Association Between Socio-Ecological Factors and Physical Activity in 10-13 Years Old Children – A Cross-Sectional Study

Vilka faktorer associerar med graden av fysisk aktivitet hos barn i åldrarna 10 – 13 år – En tvärsnittsstudie

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Abstract

Background/aim: Physical activity (PA) associate with health-related benefits. Our aim was to identify socio-ecological factors associated with PA in children.

Methods: Data were collected from 141 children aged 10-13 in the Paediatric Osteoporosis Prevention (POP) study, a prospective controlled PA intervention study. For the intervention group (n=84), in-school PA was increased to 60 min/week. The control group (n=57) continued with 60 min/week. PA was measured with accelerometers 4 year into the study during 3-4 consecutive days, General PA was defined as average counts per minutes (cpm), moderate to vigorous PA (MVPA) as minutes (min) >3500 cpm/day and vigorous PA (VPA) as min >6000 cpm/day. A questionnaire identified socio-ecological variables. Anthropometry was measured by standard equipment. Analyses of covariance (ANCOVA) identified variables that were independently associated with PA. Data are presented as mean ± standard deviation or mean (95% confidence intervals).

Results: The children spent 597 ± 185 cpm in general PA, 40.2 ± 18.3 min/day in MVPA and 8 ± 7.4 min/day in VPA. Boys spent 75 (11, 139) cpm more in general PA and 8.7 min/day (2.6, 4.7) more in MVPA than girls. Each year younger age was associated with 65 (2, 127) cpm higher general PA. The intervention group was associated with 9.2 min/day (95% CI 1.6, 16.8) less MVPA than the control group.

Conclusion: Age and gender associate with level of PA in 10-13 years old children. Our intervention was associated with less MVPA. Girls and older children might need support to reach the World Health Organization (WHO) recommendations of PA. We suggest that the intervention would benefit from including more MVPA. More research is needed to confirm our results and identify other factors associated with PA.

Populärvetenskaplig sammanfattning

Bakgrund: Under 1900-talet har vi blivit allt mindre fysiskt aktiva. Vi tillbringar mer och mer tid stillasittande. Ny teknik som elcyklar, bilar, tåg och hissar bidrar till detta. Vi behöver numera inte ens gå till affären för att handla matvaror. Dessa kan i stället bli levererade, direkt till hemmet. Färre barn går eller cyklar till skolan medan allt fler åker bil eller skolbuss. Och tid tillbringad framför datorskärmar har ökat. Denna utveckling har gått snabbt, något som har lett till att fler barn och vuxna uppnått en ohälsosamt låg fysiskt aktivitet. Utvecklingen är oroande då vår nya livsstil förmodligen är en av förklaringarna till den ökande förekomst av övervikt och fetma som vi ser hos dagens barn. Enligt Världshälsoorganisationen (WHO) har denna förekomst globalt ökat från 4.2% år 1990, till 6.7% år 2010. Ökningen beräknas dessutom fortsätta upp till ca 9% år 2020. Förutom övervikt är otillräcklig fysisk aktivitet kopplat till ökad förekomst av de stora sjukdomskategorierna som kardiovaskulärt sjukdom och diabetes. Vi står alltså inför ett förmodat framtida ökande folkhälsoproblem.

Om samhället skall kunna stoppa trenden med ökad övervikt, bör ökad fysisk aktivitetsnivå ingå som en viktig komponent. Tillräckligt intensiv fysisk aktivitet medför ett flertal positiva hälsoeffekter såsom lägre body mass index (BMI), lägre nivåer av triglycerider, minskat faste-insulin, ökad muskelstyrka och ökad benmassa. Därför rekommenderar World Health Organisation (WHO) att barn mellan 5-17 år ska vara måttligt till intensivt fysiskt aktiva minst en timma/dag. Och minst tre gånger per vecka ska den fysiska aktiviteten inkludera aktiviteter som stärker ben- och muskelmassa.

Flera försök har därför utförts med mål att öka barns fysiska aktivitetsnivå. Vissa av dessa studier har dragit slutsatsen att det går att öka barns fysiska aktivitetsnivå, medan andra har varit osäkra. Detta kan bero på att olika studier har försökt att öka aktivitetsnivån på olika sätt. Skillnaderna i studiernas slutsatser kan även bero på att man har uppskattat graden av fysiskt aktivitet på olika sätt. Vi vet nämligen att det är väldigt svårt att få en rättvis uppskattning av hur barn egentligen rör på sig. Frågeformulär är enkelt att använda och utvärdera men individen överskattar ofta i sina svar hur fysiskt aktiva de är. Accelerometrar, ger visserligen ett objektivt värde men endast under den begränsade tid man mäter. Graden av fysisk aktivitet kan alltså i vissa studier ha missuppfattats, i såväl positiv som negativ riktning.

För att öka den fysiska aktiviteten måste man identifiera faktorer som verkligen leder till högre fysisk aktivitetsnivå. Första steget blir då att identifiera faktorer inom olika områden (biologiska, sociala, psykologiska, omgivningsmässiga) som är associerade med hög fysisk aktivitet. Sannolikt skiljer sig dessa faktorer i olika åldrar. Man kan t.ex. gissa att föräldrarnas påverkan är större i yngre åldrar medan kamraternas påverkan blir större ju äldre barnet blir. Därför behöver man identifiera vilka faktorer som associeras med fysisk aktivitet i olika åldrar.

Denna studie syftar att utvärdera vilka faktorer inom biologiska-, sociala- och miljödomäner som associeras med objektivt mätt fysisk aktivitet hos i medeltal 12-åriga barn.

Metod: Studien är en del utav Bunkeflostudien. I vår studie inkluderades 80 pojkar och 61 flickor från fyra skolor belägna i samma geografiska område i Malmö. Barnen var 6-9 år när studien startade och 10-13 år när de data vi använder i studien samlades in. En interventionsskola utökade antalet schemalagda idrottstimmar efter grundmätningarna, från 60 minuter (min)/vecka till 40 min/dag (200 min/vecka) under grundskoleperioden. De tre kontrollskolorna fortsatte med Svensk standard på 60 min/vecka. Idrottstimmarna inkluderade vanliga gymnastikaktiviteter som dans, bollsporter, redskapsgymnastik och löpning. Barnen utvärderades under studien årligen med frågeformulär och tester/mätningar. Även barnens föräldrar fick vid studiestarten svara på ett frågeformulär. Testerna/mätningarna inkluderade bl.a. mätning av längd och vikt med standardapparatur. Från dessa värden räknade vi ut body mass index (BMI). Mängden fett och ”*lean body mass* ” (som i huvudsak består av muskelmassan) mättes med dual x-ray absorptiometry (DXA). Graden av fysisk aktivitet mättes när barnen var i medeltal 12 år (10-13 år) med accelerometrar under tre till fyra påföljande dagar. Minst en av dagarna var en helgdag. Accelerometrar mäter vertikala rörelser, som sedan räknas om till enheten *"counts per minute"* (cpm). Allmän fysisk aktivitet definierades som antalet cpm/dag, måttlig till intensiv fysisk aktivitet (MVPA) hur många minuter (min)/dag som barnen tillbringade med aktiviteter >3500 cpm och intensiv fysisk aktivitet (VPA) hur många min/dag de tillbringade med aktiviteter >6000 cpm. I stort motsvarar då MVPA rask promenad och VPA löpning. Vi analyserade mätvärden i statistikprogrammet SPSS. Där skapade vi en modell som inkluderade faktorer som i litteraturen har påståtts påverka graden av fysisk aktivitet. I en statistisk modell som benämns "*analyses of covariance" (ANCOVA),* beräknade vi vilka av dessa faktorer som oberoende av övriga var associerad med graden av fysisk aktivitet.

Resultat: Vi fann i vår modell att pojkar var mer allmänt fysiskt aktiva samt mer aktiva i MVPA än flickor. Bland 10-13 åriga barn, var det de yngre barnen som var mer fysiskt aktiva. Vi fann även att barn inom interventionsgruppen var mindre aktiva i MVPA än barn i kontrollgruppen. Slutligen hittade vi inga faktorer som var associerade med hur aktiva barnen var i VPA.

Konklusion: Hos 10-13 år gamla barn verkar ålder och kön vara associerad med fysisk aktivitet. Man kan tolka våra fynd som om flickor jämfört med pojkar och barn närmare puberteten jämfört med yngre barn är riskgrupper för att ha låg fysisk aktivitet. Möjligen bör man därför rikta stöd till nämnda grupper för att de skall upprätthålla hög fysiskt aktivitet. Att barn i interventionsgruppen spenderade mindre tid inom måttlig till intensiv fysisk aktivitet, jämfört med barn i kontrollgruppen är ett oväntat fynd som vi inte kan förklara. Vi spekulerar att en dylik intervention i framtiden kanske borde inkludera mer av denna typ av aktivitet. En annan möjlighet är att detta är ett slumpfynd. Vi rekommendera därför andra forskargrupper att verifiera eller motsäga dessa fynd i nya studier.

Introduction

During the 20th and the 21st century, mankind has become more and more sedentary. With the introduction of the modern societal life, including industrialisation, less manual work, more comfortable living conditions, inventions such as industrial robots, cars, electrical bikes and computers, physical activity is no longer the natural part of life it once was. We do not longer have to walk to the grocery store, since groceries can nowadays be delivered at the door. Transportation occur by cars, busses and trains. There are elevators in virtually all modern official buildings, where you read *"emergency stairs",* being a hidden recommendation to use elevators, instead of climbing stairs. The development have created a myriad of machines which serve to ease or replace manual work in households. Children no longer have to walk or cycle to school, they are more often than not brought to school by school busses or cars. These are examples of structural changes in society that have meant children, as well as adults, are less physical active than in the past. In addition, the dominance of new, mainly passive, activities such as television, computers and smartphones, mean individuals spend more and more time with direct sedentary activities.

When discussing the life-style of children of today, it is critical to acknowledge that physical activity (PA) is not just one specific activity. PA may occur during a variety of activities, such as walking, cycling to school, cleaning your home, playing football, school physical education (PE), building a tree house or playing hide and seek. The definition of PA, according to The World Health Organisation (WHO), is currently *"any bodily movement produced by skeletal muscles that requires energy expenditure".* (1)

There is therefore a common view that declining PA in society is part of a growing global problem, which includes an increasing overweight population (2), the exponential rise of inactivity related diseases (2, 3), and possibly also declining academic achievements (4). The increase of obesity, among adults and children, is actually one of the great global health problems, a problem that has exploded worldwide during the last three decades (2). The global prevalence of overweight and obese children has increased from an estimated 4.2% in year 1990 to 6.7% year 2010, and with an expected prevalence of 9% year 2020 (2). Many researchers naturally conclude that this development is directly linked to the decreasing level of PA in society and the introduction of more direct sedentary children activities (5).

Further, it is well known that increased PA in children is associated with several health-related benefits (5, 6, 7, 8, 9, 10). Children with more PA in school benefit from higher bone mass, increased muscle strength (7, 11) and reduced fracture rates (7). Among boys, increased PA is also associated with better grades and a higher acceptance rate to onward education (12). Other health-related benefits among adolescents after a seven weeks long training period are reduced cardiovascular risk factors, such as waist circumference and triglycerides, known to be inversely related to level of PA (6), and systolic blood pressure improvement (10). Increased level of PA in children is also associated with decreased body mass index (BMI) (8), lower body fat percentage (9,10), decreased waist circumference and decreased fasting insulin (6). These are just a few examples from the vast literature that support beneficial effects of increased PA. With this in mind, there is probably a huge potential for society to reverse negative health trends by influencing children to become more physical active and maintain a high physical activity level into adulthood.

The physical inactivity problem has been highlighted by The World Health Organization (WHO), which has recommended that children aged 5-17 years should engage in at least 60 minutes (min) moderate to vigorous physically active/day (3). Moderate activity refers to activity that is performed at 3.0-5.9 times our basal metabolic rate, and vigorous activity is performed above 6.0 times our basal metabolic rate. If children spend more time than 60 min in moderate to vigorous physical activity each day, it provides additionally health benefits. According to the recommendation, the majority of PA should be aerobic activities, three times/week accompanied by vigorous activities that strengthen muscles and bones. Only one out of five 11-17-years old children, however, meet these recommendations (1). This is disquieting, since PA habits seem to persist from childhood to adulthood, the period where most inactivity related diseases occur (13).

There is therefore a need to identify suitable methods to increase the level of PA in children. Such efforts could start with an attempt to identify factors that associate with PA in the population. There are probably several factors, across several domains within a socio-ecological framework that may influence children's PA levels. For example, modifiable factors such as PA intervention programs in school (7, 8) and influence from family and friends (14, 15, 16, 17) have been found to associate with a high level of PA. However, there are also non-modifiable factors such as age, body height, BMI and gender that may be associated with children's PA behaviour (6, 9, 16, 18, 19). These factors are also of importance, since they could hypothetically be used to identify children that need support to be physical active.

Existing research describes a variety of PA interventions that aim at increasing PA in children, but have come up with contradictory conclusions (14, 18, 20, 21, 22). This could, at least partly, be due to the fact that there are different methods to estimate level of PA in children, where some may misinterpret the true level of PA. Methods like accelerometers, pedometers and questionnaire have been used (6, 9, 23). A large systematic review concluded that previous interventions may lead to a modest effect at best, but that more reliable methods to measure level of PA in children and more effective intervention strategies are needed (24). This may be achieved by starting to identify factors that associate with PA within different socio-ecological domains and then test in randomized prospective trials (RCT), by objective methods, if a multi-intervention program could reach a more beneficial outcome.

Before we launch such programs, it is important to address the *"active stat theory*". The active stat theory suggests that the level of PA is specific for each individual and centrally regulated (25). That is, if a child increases the amount of PA in one domain, for example in school, the theory suggests the child will reduce the level of PA in another domain, for example during leisure time. This is a phenomenon that has been described as a possible contributor to which level of PA a child chooses and a reason some intervention studies have inferred that PA intervention program are without effect (22).

The relative age effect (RAE) is another important aspect when discussing the level of PA in children. RAE implies that children born in the beginning of the year hold advantages in motor skills, body height and body weight compared to children born at the end of the year (26). Children born in the beginning of a calendar year is therefore overrepresented among athletes, compared to children born later during the same calendar year (27, 28). These early born children probably also have mental maturational benefits. It is unclear, however, if children with physical advantages may find it more enjoyable to engage in leisure exercise and therefore choose higher PA levels, i.e. if the phenomenon also exists among non-competitive school-children. Younger children within the same birth year could, if there is a RAE, be supported to be as physical active as their classmates born early in the calendar year. This is one example of non-modifiable risk factors for developing low PA which could be valuable to identify.

The primary aim of this cross-sectional study was to evaluate if different factors within biological, social and environmental domains associate with objective measured level of PA in 10-13 years old children. We hypothesized, based on conclusions in the literature (15), that gender and parental attitude towards PA would associate with level of PA.

Material and Method

This study use data from the Paediatric Osteoporosis Prevention (POP) Study, described in detail in previous publications (11, 23, 29). In summary, children in four primary schools were invited to participate in an intervention study when they started grade one or two. One school was chosen as intervention school whereas three schools served as control schools. All four schools were located in the same geographical area in Malmö/Sweden. The children were at inclusion mean 7.7 ± 0.6 years (mean ± SD) (range 6 – 9 years). The intervention school increased the physical education (PE) in school to 40 minutes (min)/day (200 min/week), while the control schools continued with the Swedish standard curriculum of 60 min/week. The intervention, which included standard activities in the Swedish school PE curriculum, such as running, jumping, dancing and ball games, continued throughout all nine compulsory school years. The children were evaluated with questionnaires, anthropometric measurements and physical performance tests at baseline and then annually during the study period. Level of PA was measured by accelerometers, two and four years after the start of the study. In this report, we utilized POP data from the baseline and the four-year follow-up evaluation, when the children were 11.7 ± 0.6 years (mean SD) (range 10 – 13 years).

349 of the 564 children (192 of 302 boys and 157 of 262 girls) accepted to participate. We excluded in this report six children (two boys and four girls) who did not attend the baseline exam and two children (one boy and one girl) who had diseases that affected their possibility to perform PA. Among the 341 children (189 boys and 152 girls) remaining children, 297 children (169 boys and 128 girls) participated at the four-year follow-up exam. 155/297 children (89 boys and 66 girls) were excluded by us as they had not answered all the questions that we included in

our model and one child (a girl) had an outlier value in the accelerometer measurement. The analysis in this report thus includes 141 children (80 boys and 61 girls) (Figure 1).

We used the POP study's non-validated questionnaires (23), which were answered at each annual visit. One part of the questionnaire was answered by the child, with or without help from their parents or guardians. A second part of the questionnaire was answered by the children´s parents. For this report, we included variables that research suggests is associated with level of PA in children (6, 9, 14, 15, 16, 17, 18), with the aim of covering the multilevel influence of PA and capturing different aspects in a socio-ecological model (SEM) (30). In SEM three domains must be taken in consideration. The biological domain includes age, gender, if you are born in first or second half of the year, height, total body fat and total body lean mass. The social domain includes educational level of the parents, the parents attitude towards PA, if the index child has any siblings active in sports and how many hours/week the index child spend in front of television and screens. Finally, the environmental domain put focus on how you live, in an apartment or a house and if you are a part of the intervention group or the control group. A full layout of the included questions and how the questions were categorized is presented in appendix 1.

Anthropometric measurements at baseline and follow-up included height measured by a Holtain Stadiometer, weight by a standard electric weight meter. Total fat proportion (%) and total lean mass (%) were measured by a dual energy x-ray absorptiometry (DXA) (DPX-L version 1.3z, Lunar®). DXA works through X-rays that are absorbed differently in tissues of the human body. In this way you can measure both fat mass, lean mass and skeletal regions surrounded by soft tissue. All measurements were done by research technicians at the hospital with the children dressed in light clothing.

PA levels at follow-up were measured by MTI model 7164 accelerometers (Manufacturing Technology Incorporated, Pensacola, FL, USA), an apparatus also called *actigraph.* The accelerometer records movements in the vertical plane as counts per minute (cpm). The children were instructed to wear the accelerometer for four consecutive days, with at least one day during the weekend. One epoch was set to 10 seconds (sec). If 60 consecutive epochs or more were recorded with no activity (value 0) the data were automatically deleted, since we then concluded that the accelerometer had not been worn. The accelerometers were not waterproof and therefore not used during water activities. To be included in this report, the children had to have at least eight hours of valid recorded data during three of the four required days. We registered general PA (average cpm), moderate to vigorous physical activity (MVPA) and vigorous physical activity (VPA). Different accelerometer cut-offs have in the literature been used for MVPA and VPA (31), but we defined, in line with previous reports (32) MVPA as >3500 cpm and VPA as >6000 cpm. We then estimated the metabolic equivalents (METs) these activities correlated to. One MET is the energy and metabolic rate one individual produce when sitting, MVPA correlates to three to six metabolic equivalents (MET) such as during brisk walking while VPA correlates to above six METs such as during running. The accelerometer data collection procedure is described in detail in previous studies (32, 33).

Before we started our analysis, we wanted to evaluate if we could identify any inclusion bias of clinical relevance. Our research group had previously conducted a baseline drop-out analysis by using the school records of first grade health examinations. We then found similar anthropometrics between the children who participated in the study and those who rejected participation (7, 23, 34). We also conducted a second drop-out analysis, comparing those children who participated both at baseline and after four years with those who only participated at baseline. Also in this analyses, we found similar data between the two groups (Table 1).

IBM SPSS 25 was used for the statistical analyses. Descriptive statistics are presented as numbers (n), proportions (%) or means ± standard deviations (SD) and inferential statistics as means with 95% confidence intervals (95% Cl). Analyses of covariance (ANCOVA) were used to evaluate if any factor was, independent of the in the model other included factors, associated with general duration of PA, time within MVPA and time within VPA. We regarded $p<0.05$ as a statistically significant difference.

Ethical reflections

There are always ethical considerations to consider when starting a study, and specific ethical considerations when the research includes small children. A relevant first concern is that our study examines children at baseline between six to nine years old . The children along with parents and guardians, received oral and written information and volunteered written consent to participate in the study. However, most children at this age are profoundly influenced by their parents and may have given their consent to participate even if they, themselves, may have preferred to drop out. We therefore, as should be done in any scientific study with a human population, stressed that participation is voluntary and that nothing in the school or health care situation would be affected, if they should decline to participate. We also clarified that they could stop participating and have all collected data removed, at any time. In addition, the research staff who conducted the actual measurements, were informed that if a child felt discomfort, in spite of signing the consent, we should immediately stop the evaluation, even if the child did not be themselves voice this opinion.

Second, we had to consider the balance between benefits, disadvantages and risk of injury during the extended time of increased PA. At study start in 1999, no one could know what to expect. Regular evaluations during the course of the study could have served to highlight any harmful interventions and allow researchers to discontinue them, or indeed guide an increase of the level of PA in the control group if indications were so positive it would be unethical to deny these children the benefits. This ethical quandary should be considered in future similar projects as the POP-study.

Third, we had to consider the ethical aspect of conducting so many examinations in growing children. DXA-scan was performed annually as to estimate bone mass, fat mass and lean mass, each year exposing the children to a small amount of radiation. The greater summarized amount of the radiation, the greater side effects. We highlighted this dilemma in our study applications to the ethics committee of Lund university and the radiation committee at Skåne University Hospital (SUS), both of whom regarded the dose of radiation so low that it should be regarded as negligible.

Fourth, we needed to consider if our study/intervention would have an effect on the children's mental health. For example, in the intervention group there were children with chronical diseases or disabilities. If they didn't have the opportunity to participate like the other children, they could be alienated from friends and, in a worst-case scenario, be subject to bullying. To minimize the risk of exclusion between children, the PE lessons included a variation of physical activities at modest level so that all children, to some content, could participate. We also collected data from all children, removing them (as in this study) from analyses only at a later stage due to pre-defined inclusion criteria in each research report.

Fifth, a consideration that was highlighted by many teachers was the effect on other school subjects in the intervention group. The intervention school increased physical education from 60 min/week to 200 min/week. To make room for the extra physical education of 140 min/week the school reduced time spent on "the student's choice", aesthetics and music, and extended the school day somewhat, within regulated limits. You could always argue the importance of these subjects and compare it to importance of PA. However, no subjects were neglected, just reduced.

Sixth, some children might have considered PE lessons a burden because they did not consider themselves talented in sports, or just found it boring. We would then expose the children in the intervention school to something they had not chosen by themselves. However, schools regularly adjust the time spent on different parts of the curriculum without asking the children's approval. For example, if someone falls back in math or Swedish, the school provides extra help and attention to help the student catch up with their peers.

The Ethics Committee of Lund University, Sweden (LU 453-98;1998-09-15) approved the study after reviewing these considerations, as did the Radiation Committee at the Skåne University Hospital (SUS). The trial was registered as a clinical trial (ClinicalTrials.gov.NCT00633828) and conducted according to the recommendations described in the Declaration of Helsinki.

Results

General PA

In our adjusted model, we found that boys were more physical active than girls (mean difference 75 (95% CI 11, 139)) cpm (Table 2) and that younger children are more physical active than older children (older age was associated with 65 (95% CI 2, 127)) lower cpm (Table 2) per additional year of life.

Moderate and vigorous physical activity (MVPA)

Boys spent more time in moderate and vigorous physical activity than girls (mean difference in MVPA 8.7 (95% CI 2.6, 4.7)) min/day and children in the intervention group had 9.2 (95% CI 1.6, 16.8) less MVPA min/day than children in the control group (Table 3).

Vigorous physical activity (VPA)

None of the factors included in the model were associated with any duration of vigorous physical activity (VPA) (Table 4).

Discussion

Our results support our hypothesis that gender in 10-13 years old children (biological domain) associates with general level of PA. Male gender has previously been found to associate with higher level of duration of PA in the same cohort in younger children (14). This view is now supported by objective measurements of PA. We can only speculate why girls spent less time in PA than boys. One reason could be that girls mature earlier than boys and that puberty is a period when PA on group level is decreased (15). Future studies should therefore evaluate if boys follow the trend of less time spent in PA, but one to two years later than girls when a larger proportion reach puberty, or if boys, as being reported in the literature, spend more time with PA than girls in general. (6, 14, 16, 18, 19)

Our data further support that age (biological domain) in children aged 10 – 13 years inversely associates with general level of PA. When comparing the same cohort of children when they were six to nine years, however, we found that age was positively correlated with PA (14). However, both our previous results (14) and the current results actually support the common view in existing research, in that children increase the level of PA with ageing until before or early puberty, whereafter there is a decline in PA, greatest seen between the ages 13-18 (35). Another aspect associated with age is the RAE, i.e. that time of birth during the year effects performance (26). We found however no RAE in this cohort of children, and therefore speculate that this effect may be significant only when performing PA on competitive level. (27, 28)

Previous results also indicate that an intervention (environmental domain) to introduce daily school PE, on population-based level, is associated with greater time spent in MVPA. However, unexpectedly we found that the intervention had a negative association with time spent in MVPA. It should be noted that we didn't find any association between the intervention and general PA or time spent in VPA. We can only speculate what the cause to these unexpected findings may be. The control group might compensate less PA in school with being more active during leisure time or, inversely, children with daily school PE may reduce the level of PA during leisure time. The finding does not, however, support the active stat theory (25), a theory inferring that the total amount of PA in children is set to a constant level in each child. The finding that the intervention group had lower duration of MVPA compared to the control group in fact contradicts this theory. This conclusion supports several previous research publications , inferring that there is no activity stat regulation in children (23, 36). Since there were no group differences in general PA or VPA, we cannot further rule out that the lower MVPA in the intervention children was a chance-finding due to the relatively small sample size.

Further, in contrast to previous research on 6-9 year old children (14), the current data did not support our hypothesis that parental attitude towards PA is significant for children's own level of PA in the ages 10-13 **.** We speculate that the attitude of the parents is of greater importance in younger than in older children, since most children become more independent when they grew older, then possibly also choosing their leisure time activities more independently. Another possibility is that older children become more influenced by their friends than their parents, and to a larger extent make the same choices as their friends. This finding shows the importance of evaluating factors that associate with PA in age specific cohorts. The findings also raise the question whether interventions, with the aim to increase the level of PA in children, should address different factors in different ages.

In this type of study, one of the greatest challenges is to accurately estimate the level and duration of PA. For instance, the children in this study were aware their PA was being measured by accelerometers. Some children may be triggered by this, purposefully being more physical active during the three to four days with recording, than during the rest of the year. This would lead to positive bias in comparison to actually performed PA. Another flaw is that accelerometers aren´t water resistant, therefore failing to register physical activities such as swimming, and only record movements in vertical direction, failing to register physical activities such as road cycling. Both these drawbacks may result in negative bias compared to actually performed PA. Further, it is difficult to compare duration spent with MVPA and VPA with other studies, since different studies uses different cut-off values for MVPA and VPA (18, 19, 31). Finally, most studies estimating amount of general PA and moderate or vigorous PA use questionnaires (36), which, when used with children, has proven to be an inaccurate method to measure actual PA (23), making it even more difficult to compare the outcome with accelerometers in our study with studies using questionnaires to estimate the amount of PA.

The way our study was designed, we can´t draw any certain conclusions regarding causality. We can only make inferences regarding associations. The modifiable factors that associates with PA in our study should be tested in prospective randomized controlled trials (RCT) to determine if changes in these factors actually leads to higher level of PA. Furthermore, in prospective observation studies non-modifiable and modifiable factors should be evaluated to determine if they can be used to identify cohorts in risk of developing low PA habits during growth. If further research could determine whether these factors could increase PA (modifiable) or identify risk cohorts (modifiable and non-modifiable) for low future PA, we could at a young age target children with effective intervention that increase level of PA, and with this probably promote health benefits of clinical significance**.**

A strength of our study is the population-based inclusion of the study participants, where all children in the neighbourhood of the four schools in Bunkeflo was given a change to participate in the study. Since all children in Sweden has obligatory school attendance. The thorough drop-out analysis indicates that there is no apparent selection bias. This indicating that our assumptions ought to be transferrable. Another strength is the objective measurements of both duration and intensity of PA. Weaknesses includes the non-randomized study design. Instead, one school was chosen as intervention school. The reason was that it had been practical impossible to conduct a strict randomization over 9 years, a suggested design that the teachers, headmasters and parents refused when we planned the study. It had also been advantageous to have children from other socio-economic districts, children with other genetic background and other variables with possible association with PA included. These are weaknesses that should be addressed in future studies.

Conclusion

Gender and age in 10-13 year old children seem to be associated with level of physical activity. We found no beneficial effect by our intervention. In contrast, and to our surprise, we registered a negative association between the intervention and duration of MVPA. This finding ought to be further evaluated in independent cohorts, as to determine if our findings occurred due to chance. We also speculate that puberty may be negatively correlated with PA, and that girls and boys approaching puberty therefore should to be supported to be more physical active.

My own work effort

I have been active and learned a lot in all the parts of my master thesis. At first, I read background material to learn about the POP-study and other dissertations in the project. Simultaneously, I made database searches for relevant articles and participated in the work of gathering data to learn how the statistics were collected.

The more I learned about the project, and after valuable discussions with my supervisor Magnus Karlsson and PhD Amanda Lahti, it became easier to choose the most important variables to include in the study.

Throughout the writing process, the statistical analysis and the presentation, I learned much thanks to my supervisor. I made a draft, discussed it with my supervisor, received feedback and explanations how to improve my work. Finally, after a lot of emailing back and forth, we were pleased with the result. This way, I always had my own thoughts tried out at first, received feedback and developed my own scientific understanding. It has been a lot of work, sometimes it has been frustrating, but most of the time a lot of fun and interesting.

I want to give many thanks to my supervisor Magnus Karlsson and PhD Amanda Lahti who helped me a lot with my project, and helped me understand the whole process of conducting a scientific study.

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Figure 1. Flow-chart of the study population

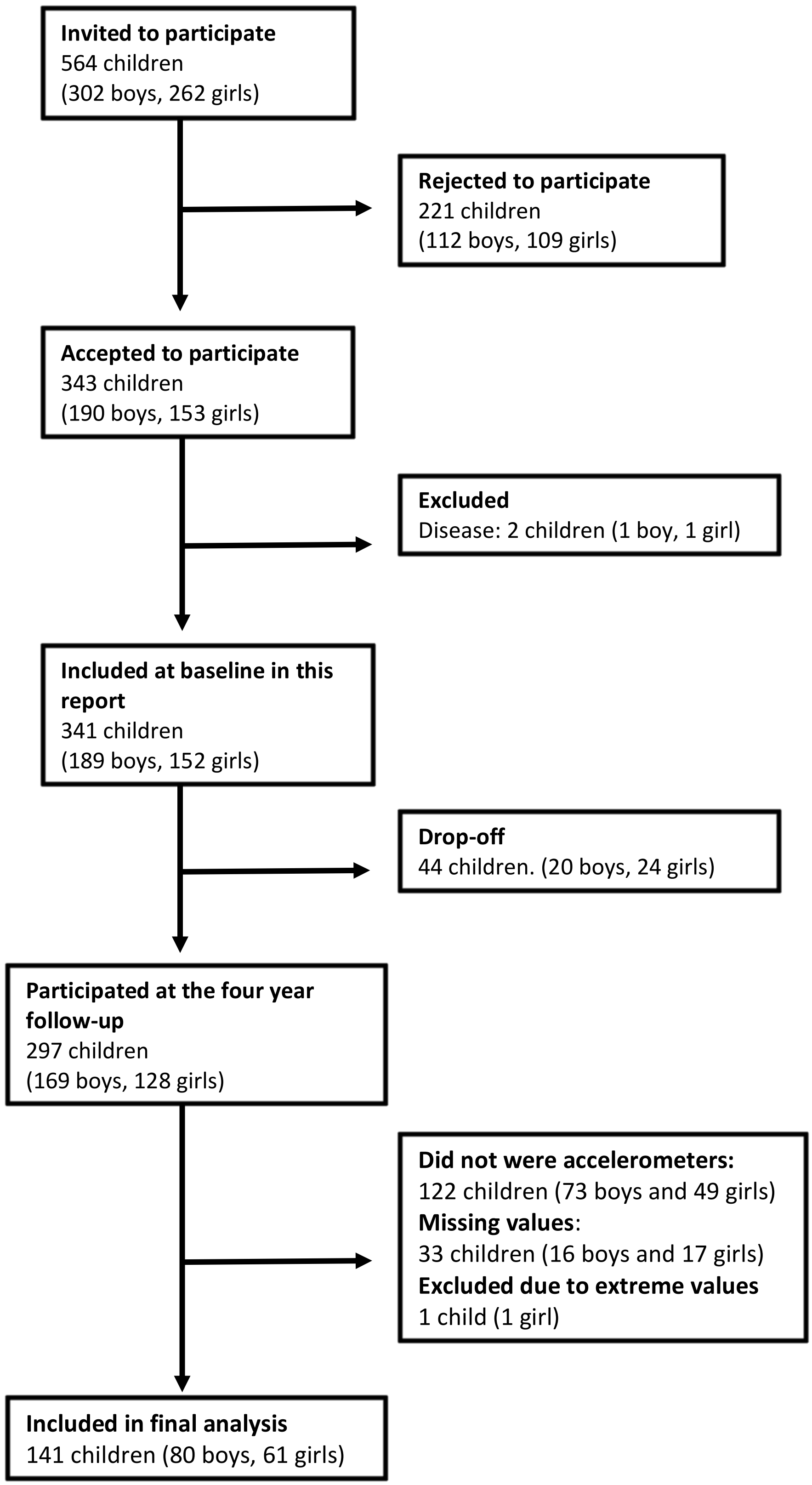

Table 1. Descriptive statistics of the 341 children included at baseline. Information as regard ethnicity was missing in one boy and 2 girls. Categorial variables are presented as numbers with % in parentheses, continuous variables are presented as means with standard deviations (SD). If not all children have data the number are presented as within parentheses as n=XX).

	Baseline value for in this study included children (n=141)		Baseline value for those who left the study and those by us during the study excluded children (n=200)	
	Boys	**Girls**	**Boys**	**Girls**
n (%)	80	61	109	91
Age (years)	7.9 ± 0.6	7.7 ± 0.6	7.6 ± 0.6	7.6 ± 0.6
Height (cm)	129.6 ± 6.8	127.8 ± 7.2 (n=60)	128.3 ± 6.3	128.2 ± 6.9 (n=90)
Weight (kg)	28.4 ± 5.4	26.8 ± 4.8 (n=60)	27.3 ± 5.8	27.7 ± 5.7 (n=90)
BMI (kg/cm^2)	16.8 ± 2.4	16.3 ± 2.1 (n=60)	16.5 ± 2.3	16.7 ± 2.6 (n=90)
Lean mass (%)	82.6 ± 7.4	78.2 ± 7.1 (n=59)	82.7 ± 7.5	77.9 ± 8.2 (n=88)
Fat mass (%)	13.6 ± 7.6	18.2 ± 7.3 (n=59)	13.6 ± 7.7	18.5 ± 8.5 (n=88)

Table 2. Associations between different variables and general PA in 141 children. Categorial variables are presented as the difference in count per minutes (cpm) from reference category (REF) and continuous variables are presented as regression coefficients (change in cpm per unit change of the variable in consideration). Each variable has been adjusted for all other variables. Uncertainty is presented as 95% confidence intervals (95% CI). Statistical significances are bolded and highlighted.

Variables	Answer options	Mean±SD or n (%)	Regression coefficient or estimated difference from reference category (95% CI)
Biological domain			
Gender (%)	**Male**	**80 (57)**	**75.1 (11.4, 138.8)**
	Female	**61 (43)**	**REF**
Age (years)		**11.8 ± 0.6**	**-64.6 (-126.9, -2.2)**
Born in first or second half of the year, n (%)	Born in first half of the year	79 (56)	19.6 (-44.0, 83.2)
	Born in second half of the year	62 (44)	REF
Height (cm)		152.5 ± 8.7	-0.7 (-5.3, 4.0)
Total body fat mass (%)		19.7 ± 9.1	-110.1 (-228.9, 8.6)
Total body lean mass (%)		76.4 ± 8.8	-109.6 (-231.5, 12.2)
Social domain			
Any active siblings in sports, n (%)	Yes	85 (60)	-13.6 (-80.1, 53.0)
	No	56 (40)	REF
Screen time activity (h/week)		2.5 ± 1.8	10.5 (-7.2, 28.1)
Parental attitude, n (%)	At least one parent think PA is important	95 (67)	58.5 (-8.8, 125.8)
	None of the parent thinks PA is important	46 (33)	REF
Parents education (%)	At least one parent with university/high school education	90 (64)	-12.4 (-77.5, 52,7)
	No parent with university/high school education.	51 (36)	REF
Environmental domain			
Living form (%)	House	105 (74)	31.9 (-58.4, 122.2)
	Apartment	36 (26)	REF
Intervention	Intervention group	84 (60)	-31.4 (-111.5, 48.6)
	Control group	57 (40)	REF

Table 3. Associations between different variables and MVPA in 141 children. Categorial variables are presented as the difference in minutes spend in MVPA from reference category (REF) and continuous variables are presented as regression coefficients (change in min spend in MVPA per unit change of the variable in consideration). Each variable has been adjusted for all other variables. Uncertainty is presented as 95% confidence intervals (95% CI). Statistical significance are bolded and highlighted.

Variables	Answer options	Mean±SD or n (%)	Regression coefficient or estimated difference from reference category (95%CI)
Biological domain			
Gender (%)	**Male**	**80 (57)**	**8.7 (2.6, 14.7)**
	Female	**61 (43)**	**REF**
Age (years)		11.8 ± 0.6	-2.8 (-8.7, 3.1)
Born in first or second half of the year, n (%)	Born in first half of the year	79 (56)	4.4 (-1.7, 10.4)
	Born in second half of the year	62 (44)	REF
Height (cm)		152.5 ± 8.7	0.0 (-0.4, 0.4)
Total body fat mass (%)		19.7 ± 9.1	-2.4 (-13.7, 8.8)
Total body lean mass (%)		76.4 ± 8.8	-2.0 (-13.6, 9.5)
Social domain			
Any active siblings in sports, n (%)	Yes	85 (60)	2.0 (-4.3, 8.3)
	No	56 (40)	REF
Screen time activity (h/week)		2.5 ± 1.8	0.5 (-1.2, 2.1)
Parental attitude, n (%)	At least one parent think PA is important	95 (67)	4.4 (-2.0, 10.8)
	None of the parent thinks PA is important	46 (33)	REF
Parents education (%)	At least one parent with university/high school education	90 (64)	-0.7 (-6.9, 5.4)
	No parent with university/high school education.	51 (36)	REF
Environmental domain			
Living form (%)	House	105 (74)	5.6 (-3.0, 14.2)
	Apartment	36 (26)	REF
Intervention	Intervention group	84 (60)	**- 9.2 (-16.8, -1.6)**
	Control group	57 (40)	**REF**

Table 4. Associations between different variables and VPA in 141 children. Categorial variables are presented as the difference in minutes spend in VPA from reference category (REF) and continuous variables are presented as regression coefficients (change in min spend in VPA per unit change of the variable in consideration). Each variable has been adjusted for all other variables. Uncertainty is presented as 95% confidence intervals (95% CI). Statistical significance are bolded and highlighted.

Variables	Answer options	Mean±SD or n (%)	Regression coefficient or estimated difference from reference category (95%CI)
Biological domain			
Gender (%)	Male	80 (57)	0.9 (-1.7, 3.5)
	Female	61 (43)	REF
Age (years)		11.8 ± 0.6	-1.4 (-3.9, 1.1)
Born in first or second half of the year, n (%)	Born in first half of the year	79 (56)	1.5 (-1.1, 4.0)
	Born in second half of the year	62 (44)	REF
Height (cm)		152.5 ± 8.7	-0.01 (-0.2, 0.2)
Total body fat mass (%)		19.7 ± 9.1	-1.9 (-6.7, 2.8)
Total body lean mass (%)		76.4 ± 8.8	-1.7 (-6.6, 3.2)
Social domain			
Any active siblings in sports, n (%)	Yes	85 (60)	-0.06 (-2.7, 2.6)
	No	56 (40)	REF
Screen time activity (h/week)		2.5 ± 1.8	-0.04 (-0.7, 0.8)
Parental attitude, n (%)	At least one parent think PA is important	95 (67)	0.9 (-1.8, 3.6)
	None of the parent thinks PA is important	46 (33)	REF
Parents education (%)	At least one parent with university/high school education	90 (64)	0.3 (-2.3, 2.9)
	No parent with university/high school education.	51 (36)	REF
Environmental domain			
Living form (%)	House	105 (74)	0.9 (-2.7, 4.6)
	Apartment	36 (26)	REF
Intervention	Intervention group	84 (60)	-2.6 (-5.8, 0.6)
	Control group	57 (40)	REF

Appendix 1

Factor included in the model	Query formulation in questionnaire	Answer frequency in questionnaire	Handling missing values	Comment
Age		301/343	Missing values were left blank (n=42)	
Gender	Boy or girl	343/343	No missing values	
Born on first or second half of the year	Date of birth	343/343	No missing values	
Total body fat		293/343	Missing values were left blank (n=50)	Measured with DXA
Total body lean mass		293/343	Missing values were left blank (n=50)	Measuered with DXA
Height		298/343	Missing values were left blank (n=45)	Measured with an Holtain Stadiometer
Siblings	Do you have active siblings in sport association or not	339/343	Missing values were left blank (n=4)	We categorized the answers in: 1. Have at least on active sibling in sport association. 2. Do not have a sibling in sport association.
Screen time activity (h/week)	How many hours/day do you spend in front of TV or computer? (hours/week)	283/343	Missing values were left blank (n=60)	
Parent´s education	What is your highest educational level? (i.elementary school, ii. high school, iii.university/collage)	336/343	Missing values were left blank (n=7)	We categorized the answers in: 1. At least one parent with education from university/collage 2. None of the parents with education from university/collage
Parent´s attitude towards PA	In our family, it is important with PA (i.agree ii.agree partly or do not agree)	316/343	Missing values were left blank (n=27)	We categorized the answers in: 1- At least one parent agrees. 2- None of the parents agrees.
Accelerometer data	Average accelerometer cpm	172/343	Missing values were left blank (n=171)	
Home	How do you live (i.house ii.apartment iii.other, specify)	288/343	Missing values were left blank (n=55)	“other specify” was handled as missing values because they were not able to define into house or apartment. We categorized the answers to: 1. Living in a house. 2. Living in an apartment.