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Objectively assessed vigorous physical activity and motor coordination are associated in 11-year old children

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ABSTRACT

This cross-sectional study examined the associations between gender, sports club (SC) participation, physical activity (PA), motor coordination (MQ) and object control skill (TC). 11-year-old children (n=477) wore accelerometers during seven consecutive days for the analysis of moderate PA (MPA) and vigorous PA (VPA). To detect motor competence (MC), children's motor coordination was measured using the KTK (MQ), and object control skill with throw-and-catch task (TC). Sports club (SC) status was obtained by a questionnaire. Boys had higher levels of MPA (F=50.45, P<.001) and VPA (F=11.13, P=.001), and were better in TC (F=39.83, P<.001) than girls. SC participants outperformed nonparticipants in MPA (F=5.45, P=.020) and VPA (F=11.71, P=.001), MQ (F=31.56, P<.001), and TC (F=15.60, P<.001). Moreover, better TC was associated with higher MPA (β=0.88, t=2.16, p=.031), and higher MQ was associated with higher VPA (β=0.21, t=3.87, p<.001). The association between PA and MC was found showing that different intensities of PA were associated with different aspects of MC. SC participation may be one important factor promoting PA and MC in children. Therefore, all children, especially girls, should be encouraged to participate in various practices to ensure the development of adequate level of motor competence to be physically active.

INTRODUCTION

Physical activity is vital for the physical, psychological, social, and cognitive health of school-aged children and youth. Beneficial effects of physical activity on children's body composition, cardiovascular risk factors, bone health, mental well-being, cognitive functioning, and academic achievements are well documented.[1-3] According to previous research, boys are more active than girls.[4-6] Empirical studies[7] and expert opinion[8] suggest that children and youth need at least 60 minutes of daily moderate to vigorous physical

activity (MVPA), and vigorous physical activities should be incorporated at least 3 times per week in order to have health benefits. However, many children fail to reach the PA recommendations. [9]

Motor coordination has a salient role in the development of fundamental movement skills which are needed in many different daily activities.[10] Motor coordination develops in early childhood, and it is assumed to be rather stable from the age of six.[11] Differences in motor coordination with boys outperforming girls have been found in some studies,[12-13] while others have reported no gender differences in the level of motor coordination.[14] Moreover, higher motor coordination has been found to be associated with lower BMI.[15] Longitudinal evidence suggests that motor coordination is associated with physical activity in 6-10-year-old children, and it is an important predictor of physical activity[16] and sport participation in childhood.[11,17]

Fundamental movement skills are developed in early childhood through the interaction of biological and environmental constraints.[10] Adequate proficiency in fundamental movement skills (i.e. object control, locomotor and stability skills) enables children to participate in different kinds of games and sports and to be more physically active.[10,18] Boys have been found to be better than girls in object control skills, whereas girls have been more proficient in locomotor skills and stability.[19-20] A recent review of Logan et al[21] suggests that in middle to late childhood the relationship for girls has been stronger between locomotor skills and physical activity and for boys between object control skills and physical activity. Longitudinal evidence shows that object control skill proficiency developed in the early childhood predicts both total activity time and higher intensity activity time, as well as activity behavior and health related physical fitness in adolescence.[19-20]

Organized sport participation is one of the most popular leisure time activities and an important context of physical activity in many countries. In Finland, 67% of 11-year-old children participate in sports clubs, figures being 70% for boys and 65% for girls.[22] Participation in organized sport in youth may contribute to a physically active lifestyle in adulthood.[23] In youth, sports club participation has been shown to be associated with higher levels of MPA and VPA,[24] and MVPA,[24, 25] cardiorespiratory condition,[25] motor fitness,[26] and better body composition.[27] On the other hand, sports club participation appears to be unrelated to sedentary time and BMI.[24] It has also been suggested that those who participate in sports club activities, meet the recommended levels of MVPA[9,24] and VPA[8-9] more likely than non-participants. However, sport participation alone does not ensure meeting the physical activity recommendations.[9,28] Considering motor competence, youth sports participants tend to have better motor coordination compared to non-participants.[4,11,15] Furthermore, Fransen and his colleagues[17] found that children with high motor competence participated in sports more often.

The majority of available evidence describing physical activity during childhood and adolescence focuses on combined MVPA, which may mask intensity-specific changes in activity over time.[29] In this study, we investigated the determinants of moderate and vigorous physical activity separately as it has been argued that different intensities of PA may have different effects on performance and health.[30] For example, recent research has indicated that VPA may lead to greater health benefits compared to MVPA.[7] The purpose of this study was to examine the effects of gender and sports club participation on physical activity and motor competence. Moreover, we analyzed how motor coordination, object control skill and gender are associated with physical activity. We define sports club participants as children who are

members of a sports club outside of the school environment. In Finland, most of the sports clubs are non-profit organizations that are run by volunteers through association.

MATERIALS AND METHODS

Participants

Fourth grade primary school children (n=477), 240 girls and 237 boys, served as participants for this cross-sectional study. All children were born in 2005 and were aged between 10 and 11 during the time of data collection. Children were recruited from 23 different schools in four cities. The Ethics Committee of University of Jyväskylä approved the study and written consent was obtained from the participants' parents. All measurements were carried out in accordance with the Declaration of Helsinki and Finnish legislation.

Data collection

Children completed the tests of motor coordination and object control during a school day in the school sports hall. The testing circumstances were set as similar as possible regarding space and equipment. A group of trained supervisors gave an oral instruction and a model performance for every task and scored each test. Physical activity was objectively assessed during seven consecutive days using ActiGraph GT3X+ accelerometers (Actigraph, Pensacola, FL), which were given to children face-to-face at schools. Before children were instructed how to use the accelerometers, their body height (0.1 cm) was measured using a portable stadiometer and body weight (0.1 kg) was determined on an electronic scale. Height and weight values were used to calculate [weight (kg)/height (m^2)] the body mass index (BMI) of the children.

Sports club (SC) status information was obtained through a questionnaire which has been found to be a reliable method to assess whether children take part in organized sport[24]. The question related to sports club status was "Do you currently participate in SC activities?".

Based on the answers, children were defined as SC Participants if they currently participated in SC activities and as SC Non-participants if they either had never taken part in SC activities or had participated before but did not participate in SC activities at the time of the measurements. We believe this way of measuring SC status is valid and reliable for this sample because children were instructed to answer the questionnaire with the help of their parents or guardians which increases the reliability. Moreover, organized youth sports in Finland as well as in other Nordic countries is defined clearly as membership in a sports club and a child participating in organized sport is likely to know this with a high degree of certainty.

Measures

Motor coordination and object control skill

Children's motor coordination was measured using the Körperkoordinationstest für Kinder (KTK),[31] which has been found to be highly reliable and valid instrument in assessing motor coordination of 5- to 15-year-old children.[13,14,16,31] The KTK consists of four subtests. In *balancing backwards* the participant walks backwards along three different balance beams. The difficulty of the task increases as the width of the balance beams decreases from 6 cm to 4.5 cm to 3 cm. In *hopping for height* the participant hops with one leg over a foam blocks of 5 cm, starting with one, and ending with 12 blocks. *Jumping sideways* requires the participant to jump feet together over a wooden pole in 15 seconds as many times as possible. In *moving sideways* the participant moves across the floor using two wooden platforms. Participant steps from one platform to another, moves the first platform and steps onto it and repeats this as many times as possible in 20 seconds. According to Kiphard & Shilling[31] the raw performance scores were converted into standardized scores for age. Hopping for height and jumping sideways were also adjusted by sex. Further, standardized scores for each subtest

were summed and converted in to a total motor quotient (MQ), which indicates the level of participant's overall motor coordination.

Object control skill of the participants was measured by overarm throw and catch a ball test (TC). TC test was modified from the MOVE physical test battery, which has been validated in Finnish children of 12–14 years of age.[32] Jaakkola et al[32] reported a test-retest reliability coefficient of 0.76 and intraclass correlation coefficient (ICC) of 0.69. A tennis ball was thrown overarm 10 times to a target area at a height of 90 cm on the wall from the distance of 6 m (girls) or 7 m (boys) and caught after a bounce off the floor. One point was scored after each successful performance.

Physical activity

Physical activity (PA) was assessed with ActiGraph accelerometers which have been widely studied and shown to have adequate reproducibility, validity, and feasibility for both children and adolescents.[33] Children were instructed to wear an accelerometer attached on the right hip with an elastic band for the duration of seven consecutive days during wake-up hours excluding water-activities. A minimum of 4 valid measurement day per week including one weekend day was required for the analysis. A minimum wear time per day was 500 minutes and non-wearing time was calculated as periods of 30 minutes or more consecutive zero counts. Data were collected in 30-Hz and converted into 10-second epoch counts. Cut-points were used to calculate time spent in four activity intensity classes: sedentary time < 100 cpm, light physical activity (LPA) 101-2295 cpm, moderate physical activity (MPA) 2296-4011, and vigorous physical activity (VPA) > 4011 cpm. Over 20 000 counts per minutes were excluded as spurious data.[34]

Statistical analysis

All the analyses were done using IBM SPSS Statistics version 24 program. Missing values appear in the one independent variables MQ (5.5% missing) and one dependent variable sports club participation (35.3 %). The missing values according Little's MCAR test was completely random (χ^2 (36)=44.99, p=.145). General linear model (GLM) was used to analyze all research questions. Due the skewness of physical activity variables, in the first and second research question the results are checked using bias corrected accelerated bootstrapped 95 % confidence interval for difference (BCB 95 % CI). Bootstrap method uses 5000 samples. For the third research question we used multiple imputation method creating 50 imputed data. The results are based on pooled estimates. Because bootstrap method is not available in the case of multiple imputations, the results were checked saving the Cooks distance to get information if some of the cases have too strong effect in the analysis.

RESULTS

Physical activity was measured from 477 children (237 girls, 240 boys) of which 309 answered the questionnaire for SC status determination. Of these 309 children (153 girls, 156 boys), 77.3% participated in SC (girls 70.6 %, boys 84, 0%). There were no gender differences in weight, height or BMI (Table 1). Sports club participants had lower BMI than non-participants (t=2.478, p=.015). Physical activity guidelines of MVPA were met by 61,6% of the children (n=477). 73,3% of boys and 49,8% of girls met the PA guidelines (Chi Squared 27.95, p=.000). Of SC participants, 66,9% met the PA guidelines and of non-participants 47,1% met the guidelines (Chi Squared 9.06, p=.003).

There were no gender and sports club participation interactions either in MPA (F(1,305)=2.97, p=.086, BCB 95 % CI -2.04, 15.57) or VPA (F(1,305)=.073, p=.787, BCB 95% CI -8.51, 5.90). Girls had lower value in MPA and VPA than boys (Table 2). Children engaged in sports clubs had higher MPA and VPA compared to the non-sports club participants.

There were no gender and sports club participation interactions either in MQ (F(1,295)=.003, p=.956, BCB 95 % CI -8.41, 8.11) or TC (F(1,299)=3.11, p=.079, BCB 95 % CI -0.18, 2.67. There were no gender differences in MQ, however, girls were weaker in TC than boys (Table 2). Children engaged in sports clubs had higher MQ compared to the non-sports club participants. They were also better in TC compared to their peers not involved in SC.

There were not any interaction effects in gender and MQ (t=-.84, p=.401) or gender and TC (t=-0.48, p=.634) in MPA. Further, there were no interaction effects in gender and MQ (t=1.28, p=.202) or gender and TC (t=-0.02, p=.984) in VPA. Pooled parameter estimates of multiple imputed data showed that better TC was associated with higher MPA (β=0.88, t=2.16, p=.031), whereas MQ was not associated with MPA (β=0.12, t=1.85, p=.064). Those having higher value in the MQ had higher value in VPA (β=0.21, t=3.87, p<.001). TC was not associated with VPA (β=0.33, t=1.02, p=.309).

DISCUSSION

Overall, this study showed a relationship between motor competence and physical activity. Specifically, better motor coordination was associated with higher amount of VPA, whereas better object control skills were associated with higher amount of MPA. Our results are in line with the recent findings of Lima et al[35] where VPA presented direct association with

motor coordination during a 7-year follow-up. Our results also support the findings of Hume et al[36] who found in 10-year-old children weak, but positive relationship both between object control skill and time spent in MPA, and between locomotors skills and VPA. Our findings can be interpreted with the dynamic association model of relationship between motor competence and physical activity presented by Stodden et al.[37] They suggest that children's physical activity in early childhood supports their development of motor skill competence as a form of fundamental motor skill acquisition, whereas later, during middle and late childhood and adolescence, the reciprocal relationship between physical activity and motor skill development will grow stronger and become more significant.

In accordance with other studies,[24,35] our results showed that boys were more active than girls.

This was seen both in moderate and vigorous physical activity. Gender differences may be related to different expectations of social roles. Girls may also be more interested in social leisure and individual artistic activities, whereas boys are often engaged in sport activities.[24] Furthermore, previous research suggests that decline in physical activity per year is greater among girls than boys at age 9-12.[38] Therefore, it would be important to intervene at earlier ages among girls to stimulate involvement in a variety of physical activities.

In this study, sports club participants were physically more active than non-participants, measured both in MPA and VPA. Similar findings have been previously reported by Marques et al[24] and Telford et al.[25] This may indicate that children get more exercise when participating in sports clubs. Especially in VPA, the difference between sports club participants and non-participants was apparent. In addition to recommendation of daily 60 minutes in MVPA, WHO suggest that vigorous intensity PA should be included at least 3

times a week. However, for the time being no specific dose of VPA is recommended even though, it has been shown to have several health benefits in children and youth.[39]

One of the most examined correlates of gross motor competence has been gender. The findings suggest that boys are more skilled than girls in motor coordination and object control.[19-20] The present study, on the other hand, detected significant differences between genders only in object control skills. In late childhood, the physical characteristics are quite similar in boys and girls, therefore, gender differences in motor competence may be due to environmental factors. Different sport preferences of boys and girls might be one possible explanation for this difference. Eye-hand coordination and abilities, such as speed and strength, may develop more in boys because of the type of games and other activities they take part more frequently compared to girls. As object control skills have been found to predict both physical activity time and health related physical fitness in the adolescence,[19-20] it seems important to emphasize learning of object control skills especially in girls.

In line with previous studies,[11,17] sport participation showed beneficial effects on motor competence. Sports club participants of this study had higher motor coordination and better object control skills than children who did not take part in sport club activities. It has been argued, that motor competence during childhood does not develop automatically, but it is influenced among other things by environmental factors, opportunities and instruction.[10] Several studies[21] have also provided support for the use of school and community-based interventions where the aim is to improve motor competence in young children. This being the case, it seems important that children are offered quality instruction and structured opportunities to practice their motor competence in a variety of physical activity contexts such as physical education classes, extra-curricular sports and sports clubs. This might be

especially important for less proficient children as low motor competence has been found to be associated with higher BMI,[15] which may increase the risk of acquiring an inactive lifestyle also in the adolescence and adulthood.

It has been suggested that vigorous intensity activities provide additional health benefits when compared to moderate intensity physical activity.[1] For example, for body composition, VPA has shown be more important than lower intensity activities.[40] For example, Lätt et al[41] suggested that in youth, at least 15 minutes of VPA per day reduces the risk of becoming overweight or obese. Our results demonstrated that children engaged in sports clubs had more VPA and lower BMI compared to the non-sports club participants. Given that VPA accounts for the lowest proportion of overall physical activity among young people and may decline more rapidly than any other activity intensity during adolescence,[29] great efforts are needed to enhance possibilities to promote VPA in various settings and environments across childhood.

In this study, physical activity guidelines of MVPA were met by 61,6% of the children. According to the recent study of children 9-11 years in 12 countries, Finnish children were most likely to comply the daily MVPA recommendations. This result was proposed to arise from favorable social norms, supportive policies, and supporting infrastructure.[42] Furthermore, in the present study, the recommendation compliance percentage was higher in boys than in girls, which supports the previous findings of gender differences.[9,42] With regards to involvement in organized sports, the percentage of children meeting MVPA guidelines was higher in sports club participants than in non-participants. Yet, consistent with previous observations,[9,24,25,28] our results indicate that sports club participation alone is not sufficient to meet the recommendations of daily MVPA. Therefore, it is important further to

emphasize that sports club participation does not automatically guarantee that child is physically active enough.

When interpreting the results of this study, some limitations should be considered. Although using objective measurements in physical activity is one of the strengths of this study, it causes some limitations in interpreting the results, as well. Firstly, some physical activities, such as swimming, were not captured. Secondly, when interpreting and comparing results of the studies with objectively measured physical activity, it should be noted that intensity thresholds are used inconsistently in different studies. Furthermore, the results of the MVPA recommendations compliance may not be comparable, as the data analysis method may be different, such as different measured or valid days, or using averaged MVPA versus day-to-day analysis. Finally, the cross-sectional design of the study precludes any inference of causal association, for example whether sports club participation was causing the children to be more active and/or more motor competent, or whether more active and competent children joined in sports clubs. Main strengths of this study, in addition to objective assessments of PA, were the examination of different intensities of physical activity separately (MPA and VPA), as well different dimensions of motor competence, namely motor coordination which reflects locomotor skills when measured with KTK, and object control skill.

PERSPECTIVES

It can be proposed that that higher level of motor competence enables children to participate in various physical activities, especially in some vigorous intensity activities. Vigorous physical activity has been shown to have several health benefits in children and youth.[39] In Finland, more attention has been recently directed to promoting physically active culture and children's positive development with sports and physical activity. Special programs have

been launched, such as Finnish Schools on the Move and Sports Club for Health.[43] The first is a national key project in the field of knowledge and education in the Government Programme of Finland, and the other is EU-member states network to develop the health promoting actions of the schools and sports clubs. Overall, it is important that all children are offered a variety of participation opportunities that are well instructed and developmentally appropriate to ensure that children develop adequate level of proficiency in motor competence to be physically active. Evidence regarding the pattern of vigorous intensity physical activity throughout childhood and adolescence is inconclusive and more evidence is needed to reflect a wide age range and large population samples.

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TABLES

Table 1. Descriptive statistics across gender (n=477) and sports club (SC) participation (n=309).

	Girls			Boys			SC Participants			SC Non-participants		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Height (cm)	144,1	7,1	237	145,0	6,47	240	145,2	6,9	239	144,8	6,8	70
Weight (kg)	36,6	6,5	237	37,5	6,88	240	36,7	6,3	239	38,6	8,5	70
BMI	17,6	2,2	237	17,8	2,51	240	17,3	2,2	239	18,3	2,9	70

Table 2. Descriptive statistics and group differences across gender and sports club participation.

	Girls			Boys			Group differences		
	Mean	SD	n	Mean	SD	n	F	P	95%CI
MPA (min)	42,44	11,72	237	51,79	16,58	240	50.45[1]	<.001	(-11.89, -6.77)
VPA (min)	21,39	12,14	237	25,12	12,23	240	11.13[1]	.001	(-5.85, -1.60)
MQ (index)	98,63	15,51	224	100,44	15,77	227	1.50[2]	.222	(-4.81, 1.15)
TC (score)	5,21	2,70	226	6,78	2,60	230	39.84[3]	<.001	(-2.04, -1.09)
	SC Participants			SC Non-participants			Group differences		
	Mean	SD	n	Mean	SD	n	F	P	95%CI
MPA (min)	48,63	15,42	239	43,78	14,82	70	5.45[4]	.020	(-8.34, -1.10)
VPA (min)	24,55	12,48	239	18,85	11,44	70	11.71[4]	.001	(-8.72, -2.58)
MQ (index)	102,59	15,15	230	91,09	14,14	69	31.54[5]	<.001	(-15.45, -7.60)
TC (score)	6,51	2,68	233	5,09	2,55	70	15.60[6]	<.001	(-2.11, -0.73)

[1]F(1,475),[2]F(1,449),[3]F(1,454), [4]F(1,307), [5]F(1,297), [6]F(1,301)

Note. MPA=moderate physical activity, VPA=vigorous physical activity, MQ=motor quotient, TC=throw and catch test