is especially evident with girls (20, 71, 128, 138, 144).

It has been demonstrated, that children are most active around noon, both on weekends and weekdays, in the morning travelling to school and after school on weekdays (96, 106). Studies have also reported differences in activity on weekdays and weekends, where children are more active on weekdays and the activity pattern is smoother on weekends, without the peeks observed on weekdays (72, 106, 120, 131-133). Results regarding weekday vs. weekend differences in average level of physical activity, have however proved to be inconsistent (154) and vary between countries, especially in younger children. Results in Danish and Norwegian children demonstrated a higher level of physical activity on weekdays, on weekends in Portuguese children but no difference was observed in Estonian children (91).

Physical activity recommendations

There is no doubt about the positive health effects that physical activity has in children and adolescents. However, the optimum amount of physical activity required for normal development and health in children and young people has been difficult to determine (24, 85). Physical activity recommendations have been published over the years with variable emphasis. Physical activity guidelines for young people were first formulated in 1988 by the American College of Sports Medicine (ACSM) and recommended 20 to 30 min of vigorous exercise every day for both children and adolescent (2). The Center for Disease Control and Prevention (CDC)/ACSM recommended a minimum of 30 min of moderate to vigorous physical activity every day, which could be spread over the course of a day (100). Biddle and co-workers (12) published a framework of physical activity recommendation in 1998. Their primary recommendation was that young people should participate in physical activity of at least moderate intensity for one hour a day and that young people who did little activity should participate in physical activity of moderate intensity for at least 30 min a day. Their secondary recommendation was that if some of these activities were done twice a week or more, it could help to enhance and maintain muscular strength, flexibility, and bone health.

In 2004 the Nordic Nutrition Recommendation (86) published the following for children and adolescents: 1) A minimum of 60 minutes of physical activity every day, both moderate and vigorous intensity. 2) The activity can be divided into shorter intervals during the day. 3) Activities should be as diverse as possible, to provide optimal opportunity for developing all aspects of physical fitness including cardio-respiratory, muscle strength, flexibility, speed, mobility, reaction time and coordination. In 2005, Strong and co-workers (124) published a systematic review of recommendations for physical activity and health for school-aged children. They concluded that school-aged children should participate in at least 60 minutes of moderate-to-vigorous physical activity every day. The activity must be developmentally appropriate, enjoyable, and involve a variety of activities. They also suggested decreasing sedentary behaviour to less than two hours a day. The Public Health Institute of Iceland recommends that children and young people should be active for at least one hour a day. The activity should be both moderate and vigorous and can be divided into shorter bursts during the day, e.g., 10 to 15 min (78).

When physical activity is expressed as energy expenditure, heavier adolescents logically use more energy than normal-weight adolescents for given activity (27, 58). However, when physical activity is expressed as movement, heavier adolescents appear to engage in less physical activity than those of normal weight (27, 35, 58). Interventional studies have shown that exercise programs composed of activity of moderate intensity for 30 to 60 min a day, do not influence body fatness in normal weight children and adolescents (41, 110). It seems that rather large amounts of vigorous activity may be needed to influence body fatness in normal weight children and adolescents. In fact, it has been suggested that non-obese adolescents, should accumulate activity of high intensity and duration, more than 80 min a day (40, 58). Findings for obese children and adolescents are slightly different. In overweight children, beneficial effects of body fat control may be attained with moderate activity for 30 to 60 min a day, 3 to 7 days a week (8, 57, 95, 113). Obese adolescents who spend more time engaged in vigorous physical activity tend to be those who loose the most body fat (8, 57). Despite this, it is reasonable to recommend only moderate physical activity for obese children and adolescents, at least at first until greater intensity is tolerated. A training program which is too vigorous from the start may well lead to less activity the following day (8, 75, 95), less compliance overall, and may also lead to injuries (113). Therefore, obese children and those who have been physically inactive for some time, should be trained in incremental steps to reach the 45 to 60 min a day goal of moderate physical activity five or more days a week (124). In general, exercise recommendations should endeavour to incorporate physical activity of varying intensities (35, 113).

Assessment of physical activity

Physical activity as a parameter is difficult to measure. It is a multidimensional human behaviour and been defined as “any bodily movement produced by skeletal muscle that results in energy expenditure” (21). It has been difficult to assess because of its complex nature, particularly under free-living conditions. As a result, no single method is available to quantify all dimensions of physical activity (121, 152). Through the years, many studies have relied almost exclusively on self-report methods, but the applicability and validity may be questioned. Self-reports are known to have limitations not lest with younger age-groups, (6, 46, 117, 136) and in some cases are considered totally inappropriate for use with children under age 12 (6, 7).

There are two methods that have been considered reliable to estimate physical activity: 1) the double labelled water (DLW) technique (152); 2) the use of motion sensors which are based on accelerometry. DLW provides a very precise estimate of energy expenditure over a given period of time, but it is expensive, and provides little information about the pattern or sources of energy expenditure (102). Numerous studies have assessed the validity and reliability of accelerometers over the past years (47, 150). Accelerometery based motions sensors provide detailed information about the duration and intensity of physical activity on a minute-by-minute basis, and have a proven validity in comparison with gold standard methods like DLW technique (38). Accelerometers are practical to use in large studies and provide information about the total amount of activity and its subcomponents (105). It can also provide information about duration and intensity of physical activity and can ordinarily be used at a reasonable cost (102). Accelerometers are however not without flaws. They measure vertical acceleration of body movements, and are thus limited in their ability to accurately detect static activities, like weight training and cycling, and can-not be used in water for activities like swimming (16, 38, 82, 139). Accelerometers have been shown to correlate well with measured oxygen uptake, although they tend to underestimate oxygen uptake for running speeds greater than 9 km/hour, stair climbing, household chores, and yard work (16, 123). Accelerometers also tend toward misclassification errors. They are unable to distinguish between two activities that produce similar acceleration over time but have different energy costs, e.g., walking at a given speed over a level surface, approximately 3 METs (1 MET equals the resting metabolic rate in adults and is 3,5 mL O_2/kg · minute or 1 kcal/kg · hour) versus walking at that same speed over an uneven surface, which accounts for approximately 6 METs (85). Further, they tend to incorrectly place activities with different total acceleration over time but similar energy requirements into different categories (63, 102). Despite these limitations, accelerometers have been used extensively in field settings to monitor activity patterns and have proven validity for measurements in children (16, 38, 82, 139).

Energy expenditure

Accelerometer technology is based on biomechanical principles, while energy expenditure is a biological measure. Calibrating acceleration signals can thus be challenging, and especially so in children and adolescents because they are growing and maturing over the period of study. The metabolic cost of movement, expressed relative to body mass (mL/kg · min), decreases as children mature. Also, children have higher basal metabolic rate (BMR) than adults (17, 46, 64).

In previous studies on adults, thresholds of 3, 6 and 9 METs (100) have been established, to define for moderate, vigorous and very vigorous activity respectively. These thresholds have often been used for estimation of children´s physical activity (47) despite being developed for adults (47, 63, 126) and thus fail to take into account the aforementioned unique physiology of children (e.g. differences in resting metabolic rate (RMR)) (103, 136, 149). For example, predicted energy expenditure at rest calculated from a prediction equation for 9YO child is 2 MET, but 1 MET for adults (136).

Aims

From the above it can be concluded that physical activity is a complex phenomenon. Not only can it be described by total energy expenditure and intensity but also by the daily and weekly activity pattern. Furthermore, the activity pattern is composed of activity bursts or bouts of different duration with different intervals between them. It is unclear which factors of the activity pattern are most strongly associated with variables like fitness and fatness. It is also unclear how lifestyle variables like screen time and sport participation affects the physical activity pattern. Therefore, the aims of this study were divided into two parts:

1. To investigate the activity pattern of 9 and 15YO children and examine its connection to body composition and fitness.
2. To investigate how leisure time activities and screen time (TV-, DVD-, video- and computer time) is associated with different factors of the activity pattern.

METHODS

Study population and participation

Eighteen schools were randomly selected for this study, based on geographical distribution of the Icelandic population, to get as diverse sample as possible. Every child in 4^{th} (9YO) and 10^{th} grade (15YO) of the selected schools was included in the study (n = 1323), which took place from September 2003 to February 2004. Informed consent was obtained from a parent or legal guardian of 934 children (71% participation rate) after the study had been explained to them. Approximately 15% of all children born in 1994 and 1988 in Iceland were sampled, and more than 10% of this population participated.

Anthropometrics

Measurements were conducted in a private setting with students dressed in light clothing and barefoot or wearing socks. Height was measured to the nearest mm with a portable stadiometer (Seca 220, Seca Ltd., Birmingham, UK) and weight was measured to the nearest 0.1 kg, using a calibrated balance beam (Seca 708, Seca Ltd., Birmingham, UK). Body mass index (BMI) was calculated from body mass (kg) divided by height (m) squared (kg/m^2). Waist circumference was measured twice at the umbilical level to the nearest mm and the mean value divided by height raised to the 0.9282 power (adjW) was used for analysis (4). Skinfold thickness was measured with skinfold caliper (Lange, Beta Technology Incorporated, Cambridge, Maryland) at four places (triceps, biceps, subscapular and suprailiac) on the left side of the body. Two measurements were taken at each place of the body, and if the difference between these two measures was more than 2 mm, a third measurement was done. The mean value of the two closest measurements was calculated, and the sum of the four skinfolds used for analysis. Hence, three different indicators of body composition were used: sum of four skinfold measurements, adjW, and BMI.

Fitness

Aerobic fitness was measured by a graded exercise test on an electrically braked bicycle ergometer (Monark 839E, Vansbro, Sweden). The initial workload was 20W, 25W, 40W and 50W for the 9YO children < 30 kg, for 9YO ≥ 30 kg, for 15YO girls and for 15YO boys, respectively with equal increases in workload every third minute (5). Every child cycled until voluntary exhaustion, or until they could not maintain pedal rate of 40 RPM. The children were verbally encouraged, but were also told they could stop at any time.

Questionnaire

All participants received a questionnaire to fill out about their physical activity, health, nutrition and sociological factors. The 15YO answered the questionnaire at school, but the younger group answered the questionnaire at home with parent´s assistance. Questions on sport participation and sedentary activities, such as TV-, DVD-, video watching and computer usage (screen time) were selected for analysis in this study. Screen time was calculated from the questionnaire by summarizing estimated time spent watching TV, DVD, video and computers. Weighted average of screen time on weekdays and weekends was calculated and used in the analysis. Sport participation was calculated from the questionnaire, using question about how often the child participated in sports for recreation or competition with a sport club.

Physical activity analysis

Physical activity was assessed with Actigraph activity monitor (MTI accelerometer, model 7164). The accelerometer was worn on a belt around the waist, positioned above the hip. The children were asked to wear the accelerometer during all walking hours, except when swimming and bathing, for six consecutive days, including both weekend days. Subjects who did not have at least three days of measurements and thereof at least two weekdays, were excluded from the analysis. The first day was always discarded from the analysis to avoid possible error, resulting in three to five analyzed days for each subject. The activity, counts detected by the accelerometer, were summed over one minute period, recorded in the monitor´s memory, and downloaded to a computer. Only days with > 600 min of registered data were included in analyses. If no activity was recorded for 10 min or longer, no data was registered (i.e. the child was assumed not to be wearing the monitor). Bouts of no activity of shorter duration were included in the analysis (i.e. the child was inactive).

Six different thresholds of energy expenditure were defined: 3 METs (3M), 6 METs (6M), 9 METs (9M), 2 METs + RMR (2+M), 5 METs + RMR (5+M) and 8 METs + RMR (8+M). The age-specific thresholds and RMR (0 counts/min) were derived from the energy expenditure prediction equation developed by Trost et al. (136):

$$\text{METs} = 2.757 + (0.0015 \cdot \text{counts/min})$$
$$-(0.08957 \cdot \text{age (y)}) - (0.000038 \cdot \text{counts/min} \cdot \text{age (y)})$$

A bout was defined as a continuous period of energy expenditure over a given threshold. For each threshold, following variables were calculated: 1) total length of bouts in a day; 2) average length of bouts; 3) total number of bouts in a day; 4) number of bouts that equalled 1 min; 5) number of bouts that were 2 to 5 min in duration; 6) number of bouts that were 6 to 9 min in duration; 7) number of bouts that were 10 min or longer; and 8) total length of bouts over 10 min; 9) average length of bouts that were over 10 min. The same nine variables were also calculated for the intervals between the bouts for each threshold. A period was defined as the longest period found where the mean energy expenditure, over the whole period, was over certain threshold. A period consists usually of more than one bout of activity. Variables calculated for periods were: 1) the total length, 2) the average length, and 3) number of periods in a day over each of the six thresholds, were calculated. Also, 4) the total length, 5) average length and 6) number of periods that lasted 10 min and longer, were calculated. In addition, a total activity variable per day (kcounts/day) was calculated and the total activity was also divided into four sections of the day; 12 to 6 am, 6 am to 12 pm, 12 to 6 pm and 6 pm to 12 am. Intensity of activity was also calculated as the average activity (counts) per active min of registered activity (counts/min). All of the above variables were calculated for both weekdays and weekends. Furthermore, a weighted average of weekdays and weekends was calculated to represent average activity over the week. Average time of registered activity each day was also included as a variable. The final number of variables was 450.

Statistical analysis

Minute-by-minute activity counts were uploaded to a computer from the accelerometers. Matlab (MATLAB version 7.4 (R2007a)) program was developed to calculate all the variables for each day and Excel used to calculate average values for weekdays, weekend days and weighted averages. Statistical analysis was done with the SPSS statistical program (SPSS 15.0 for Windows®). Crosstables and chi-square was used to compare gender and age differences in sport participation and screen time. Daily activity patterns were analyzed with four-way factorial mixed models repeated measures ANOVA (gender by age group by daily activity pattern (the repeated variable)), using Greenhouse-Geisser correction for sphericity ($p < 0.05$). Principal components analysis (PCA) was used to identify independent components of the physical activity data. PCA is one of the methods collectively called factor analysis. These methods are designed from many statistical techniques and are used to simplify complex sets of data. These techniques can be used where the data is complex and unclear which variables (factors) are most important to describe the variability of the data. One variable (key variable) was selected for each factor, which was dominant for 9 and 15YO together and 9 and 15YO separately, and was correlated with the components identified by PCA, demographical and physiological variables, sport participation, and screen time. Varimax method was used for rotation of components. A factor score was calculated for each subject with the use of regression methods and linear regression was used to determine which components (identified by PCA) where the strongest predictors of demographical and physiological variables, sports participation, and screen time. The level of statistical significance was 5%.

Approval

The National Bioethics Committee approved the study and the Icelandic Data Protecion Commission was informed.

The author did not participate in the collection of data for this study, but conducted the aforementioned statistical analysis.

RESULTS

Of the 934 subjects who participated in the study, 743 answered the questionnaire. Usable physical activity data was obtained from 339 subjects on weekends, 439 on weekdays and 338 for the weighted average of these days. Significantly more of the 15YO adolescents than the 9YO children participated in daily organized sports (Table 1). However, the 15YO also participated fewer times each week than the 9YO. More boys than girls participated in daily informal sports (i.e. sports outside the school setting, which are not organized by a sport club) (Table 2). More boys than girls spent an hour or more playing computer games, both on weekdays and weekends (Table 3). More of the 15YO than the 9YO, spent more than 3 hours watching TV, DVDs or videos on weekdays (Table 4). Less than 10% of the 9YO children spent an hour or more on the internet while more than 50% of the 15YO did so (Table 5).

Table 1. How often do you participate in sports for recreation or competition with a sport club? (p= 0.001)

	9YO girls n= 180	**9YO boys n= 176**	**15YO girls n= 187**	**15YO boys n= 193**
≤1 times/week	32.8%	22.7%	45.5%	33.7%
2-3 times/week	48.3%	60.2%	23.0%	15.5%
Almost every day	18.9%	17.0%	31.6%	50.8%

Table 2. How often do you participate in sports that are not supervised by a sport club or the school? (p= 0.001)

	9YO girls n= 178	**9YO boys n= 175**	**15YO girls n= 189**	**15YO boys n=195**
≤1 times/week	59.0%	44.0%	44.4%	37.9%
2-3 times/week	30.3%	36.0%	43.4%	42.1%
Almost every day	10.7%	20.0%	12.2%	20.0%

Table 3. How much time do you spend on playing computer games on the weekends (p< 0.001) and on weekdays (p< 0.001)?

Weekends	9YO girls n= 179	9YO boys n= 178	15YO girls n= 190	15YO boys n= 195
< 1 hour	80.4%	36.0%	87.9%	31.8%
1-2 hours	17.9%	41.6%	7.9%	19.0%
> 3 hours	1.7%	22.5%	4.2%	49.2%
Weekdays	**9YO girls n= 179**	**9YO boys n= 177**	**15YO girls n= 190**	**15YO boys n= 195**
< 1 hour	91.6%	59.3%	89.5%	39.0%
1-2 hours	7.3%	30.5%	6.3%	27.7%
> 3 hours	1.1%	10.2%	4.2%	33.3%

Table 4. How much time do you spend on watching TV/DVD/video on the weekends (p= 0.04) and on weekdays (p< 0.001)?

Weekends	9YO girls n= 179	9YO boys n= 178	15YO girls n=189	15YO boys n=193
< 1 hour	14.5%	6.2%	6.9%	8.3%
1-2 hours	26.8%	30.3%	29.1%	36.3%
> 3 hours	58.7%	63.5%	64.0%	55.4%
Weekdays	**9YO girls n= 180**	**9YO boys n= 177**	**15YO girls n=188**	**15YO boys n= 194**
< 1 hour	45.6%	38.4%	16.5%	19.1%
1-2 hours	41.1%	40.7%	41.0%	46.4%
> 3 hours	13.3%	20.9%	42.6%	34.5%

Table 5. How much time do you spend on the internet or a chat through the internet on weekends (p< 0.001) and on weekdays (p< 0.001)?

Weekends	9YO girls n= 180	9YO boys n= 178	15YO girls n= 189	15YO boys n= 193
< 1 hour	89.4%	93.8%	43.9%	40.4%
1-2 hours	9.4%	6.2%	35.4%	32.1%
> 3 hours	1.1%	0%	20.6%	27.5%
Weekdays	**9YO girls n= 178**	**9YO boys n= 175**	**15YO girls n= 189**	**15YO boys n= 191**
< 1 hour	94.9%	94.3%	47.1%	45.0%
1-2 hours	4.5%	5.1%	28.0%	32.5%
> 3 hours	0.6%	0.6%	24.9%	22.5%

Table 6. Anthropometric, aerobic fitness and physical activity characteristics of the subjects.

	9YO girls n= 96		9YO boys n= 80		15YO girls n= 72		15YOboys n= 90	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight [kg]	33.4	6.9	34.0	6.4	57.6	8.9	66.3	11.7
Height [m]	1.4	0.07	1.4	0.06	1.7	0.06	1.8	0.07
BMI [kg/m^2]	17.4	2.5	17.5	2.5	21.0	2.7	21.2	3.1
Sum of 4 skinfolds [mm]	46.9	23.6	39.0	22.2	64.9	21.4	47.4	24.3
adjW [cm/m^{0,9282}]	47.4	4.6	47.0	4.8	48.0	4.1	46.6	5.1
Fitness [W/kg] †	3.0	0.6	3.5	0.7	3.1	0.4	3.8	0.6
Total activity (TA) [kcounts/day]	498	158	579	153	385	103	499	176
Activity level (AL) [counts/min]	613	192	697	173	459	123	583	209
Total time> 3METs (TT3M) [h:min]	2:44	0:48	3:10	0:42	1:03	0:22	1:24	0:33
Total time> 6METs (TT6M) [h:min]	0:22	0:14	0:31	0:17	0:09	0:07	0:19	0:14
Total time> 9METs (TT9M) [h:min]	0:05	0:06	0:07	0:07	0:02	0:03	0:05	0:06
Total time> 2+METs (TT2+M) [h:min]	1:21	0:32	1:44	0:32	0:50	0:19	1:08	0:30
Total time> 5+METs (TT5+M) [h:min]	0:13	0:10	0:18	0:12	0:07	0:06	0:15	0:12
Total time> 8+METs (TT8+M) [h:min]	0:04	0:05	0:05	0:06	0:02	0:03	0:04	0:06

† = n = 78 for 9YO girls, 62 for 9YO boys, 52 for 15YO girls and 73 for 15YO boys.

Physical characteristics, anthropometrics and aerobic fitness of those that had usable physical activity data are listed in Table 6. To study the daily activity pattern, activity (kcounts/day) was divided into four sections, from 12 to 6 am, 6 am to 12 pm, 12 to 6 pm and 6 pm to 12 am (Figure 1). Both 9YO and 15YO children were most active from 12 to 6 pm, on weekdays (wd) and weekends (we) (Figure 1). Both age groups were less active on the weekends ($F[2.6;856]= 585$; $p< 0.001$). The difference between weekdays and weekends was not the same for the two age groups, (daily activity pattern x (wd/we) x age; F[2.6;856]= 97.2; p< 0.001). From 6 to 12 am on weekdays, 9YO boys and girls were much more active than the 15YO boys and girls. On weekends this difference between 9 and 15YO was much smaller. The 9YO become more active from 6 pm to 12 am on weekends than they are on weekdays. Both 15YO boys and girls increase their activity after midnight on weekends, but not 9YO children. The difference between weekdays and weekends was not the same for boys and girls, (daily activity pattern x (wd/we) x gender; F[2.6;856]= 7.22; p< 0.001). Boys increase their activity on weekends from 12 to 6 am more than the girls do. Also, boys decrease their activity from 6 am to 12 pm more than the girls.

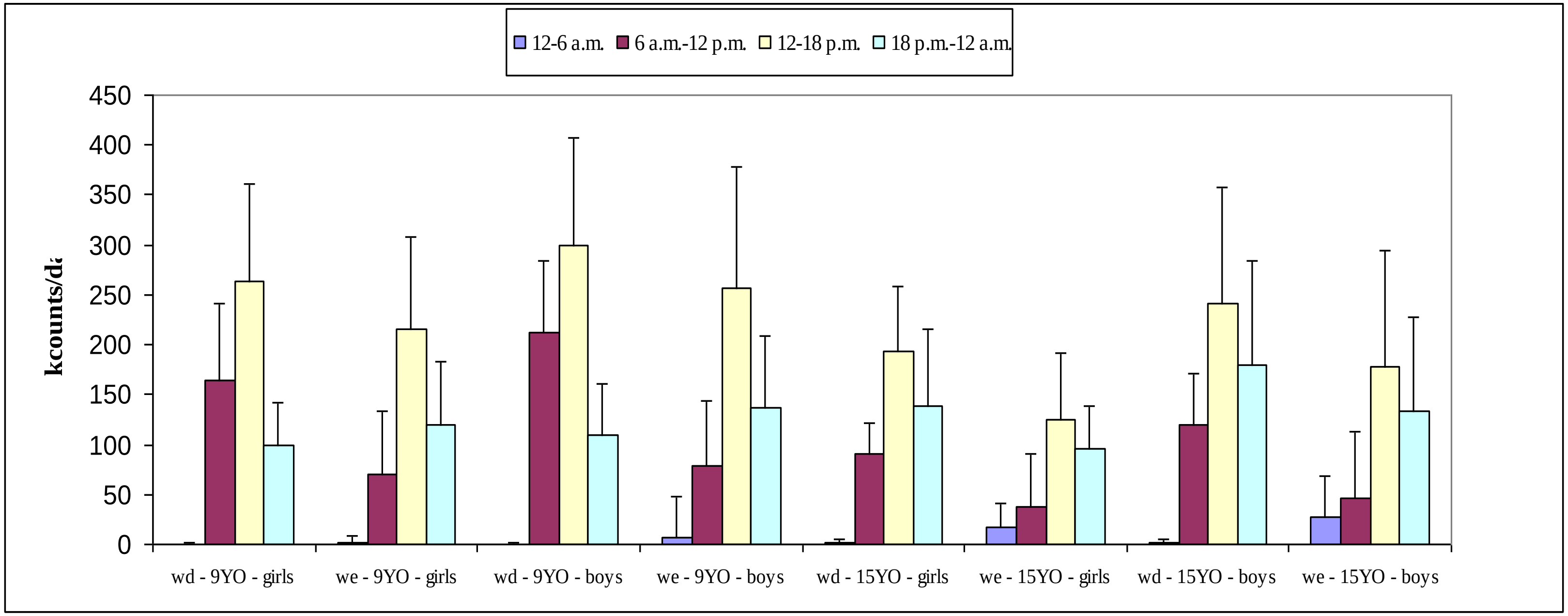

Figure 1 Activity monitors were used to assess activity on weekends and on weekdays. The activity (y-axis) is shown for 9 and 15YO girls and boys (x-axis) with standard deviation. Wd = weekdays; we = weekend.

All 450 physical activity variables were selected for the PCA. The first component accounted for 38% of the variance of the physical activity variables and each of the next six components explained 2.6 to 11.0% of the variation. These seven components accounted for 72% of the variability. The next six components (Components 8 to 13) explained each 1 to 2% of the variability. Scree-plot showed a break between Components 7 and 8. Therefore, it was decided to use only seven components for rotation (Table 7). The key variable (variable that had the strongest correlation with respective component) for each component after rotation is shown in Table 7 and also the portion of the variation explained by each component. The PCA was also conducted separately on the data for the two age groups, 9YO and 15YO (Table 7). The first seven components were the same for both 9YO and 15YO and for the combined data, although the portion they accounted for of the variation and their key variables was slightly different, as shown in Table 7. For most of the components, a few variables (0 to 8 variables) correlated almost as strongly with the components as the key variables did (Δr = 0.01-0.05). Variables that indicated numbers of bouts or intervals between bouts over 8+METs or 9 METs on weekdays had the strongest correlation with Component 1. Of these, the number of bouts over 9 MET on weekdays (NB9Mwd) had the strongest correlation for the combined data. Variables that indicated number of bouts over 3 MET over the whole week (NB3M) had the strongest correlation with Component 2. Variables that indicated total length of activity over 8+METs and 9 METs during the weekends had the strongest correlation with Component 3, where total time over 8+METs during weekends (TT8+Mwe) was the most strongly correlated. Variables that indicated total length of bouts over 8+METs or 9 METs, which last 10 min or more on weekdays or during the whole week, had the strongest correlation with Component 4. Total length of bouts that lasted more than 10 min over 9 METs during the whole week (TT9M10) was the most strongly correlated. Average length of bouts over 3 METs (AB3M) had the strongest correlation with Component 5. Variables that indicated number or length of intervals between bouts of 8+METs and 9 METs, had the strongest correlation with Component 6. Average number of intervals between bouts over 8+METs during the whole week (AI8+M) had the strongest correlation. Total time in intervals between bouts over 2+METs during the whole week (TI2+M) and total time in long intervals between bouts over 2+METs or 3 METs had the strongest correlation with Component 7.

Table 7. Key variables, physical activity variance explained after rotation by the component and correlation coefficient of the key variable from the PCA for the first 7 components. Key variable for each component was chosen as the variable that had the strongest correlation with each component (1-7).

Comp	Var.* 9 and 15YO	Var. exp.*	r	Var. 9YO	Var. exp.	r	Var. 15YO	Var. exp.	r
1	NB9Mwd	18.2%	0.89	NB9Mwd	19.8%	0.91	NB9Mwd	22.5%	0.91
2	NB3M	18.1%	0.95	NB3M	10.8%	0.89	NB3M	11.2%	0.91
3	TT8+Mwe	11.5%	0.87	TT8+Mwe	13.0%	0.89	TT8+Mwe	13.5%	0.83
4	TT9M10	9.2%	0.92	TT9M10	11.9%	0.93	TT9M10	4.6%	0.79
5	AB3M	6.0%	0.82	AB3M	6.9%	0.81	AB3M	7.9%	0.83
6	AI8+M	5.0%	0.56	AI8+M	5.9%	0.71	TI9M10we	7.0%	0.71
7	TI2+M	3.5%	0.78	TI2+M	4.0%	0.64	TI2+M	3.9%	0.68

* Percent of variance explained in all physical activity variables after rotation. NB9Mwe = number of bouts over 9 METs on a weekday; NB3M = number of bouts over 3 METs; TT8+Mwe = total time over 8+METs on weekends; TT9M10 = total time that lasted more than 10 min over 9 METs; AB3M = average length of bouts over 3 METs; AI8+M = average length of intervals between bouts over 8+METs; TI2+M = total time in intervals between bouts over 2+METs; TI9M10we = total time in intervals between bouts that lasted more than 10 min over 9 METs on weekends. ** Var.= Variable.

All the key variables were strongly correlated with their corresponding component but had much lower correlation with the other components (Table

8). Of the traditional variables (total time over 3 METs, 6 METs, 9 METs, 2+METs, 5+METs and 8+METs, total activity and activity level), total time of vigorous or very vigorous activity had the strongest correlation with Component 1. Total time of activity of moderate or higher intensity had the strongest correlation with Component 2. The traditional variables had much lower correlation than the key variables with the other components. Total activity and activity level had low to moderate correlation with all components.

Table 8. Correlations between the components (1-7) and different physical activity variables. The physical activity variables shown are the seven key variables and 8 traditional variables.

	1	2	3	4	5	6	7
Key variables							
NB9Mwd (1)*	**0.89**	0.28	0.19	0.16	0.02	0.14	0.04
NB3M (2)*	0.20	**0.95**	0.08	0.02	0.05	0.06	0.06
TT8+Mwe (3)*	0.25	0.11	**0.87**	0.13	0.02	0.24	0.02
TT9M10 (4)*	0.04	0.01	0.01	**0.92**	0.02	0.08	0.06
AB3M (5)*	0.26	0.05	0.13	0.14	**0.82**	0.04	0.05
AI8+M (6)*	0.15	0.33	-0.04	-0.01	0.01	**0.56**	0.28
TI2+M (7)*	0.01	0.03	0.04	0.01	0.02	0.06	**0.78**
Traditional variables							
TT3M	0.33	0.87	0.14	0.01	0.27	0.10	0.10
TT6M	0.70	0.42	0.26	0.22	0.36	0.18	0.02
TT9M	0.74	0.20	0.41	0.42	0.00	0.18	0.04
TT2+M	0.48	0.64	0.19	0.08	0.50	0.16	0.04
TT5+M	0.75	0.22	0.34	0.31	0.30	0.18	0.04
TT8+M	0.70	0.12	0.43	0.49	0.04	0.17	0.02
Activity level	0.53	0.52	0.28	0.30	0.38	0.18	0.08
Total activity	0.57	0.48	0.29	0.29	0.38	0.18	0.14

* Component number in parenthesis. For further explanation for abbreviations, see Table 6 and 7.

The association between the seven components, on one hand, and age, gender, BMI, fitness, skinfold, adjW, sport participation and screen time, on the other hand, was examined. This was done for both 9 and 15YO, combined and separately (Table 9). Component 2 was the most effective component to separate the two age groups. This component also had the strongest association with BMI, skinfold and screen time of the combined data, and of screen time and adjW for the 15YO. Component 5 was the most effective component to separate the gender, both for 9YO and 15YO and the combined data. Also, this component had the strongest association with fitness, adjW and sport participation for the combined data, as well as fitness, skinfold, sport participation and screen time for the 9YO and BMI, fitness and skinfold for the 15YO.

Table 9. Associations between components 1-7 and age, gender, BMI, skinfold, adjW, fitness, sport participation and screen time.

	9 and 15 YO			Adj. for age and gender*			9YO			15YO		
Dependent variable	**Component**	**Beta**	**p**	**Component**	**Beta**	**p**	**Component**	**Beta**	**p**	**Component**	**Beta**	**p**
Age	2	-0.83	>0.001	-	-	-	-	-	-	-	-	-
	7	0.23	>0.001	-	-	-	-	-	-	-	-	-
	5	0.09	0.001	-	-	-	-	-	-	-	-	-
	1	-0.07	0.02	-	-	-	-	-	-	-	-	-
Gender (girls=1; boys=2)	5	0.34	>0.001	-	-	-	5	0.42	>0.001	5	0.27	>0.001
	1	0.17	0.001	-	-	-	1	0.18	0.01	3	0.22	0.004
	-	-	-	-	-	-	6	-0.13	0.05	1	0.18	0.02
	-	-	-	-	-	-	-	-	-	6	0.18	0.02
BMI	2	-0.51	>0.001	5	-0.14	0.003	Not signific.	-	-	5	-0.19	0.02
	7	0.12	0.01	-	-	-	-	-	-	-	-	-
Skinfold	2	-0.28	>0.001	2	-0.19	0.04	5	-0.25	0.001	5	-0.31	>0.001
	5	-0.25	>0.001	5	-0.19	0.01	-	-	-	2	-0.25	0.001
	3	-0.11	0.03	-	-	-	-	-	-	-	-	-
adjW	5	-0.14	0.01	5	-0.12	0.03	Not signific.	-	-	2	-0.17	0.03
	-	-	-	-	-	-	-	-	-	5	-0.17	0.03
Fitness	5	0.31	>0.001	5	0.16	0.005	5	0.24	0.004	5	0.39	>0.001
	2	-0.16	0.01	-	-	-	-	-	-	-	-	-
	3	0.13	0.03	-	-	-	-	-	-	-	-	-
	7	0.12	0.04	-	-	-	-	-	-	-	-	-
Sport participation	5	0.20	0.001	5	0.17	0.005	5	0.18	0.03	5	0.23	0.004
	1	0.12	0.03	-	-	-	-	-	-	3	0.22	0.01
	-	-	-	-	-	-	-	-	-	1	0.16	0.04
Screen time	2	-0.39	>0.001	3	-0.12	0.02	5	0.30	>0.001	2	-0.32	0.001
	3	-0.11	0.05				-	-	-	5	-0.23	0.01
	-	-	-				-	-	-	7	0.23	0.01
	-	-	-				-	-	-	3	-0.17	0.03

*Adjusted for age and gender. For further explanation for components numbers, see Table 7.

To verify the PCA and regression analysis, bivariate correlations between the demographic (age and gender), anthropometric (adjW, skinfold, BMI), and physical (fitness) variables and behavioural indicators (sport participation and screen time) on the one hand and the key and traditional physical activity variables on the other were calculated (Table 10). All demographic, anthropometric, physical, and behavioural variables correlated most strongly with the key variables, which represented the component that was the strongest predictor for each of the demographic, anthropometric, physical, or behavioural variables, respectively. Although, the key variables had usually stronger correlation than any of the traditional physical activity variables, some of the traditional variables had correlation coefficients similar to the key variables. The exception was the sum of four skinfolds, where several of the traditional variables had a stronger correlation than any of the key variables. However, skinfold was predicted almost equally by Components 2 and 5, and the corresponding two key variables had similar correlation coefficients with skinfold. Mean and standard deviation for the seven key variables are shown in Table 11.

Table 10. Bivariate correlation between age, gender, BMI, fitness, skinfold, adjW, sport participation and screen time.

	Age	Gender	BMI	Skinfold	adjW	Fitness	Sport part.*	Screen time
Activity level n=338 †	-0.31*	0.23*	-0.24*	-0.33*	-0.11*	0.16*	0.20*	-0.22*
Total activity n=338 †	-0.26*	0.26*	-0.21*	-0.32*	-0.11*	0.18*	0.20*	-0.19*
TT3M n= 338 †	-0.78*	0.10*	-0.48*	-0.34*	-0.06	-0.04	0.05	-0.34*
TT6M n= 338 †	-0.37*	0.25*	-0.25*	-0.31*	-0.09	0.13*	0.19*	-0.18*
TT9M n= 338 †	-0.21*	0.16*	-0.10*	-0.17*	-0.02	0.04	0.13*	-0.12*
TT2+M n= 338 †	-0.46*	0.26*	-0.33*	-0.37*	-0.12*	0.14*	0.16*	-0.23*
TT5+M n= 338 †	-0.17*	0.26*	-0.13*	-0.26*	-0.08	0.17*	0.22*	-0.12*
TT8+M n= 338 †	-0.12*	0.15*	-0.05	-0.15*	-0.03	0.06	0.12*	-0.09
NB9Mwd n= 439†† (Comp.1)	-0.32*	0.20*	-0.16*	-0.19*	-0.03	0.06	0.11*	-0.11*
NB3M n= 338 † (Comp.2)	-0.87*	-0.06	-0.51*	-0.28*	-0.03	-0.17*	-0.04	-0.39*
TT8+Mwe n= 339††† (Comp.3)	-0.11*	0.14*	-0.09	-0.17*	-0.07	0.08	0.12*	-0.12*
TT9M10= 338 † (Comp.4)	0.07	0.03	0.02	-0.03	0.01	0.00	0.08	-0.01
AB3M n= 338 † (Comp.5)	0.10	0.37*	-0.03	-0.23*	-0.10	0.33*	0.22*	-0.02
AI8+M n= 338 † (Comp.6)	-0.28*	0.04	-0.11*	-0.13*	0.00	-0.02	0.15*	-0.12*
TI2+M n= 338 † (Comp.7)	0.21*	0.02	0.14*	0.04	0.02	0.06	0.01	0.10

* Significant difference. † = n = 270 for fitness, 337 for adjW, 293 for sport participation, 298 for screen time. †† = n = 349 for fitness, 438 for adjW, 377 for sport participation, 383 for screen time. ††† = n = 271 for fitness, 338 for adjW, 293 for sport participation, 298 for screen time. For further explanation of abbreviations, see Table 6 and 7. * Sport participation.

Table 11. Mean and standard deviation for the seven strongest variables listed according to age and gender.

	9YO girls n= 96†		9YO boys n= 80†		15YO girls n= 72†		15YO boys n= 90†	
	Mean	SD*	Mean	SD	Mean	SD	Mean	SD
NB9Mwd	3.9	3.6	5.8	4.9	1.6	2.0	3.1	3.3
NB3M	66.2	14.0	65.6	10.7	25.9	6.0	28.2	10.0
TT8+Mwe [min]	2.1	3.6	3.0	6.0	0.5	1.5	2.4	4.7
TT9M10[min]	0.2	1.7	0.1	0.5	0.1	0.8	0.4	1.1
AB3M[min]	2.4	0.4	3.0	0.5	2.5	0.6	3.0	0.8
AI8+M[min]	46.3	59.1	43.0	48.6	13.1	27.8	28.1	44.7
TI2+M[min]	695.6	80.3	690.1	79.2	746.6	152.0	749.3	128.9

† = n = 122 for NB9Mwd with 9YO girls, 106 for 9YO boys, 100 for 15YO girls and 111 for 15YO boys. * SD = standard deviation. For further explanation of abbreviations, see Table 7.

DISCUSSIONS

Main findings

In this study, different factors of the activity pattern of 9 and 15YO Icelandic youngsters were investigated. The main finding was that the daily activity pattern is different both between age groups and between genders. Aside from being less active on weekends, it was found that the children showed different activity patterns on weekdays and weekends. This difference was not the same for the two age groups or genders. Seven independent components of the physical activity were identified by the use of a factor analysis (Principal component analysis). Three of these components represented different aspects of physical activity of moderate or higher intensity, wheras four of them described very vigorous physical activity. Two of the components which represented physical activity bouts of moderate or higher intensity (one that represented average length of the bouts and another that represented the number of bouts in a day) had the strongest associations with several variables examined. These were age, gender, three body composition variables, fitness and two lifestyle indicators.

Changes in activity

Physical activity declines with age and boys are more active than girls, as has been shown in previous studies (19, 20, 39, 66, 72, 96, 98, 105, 112, 128, 138, 144). Furthermore, in agreement with most previous studies, the children recorded less activity on weekends (106, 112, 120, 131-133).

Both age groups were most active from 12 to 6 pm on weekdays. This is the time from lunch break at school, until dinner time. It has been demonstrated, that after 3 pm, the active children become more active (106).

The children probably have the greatest opportunity to be active at this time of day, i.e. to go to sport training or exercise by themselves (96). Other studies have shown that children are most active around noon, both on weekends and weekdays, and also in the morning when travelling to school and after school on weekdays (96, 106). Their activity was less on weekends, and the variation over the day was not as obvious as on weekdays. This smoother activity pattern, i.e. without the peeks observed on weekdays, has also been observed by others (106, 120, 131-133). Results concerning intra-week variation in average level of physical activity, is however inconsistent between countries, especially with younger children. Results from Danish and Norwegian children demonstrated greater levels of physical activity on weekdays. No difference was observed in Estonian children but the Portuguese showed higher levels of physical activity on weekends (91).

Our results, mirroring those of others, show that the younger children were more active than the older children on weekends (131, 137). The younger children increased their activity more from 6 pm to 12 am on weekends, but the older children increased their activity after midnight on weekends. This change in activity pattern seems to indicate that both children and adolescents stayed active longer and probably slept longer on weekends than during the week. The boys stayed awake longer than the girls on weekends but also showed decreased activity from 6 am to 12 pm compared to the girls. Similar results have previously been published about intra-day variation in physical activity (91).

New thresholds were composed to get as accurate evaluation of physical activity in children as possible. The difference between the old and new thresholds was small. When the PCA was performed, 3 METs and 2+METs, and 9 METs and 8+METs often came up together in the components, but in most cases key variables based on the old thresholds were more strongly correlated. Needless to say this holds true for these data only, and further research may show different results.

Three days of monitoring is most common in studies like this one, and gives a good realistic estimation of children´s activity (82). By combining accelerometer data and self-report diaries, an even better picture of the activity pattern is established (66). The first step, to distinguish between the subcomponents of activity, is a complex process and many ways can be used to distinguish between them. By using different physical activity variables, different results might be obtained.

Different variables of moderate activity or very vigorous activity had the strongest correlation with each of the seven key variables. Four of the components (Comp. 1, 3, 4 and 6) were indicators of very vigorous activity (over 8+METs or 9 METs). These four represented: a) number of very vigorous activity bouts on weekdays (Comp. 1); b) total time spent in very vigorous activity on weekends (Comp. 3); c) total time spent in long (>10 min) very vigorous activity bouts (Comp. 4); and d) the length of the intervals between very vigorous bouts (Comp. 6). Three of the components (Comp. 2, 5 and 7) represented activity of moderate or higher intensity. These three represented: a) number of bouts of moderate or higher intensity (Comp. 2); b) average length of bouts of moderate or higher intensity (Comp. 5); and c) total length of the intervals between bouts (Comp 7).

The main difference in physical activity between the age groups was that the number of bouts of moderate or higher intensity was much higher for the 9YO than the 15YO (Comp. 2) or 66 bouts in a day on average versus 26 to 28 bouts (Table 11). Also, the 15YO bouts of moderate activity were distributed over a longer time period (Comp. 7). There was only a weak correlation of Comp. 5 (length of moderate or more intense bouts) and 1 (number of very vigorous bouts on weekdays) with age. Butte and co-workers (19) have shown that physical activity among 4 to 19YO Hispanic children was intermittent and not sustained for long periods of time. It is also evident that vigorous activity is not very common in young children, and is usually performed in only short bursts (105, 138). In this study, the number of very vigorous bouts was only weakly associated with age.

The main difference between the gender was that boys had longer bouts of moderate or higher intense activity than girls (Comp. 5). The average bout was 2.4 to 2.5 min for girls but 3.0 min for boys (Table 11). Also, boys did more numerous bouts of very vigorous activity than girls on weekdays (Comp. 1) and for the 15YO, the boys spent more time on weekends in very vigorous activity than girls (Comp. 3). Although the 15YO boys spread their very vigorous activity over a longer time during the day than the girls, the reverse was true for the 9YO (Comp. 6). This difference in activity between boys and girls is consistent with previous studies (112, 116, 138). It has been reported that middle school girls spend a lot of time in sedentary and light physical activity and that boys tend to show more vigorous activity at all age levels (98, 99, 133, 151). Previous studies have also shown that duration and intensity of bouts were greater in boys than in girls (98, 112, 117) which is in agreement with this study.

BMI was negatively associated with the number of bouts of moderate or higher intensity activity (Comp. 2). The children who had higher BMI distributed these bouts over a longer period of the day (Comp. 7). After adjustment for age and gender, the length of bouts of moderate or higher intensity activity was negatively correlated with BMI. It has previously been found that types and levels of physical activity (e.g. total activity counts and partitioning of awake time into sedentary, light, moderate and vigorous levels of physical activity) are influenced by BMI among other things (19, 70).

Both the number (Comp. 2) and length of bouts (Comp. 5) of moderate or high intensity had a similar association with skinfold thickness before and after adjusting for age and gender. Very vigorous activity on weekends also correlated with skinfold, but not after adjustment for age and gender. AdjW was negatively associated with the length of bouts of moderate or higher intensity (Comp. 5). Thus, this study indicates that it is the length of the bouts, rather than the intensity that is most strongly associated with fatness. Ruiz and co-workers (113) showed that the intensity of physical activity, especially very vigorous intensity, was negatively related to body fatness, but not total physical activity. Gutin and co-workers (58) showed similar results, where children who engaged in a relatively large amount of physical activity tended to have lower body fat. On the contrary, some studies show no association between vigorous physical activity and body fatness (104).

Fitness was most strongly associated with length of bouts of moderate intensity or greater (Comp. 5). Also, increased fitness was negatively associated with the number of bouts of moderate or higher intensity (Comp. 2), positively with number of bouts of very vigorous activity on weekends (Comp. 3) and positively with the distribution of bouts of moderate activity or greater (Comp. 7). After adjustment for age and gender, fitness was only associated with the length of bouts of moderate activity or greater. Previous studies have usually shown a relationship between very vigorous activity and fitness, that is, high intensity activity is required to have an effect on fitness (58, 97, 113, 124). The results of this study suggest that the length of the bouts of activity rather than their intensity is important to fitness. Further study is needed to confirm these results. However, this may also indicate that reduced fitness will result from only engaging in shorter bouts of activity.

Children reporting greater sport participation tended to engage in longer bouts of moderate intensity or greater (Comp. 5). This group also engaged in very vigorous activity on weekdays, but not after adjusting for age and gender. According to the children´s answers on the questionnaire regarding self-estimated activity, the older children were more likely to participate in near-daily organized sports. At the same time, more 15YO participated less than once per week in organized sports than 9YO. It would seem that those 15YO children who engage in organized sports, do so quite regularly. However, the active 9YO children do not have as many training sessions per week-, as the older children. Activity is known to decrease with age, but those who remain active, are indeed very active, wheras others decrease their activity dramatically. This finding, that children and adolescents who participate in sports achieve longer bouts of intensity, has been previously reported (118).

Screen time was negatively associated with both the number of bouts of moderate or greater intensity (Comp. 2), and also vigorous activity on weekends (Comp. 3). After adjusting for age and gender, increased screen time correlated only with very vigorous activity on weekends (Comp. 3). Consistent with these results, it has previously been reported that eighth grade adolescents spend more time sedentary during weekends compared to weekdays (66). The relationship between decreased physical activity and increased sedentary behaviour is consistent with some previous studies (60, 146), and Guinhouya and co-workers (55) who used the PCA method, showed that physical activity is inversely related to sedentary behaviour. Nonetheless, other studies have shown different results (36, 60).

According to our questionnaire results, TV, DVD and video viewing increased with age along with internet usage. Older children may have better access to computers and, therefore, spend more time on the internet for recreation. Children´s interest in TV material likely changes with adolescence. They are likely allowed to watch a greater variety of films and TV shows and thus spend more time in front of the TV. Boys play videogames more often, both on weekdays and weekends. In a recent study done by Jago and co-workers (66) it was demonstrated that even though boys appear to spend more time watching TV, DVDs, videos, or playing videogames, they are still more active than girls. These findings agree with the results of this study. However, like with all self-reports, especially with children, the results should be taken with precaution (6, 46, 117, 136).

Physical inactivity is a well documented factor in childhood obesity (136). The proven efficacy of physical activity late in childhood speaks well to starting its promotion from an early age and thus forming healthy habits (43, 99). Because of the age-related decline in physical activity in adolescents, our results support the need for intervention. The after-school period is probably the best target for these interventions, as has been suggested previously (66). Activity also decreases on weekends, despite there being more free time available. Interventions that reach adolescent girl are especially needed because they were the least active of all subjects in this study. This gender difference seems to start at an early age, and an observational study of preschool-aged children demonstrated that boys play games with greater intensity than girls, who choose games of less intensity (99). One explanation for the age decline could be that when children grow and become adolescents, they stop playing outside and the school starts to occupy more of their free time (92). This age and gender differences is recognized in many countries, e.g. Denmark, Estonia, Norway and Portugal (91), although these countries have relatively different cultures, climates and landscapes. These differences are thus not only determined by environmental factors; biological factors may play a role (105).

Prevention and treatment of obesity ultimately involves eating less and being more physically active. This may sounds simple, but long-term weight loss has proven quite difficult for many. The issue can also be complicated to explain to children, who seldom have the maturity to understand the complex interactions between physical activity, energy intake, and weight control. Peer pressure and advertisments on TV also affect children (9). It has been observed that children who are more likely to benefit from physical activity are less likely to participate in it (76). Thus it must be a priority to find novel ways to involve everyone in physical activity and enjoy it. Establishing behaviour that encourages physical activity early in life would likely be carried on into adulthood, and thus positively influence current and future health (23). The journey to school provides an opportunity for most children to increase their daily physical activity instead of being driven to school (23). Only small proportion of children live so far from their school that they cannot go there on bicycle or on foot. Those who can´t mostly attend schools in the countryside, and must go by car. One of the national health objectives for 2010 in the United States is to promote trips to school made by walking and cycling. Many programs to encourage active travel to school, are being implemented throughout the United States, Europe, and Australia (23, 84). Walking or cycling to school has been associated with higher daily physical activity and increased daily energy expenditure in children and adolescents compared with those travelling by car in the United States, Europe, and elsewhere (23, 84, 122, 142). Some studies have however failed to demonstrate a clear benefit of active travel (3, 46, 147).

The recommended amount of physical activity is now around 60 min of moderate to vigorous intensity, as discussed earlier. Possibly even more activity is needed for prevention of overweight and obesity (119). One or two hours per day may be closer to what is needed to prevent obesity (9, 12, 37). Active travel might not by itself be enough to fulfil these recommendations, so other ways should be explored. Increased promotion of different sports could encourage children to spend more time being active. Various sports and activities are on offer in most towns and cities, thus everyone should be able to find something suitable. Children are naturally variably gifted at sports, there are differences in fitness, coordination and flexibility. However, with the variety of activities available, a suitable activity exists for all children. All they need is motivation and an appropriate environment. Increased physical activity education in schools is also an option. By increasing education about the good health effects of an active lifestyle, children and adolescents could become more aware of their behaviour and then be more open to changes. In addition to extra allotted time at school for physical activity, there should also be lectures and education about these matters.

This study found the activity pattern varied between ages and genders and was also different on weekends compared to weekdays. In this study the activity pattern was broken down to seven independent components, which all described the activity differently. By one exception (55), this is the first study to use PCA to examine physical activity patterns in humans. The results indicate that it is the length of bouts, rather than the total time over certain intensity thresholds, activity level or total activity that is most strongly associated with fatness and fitness. These results demonstrate that it is important not only to look at traditional variables of physical activity, but also to examine different components of the activity pattern. It is also important to verify the results of this study by performing intervention studies in which the physical activity is composed of long periods of moderate activity.

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