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Longitudinal associations of fundamental movement skills with objectively measured physical activity and sedentariness during school transition from primary to lower secondary school

Running head: Physical activity, fundamental movement skills and school transition

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Abstract

Objectives: This study aimed to investigate cross-lagged associations of leaping skill and throwing-catching skills with objectively measured moderate-to-vigorous physical activity (MVPA) and sedentary time (ST) during school transition from upper primary (Grade 6) to lower secondary school (Grade 7).

Design: This study is a one-year prospective follow-up study within Finnish school settings. Students' MVPA, ST, leaping skill and throwing-catching skills were measured at Grade 6 and subsequently at Grade 7.

Method: A sample of 336 students (163 girls, 173 boys; M age = 12.0 years, SD = 0.4 at Grade 6 participated in the study. Students' MVPA and ST were measured objectively by hip-worn accelerometers. Leaping skill was measured by 5-leaps test. Throwing and catching skills were measured by throwing-catching combination test. Cross-lagged structural equation modelling was conducted to evaluate the associations between MVPA, ST, leaping skill, and throwing-catching skills at Grade 6 and Grade 7.

Results: Results demonstrated three significant cross-lagged associations among girls: 1) leaping skill measured at Grade 6 was negatively associated with ST at Grade 7; 2) objectively measured MVPA at Grade 6 associated positively with leaping skill at Grade 7; and 3) throwing-catching skills measured at Grade 6 associated positively with leaping skill measured at Grade 7. There were no statistically significant cross-lagged associations between the study variables for the sample of boys.

Conclusions: The results of this study indicated that supporting opportunities for girls' engagement in both MVPA and leaping skill development activities during their primary school education is strongly recommended.

Keywords: physical activity; fundamental movement skills, school transition

1. Introduction

The current international recommendations related to health-enhancing physical activity (PA) typically focus on sufficient amount and intensity of PA, reinforcing that children and adolescents should participate daily in at least 60 minutes of moderate-to-vigorous (MVPA) intensity PA.[1] However, empirical studies in Western countries have demonstrated that children and adolescents rarely meet these recommendations.[2] For example, in Finland only 21-40% of children aged less than 18 years are sufficiently active.[3] Research has further shown that in Finland accelerometer-determined sedentary time (ST) was 6.4 h/day and 7.2 h/day for primary school children in grades 1-3 and 4-6, respectively, and 8.2 h/day for adolescents in lower secondary school (grades 7-9).[4] Although ST has previously demonstrated an association with unfavorable health outcomes in youth,[5] a recent meta-analysis revealed that the evidence of a prospective relationship between ST and biomedical health in childhood is unconvincing.[6]

Research has demonstrated that transition from primary school to lower secondary school is related to many psychological, social and behavioral changes.[7,8] It has been acknowledged that PA engagement and ST also change during the transition. More specifically, previous studies have revealed a decrease in active transport to/from school[9], objectively measured MVPA[10], self-reported extracurricular PA, and total PA[11], and increase in ST[10,12] after commencing lower secondary school. Interestingly, there is also evidence that objectively measured MVPA has slightly increased after students have transitioned from primary to lower secondary school.[9,11] Both groups of researchers suggested that this increase is due to the more active schoolyards and increased organized PA in lower secondary school within UK and Belgium settings.[9,11]

Fundamental movement skills (FMS) include locomotor, manipulative and balance skills.[13] Mastery of FMS is reported to be significant factor explaining adolescents' PA engagement.[14] Additionally, empirical studies have demonstrated that mastery of FMS during

adolescence positively predicts PA in adulthood.[15,16] Interestingly, Kalaja et al[17] found that a group of Grade 7 students' PA levels remained constant and FMS scores increased during participation across a one academic year FMS intervention, whereas PA and FMS scores in a matched control group decreased. This result indicates that FMS mastery is one of the important factors to prevent the typical reduction in PA engagement across adolescence. However, to our knowledge the study of Barnett et al[18] is the only investigation to examine the associations between FMS and PA engagement over the transition from primary school to lower secondary school. Barnett et al[18] determined that the object control skills of primary school children were more strongly associated with self-reported MVPA and organized PA 6-7 years later than the students' locomotor skills.

It is acknowledged that transition from primary school to lower secondary school is a period when adolescents' total PA engagement decreases and ST increases.[10,11,12] Surprisingly, despite the acceptance of the association between FMS mastery and PA engagement in adolescence there is only one study identified investigating the relationship between FMS and PA engagement over school transition.[18] However, Barnett et al[18] followed students for 6-7 years and therefore did not specifically target their study to school transition period. They also used self-reports to assess PA engagement which can be considered as limitation. To our knowledge, there are no previous studies investigating the association between ST and FMS mastery over the period of school transition.

The aim of this study was to investigate associations among girls' and boys' objectively measured MVPA, ST, leaping skill, and throwing-catching skills in school transition from upper primary (Grade 6) to lower secondary school (Grade 7). We hypothesize that FMS mastery is positively linked with MVPA and negatively with ST across the school transition period.[10,11,12] The moderating effect of gender on the associations was examined, because previous research has revealed gender differences in FMS and PA engagement.[19,20] More specifically, girls have typically performed better in the balance skill task whereas boys have been scored higher in manipulative skills tasks.[19,20] Additionally, it has been reported that adolescent boys are more physically active than girls.[21]

2. Methods

This study is part of a larger 2-year follow-up study regarding the national "Finnish Schools on the Move" program from 2013 to 2015.[6] The participants were recruited from six primary and eight lower secondary schools throughout Finland. Schools were selected from different parts of Finland and were representative of both large cities and smaller communities. A total of 1778 students from grades 4 to 7 at baseline were invited to participate, leading to the recruitment of 971 participants. The current study sample focused on a 1-year follow-up during the transition from primary school (Grade 6) to lower secondary school (Grade 7). Therefore, we included in the analyses those students who during the follow-up period had transitioned from Grade 6 to Grade 7. This included 175 students in 2013-2014 and 161 students in 2014-2015, resulting in a total of 336 students (163 girls and 173 boys) at grade 6 with a mean age of 12.03 years (SD = 0.38). All students and their guardians provided written consent to participate. The study protocol was approved by the Ethics Committee of the University of Jyväskylä.

The variables of PA and ST were measured objectively using an accelerometer (Actigraph GT3X+ or wGT3X+). Participants were instructed to continuously wear a device on the right hip during waking hours for seven consecutive days, except while bathing or doing other water-based activities. Data was collected as raw acceleration in 30 Hz frequency, standardly filtered and converted into 15-s epoch counts. A customized Visual Basic macro for Excel software was used for data reduction. The valid monitoring period included measured values ≥500 min/day for at least two weekdays and one weekend day between 7:00 and 23:00. Periods of 30 min of consecutive zero counts were defined as non-wearing time, and values over 20,000 counts per minute (cpm) were ruled out as spurious accelerations.[22] Evenson et al's[23] cut-points were used to calculate MVPA (≥2296 cpm) and ST (≤100 cpm). ST was expressed as a percentage of daily wear time.

The 5-leaps test[24] was used to measure students' leaping skills. In this test, the task involves consecutively leaping five times, starting from the initial leaping position with both legs parallel. After the first jump, the leaping sequence was a leap with the preferred leg

followed by a leap with the opposite leg until the sequence of five leaps was completed. The final landing was also completed with both legs in a parallel position. The score was the length of five leaps in centimeters measured from the heel of the leg furthest back upon the landing phase. A member of the research group measured all performances. Nupponen et al[24] reported satisfactory test-retest correlations of 0.85 for Grade 6 boys and 0.86 for Grade 6 girls.

The throwing-catching combination test was used to measure students' throwing and catching skills.[25] In the throwing-catching combination test participants threw a tennis ball at a 1.5 meters x 1.5 meters sized target area situated on the wall 90 centimeters above the floor level. The throwing distances were 7 meters for Grade 6 girls, 8 meters for Grade 7 girls and Grade 6 boys, and 10 meters for Grade 7 boys. Students had 20 attempts to throw the ball from behind the marked line, hit the target area and catch the ball after one bounce. The number of correctly performed throwing-catching combinations were counted. Because throwing distance varied between gender groups, test results were standardized by using Z-scores. Previous research[24] has demonstrated that the throwing-catching combination test had satisfactory reliability. More specifically, intra-class correlation for the girls was 0.71, and for the boys 0.68, both at Grade 5.

Pubertal stage was determined using the self-assessment questionnaire and categorized according to the Tanner puberty stage.[26] Body fat percentage were measured in light clothing by bioelectrical impedance analyses (InBody 720, Biospace Co., Ltd).

Descriptive statistics and correlation coefficients were analyzed to investigate the variable means and relationships. Independent samples t-tests were used to analyse gender differences in the study variables.

In order to study cross-lagged associations among objectively measured MVPA, ST, leaping, throwing and catching skills, a cross-lagged Structural Equation Modelling (SEM) was conducted. More specifically, a multigroup method was used to test whether associations among study variables varied in the subgroups of the girls and the boys.

In order to avoid multicollinearity, a Cholesky factoring of the predictors was used to create uncorrelated latent variables of objectively measured MVPA and ST in both measurement points (Grade 6 and Grade 7). A Cholesky factoring allows a residual from a regression model to be used in further modeling. Latent MVPA represented objectively measured MVPA time whereas latent ST represented objectively measured ST from which the variation explained by MVPA time was excluded.

SEM included the autoregressive stability paths for latent MVPA, latent ST, leaping skill test and throwing-catching combination skills test scores, as well as all the cross-lagged effects among the variables. All other contemporary measurements than latent MVPA and ST were allowed to correlate. The proportion of variance in each outcome explained by the model was evaluated by using squared multiple correlations (R^2).

At the first stage of the SEM analysis, all the regression models were estimated freely for the girls and boys by using multigroup modeling (saturated model). After that, the regression coefficients were fixed to be equal across gender groups and the Satorra-Bentler scaled χ^2-difference test was used to compare the nested models (overall test). If the overall test indicated significant loss of fit, the equality of each regression coefficient between gender groups was tested for significance by defining new parameters for the differences in the regression coefficients across the groups. Missing data were assumed to be missing at random (MAR) and the parameters of the models were estimated by using the full information maximum likelihood (FIML) method with robust standard errors. This estimation method produces unbiased parameter estimates under MAR. In the SEM model all the regressions were adjusted for pubertal stage and body fat percentage. SEM were conducted by using Mplus statistical package (Version 7).

3. Results

Table 1 demonstrates that the levels of objectively measured MVPA time were higher among the boys than the girls at both the Grade 6 and Grade 7 measurement points. Additionally, the level of objectively measured ST was significantly higher for the girls than the boys. Boys performed significantly better than the girls in leaping test at both measurement

points. Correlation coefficients among study variables are presented in Table 2. Leaping skill correlated positively with MVPA time at both measurement points among the girls and the boys. Significant negative association between ST and leaping skill was observed only for the girls at the second measurement point of Grade 7. Throwing-catching combination skills correlated positively with MVPA time at both measurement points only among the boys.

TABLES 1 AND 2 HERE

The significant associations ($p < 0.05$) between study variables of the SEM are presented in the path diagram (Figure 1) and the estimation results of the complete model are presented in Table S1. The model demonstrated three cross-lagged associations between the study variables for the girls but not for the boys: 1) Girls' leaping skill at Grade 6 predicted lower latent ST at Grade 7 (b = -0.433); 2) girls' latent MVPA at Grade 6 predicted better leaping skill at Grade 7 (b = 0.140); and 3) girls' throwing-catching skills at Grade 6 predicted better leaping skill at Grade 7 (b = 0.185). Furthermore, latent MVPA correlated with leaping skill at Grade 6 among boys and girls (r = 0.227 and r = 0.266, respectively) as well as with throwing-catching skills (r = 0.233 and r = 0.198, respectively). Significant correlation between leaping skill and throwing-catching skills at Grade 6 was observed for both boys and girls (r = 0.507 and r = 0.432, respectively). At grade 7, a significant residual correlation between latent MVPA and leaping skill was observed only for girls (r = 0.308).

The Chi-squared difference test indicated that there were some gender differences in the associations ($\chi^2(24) = 36.54$, scaling correction = 1.00, p = 0.049). Further comparison of the regression coefficients revealed that the cross-lagged path from leaping skill at Grade 6 to latent ST at Grade 7 differed significantly between the girls and the boys (boys: b = 0.268 vs. girls b: = -0.433; p = 0.012). There were no significant gender differences in the paths from latent MVPA at Grade 6 to leaping skill at Grade 7 (boys: b = -0.002 vs. girls b: = 0.140; p = 0.069) and from throwing-catching skills at Grade 6 to leaping skill at Grade 7 (boys: b = 0.012 vs. girls b: = 0.185; p = 0.085). For the boys, the model explained 68% of the variation in leaping skill score, 51% in throwing-catching combination skills, 32% in latent MVPA and 27%

in latent ST (at measurement point Grade 7). For the girls, the corresponding proportions were 64%, 43%, 39% and 52%, respectively.

FIGURE 1 HERE

4. Discussion

This study aimed to investigate cross-lagged associations among objectively measured MVPA, ST, leaping skill and throwing-catching skills during the school transition period from primary to lower secondary school. Results demonstrated three significant cross-lagged associations among girls: 1) leaping skill measured at Grade 6 was negatively associated with ST at Grade 7; 2) MVPA at Grade 6 associated positively with leaping skill at Grade 7; and 3) throwing-catching skills measured at Grade 6 associated positively with leaping skill measured at Grade 7. There were no statistically significant cross-lagged associations among study variables among boys. To our knowledge, this was the first attempt to investigate associations between MVPA, ST and FMS specifically over school transition period.

This study found that girls who engage in MVPA at the end of primary school achieve higher leaping skill scores one year after. This is an important finding because previous studies have revealed that locomotor skills mastery in the beginning of lower secondary school is related to PA in later adolescence and early adulthood[15,16] Leaping can be considered as an important FMS because many physical activities and sport events include different jumps, leaps and takeoffs.[13] It is likely that girls who develop adequate leaping skills during adolescence have greater confidence to participate in activities as adults that include a variety jumps and takeoffs (e.g., dance, volleyball). We did not assess the type of activities in which girls engage that can support their MVPA, but it is evident that MVPA promoting activities contributed positively to their leaping test result one year later. Girls' higher levels of MVPA seems to predict higher levels of leaping skill one year later. However, this finding supports the proposition of a reciprocal and synergistic relationship between FMS and PA.[14] Efforts to promote girls' MVPA may also benefit the development of their leaping skills.

Additionally, this study revealed a negative association between girls' leaping skill score collected at Grade 6 and ST measured at Grade 7, indicating that girls who master leaping are sedentary for less time one year later in comparison to their peers who have scored lower on leaping skill assessments. However, to our knowledge this was the first study showing the link between any of FMS and ST during adolescence within the girls' group. This is an important finding knowing that ST is increasing in adolescent cohorts[4,27] Research has also indicated that sedentary behavior tracks from childhood to adulthood[27] reinforcing that all efforts to reduce ST in childhood are warranted. It seems that the development of leaping skills may remain an important area of focus within girls' school physical education curriculum and extracurricular activities.

The developmental perspective on the role of motor skill competence in PA is a widely used motor development model that outlines how high motor skill competence and PA engagement have a dynamic and synergistic relationship throughout development.[14] More specifically, Stodden et al[14] proposed that younger children's motor skill competency is influenced by different levels of engagement in a variety of PA experiences. As children grow older the relationship between motor skill competency and PA changes whereby PA engagement becomes influenced by motor skill competency. Higher levels of motor skill competence should typically offer greater possibilities to engage in various physical activities, sports, and games in later childhood and adolescence. It is interesting that the data for the sample of girls demonstrated a positive path from MVPA to leaping skill at the age of 12-13, which can be considered late childhood. Stodden et al[14] suggested that by this age the association between these variables should have developed other way (FMS > PA). Our data reinforces that girls' engagement in MVPA contributes to the development of their leaping skill through until late childhood, and at the same time girls' leaping skill mastery limits their ST.

It was an interesting finding that significant associations among study variables appeared only for girls. Contrastingly, the analysis showed no statistically significant paths among PA, ST and leaping skill in boys group. Thomas and French[28] studied gender differences in development of motor performance and recognized that between 12 to 13 years

of age the boys typically show remarkable improvement in the performance of vertical jump, whereas girls' performance tends to remain the stable. It should be acknowledged that the two data collection points in our study were dated exactly whilst students were from 12 to 13 years of age. Vertical jumping and leaping are rather similar motor performances due to the high demand for explosive strength. Descriptive statistics of the current study demonstrated that the boys developed their leaping test score by 50 centimeters between two data collection points, whereas girls' improvement was only 10 centimeters. This improvement in boys may be related to physical growth and especially growth in height, which may have confounded associations among leaping test results, MVPA and ST. However, it should be acknowledged that we did not investigate gender differences in the development of MVPA, ST or FMS in this study.

It was interesting that neither the girls' nor the boys' throwing and catching skills demonstrated longitudinal associations with MVPA or ST, or vice versa. This finding is in contrast with findings of Barnett et al[18] findings that showed the object control skills of primary school children were more strongly associated with self-reported MVPA and organized PA 6-7 years later, than locomotor skills. It may be that Finnish girls' MVPA develops their leaping skills but not throwing and catching skills. In Finland, girls' favorite physical activities include dancing, aerobics and other rhythmic sports[29] which can be considered as activities that contribute to MVPA, and which include different jumps and takeoffs. Therefore, it is logical that girls' MVPA linked with leaping test score but not throwing-catching skills test score. However, this explanation does not reveal why boys' MVPA, leaping, throwing and catching skills did not associate with each other, or why ST, throwing and catching were not associated in any of gender groups. Another possible explanation for the non-significant associations among throwing and catching skills, ST, and MVPA, in this data may be connected to the students' growth spurt, which is typically most rapid between 12 and 14 years of age[30]. The chronological rapidity of the growth spurt may deteriorate adolescents' coordination and subsequent performance in tasks including high demands for accuracy such as throwing[30].

Therefore, it is possible that this effect confuses associations among MVPA, ST, throwing and catching skills.

This study also found significant but low positive association between throwing-catching combination test scores measured at Grade 6 and leaping test scores measured at Grade 7 for the girls. Girls who had better throwing and catching skills mastery during Grade 6 had higher results in the leaping test during Grade 7. This study cannot propose a causal reason for this association, therefore future studies are needed to further investigate relations among FMS over time. It may be that different FMS have a broad applicability to higher levels of functional coordination and control.[13]

The results of this study indicate that MVPA, ST, leaping skill score, throwing and catching skills scores measured at Grade 6 associated strongly with MVPA, ST and leaping skill scores, throwing and catching skills scores measured at Grade 7. These results are in line with results of previous suggestions[21,27] and demonstrate that the primary school years are an important period for adopting patterns of PA and ST, and FMS. Therefore, all contexts that contribute to children's' healthy PA patterns and developing FMS are considered crucial. These include, for example, quality physical education, physically active recess, active commuting to and from school and extracurricular activities.

Strengths of this study were the longitudinal design and the use of objective measurement to analyze MVPA and ST. A key limitation of this study is that the design only used assessment data for leaping, throwing and catching as a representation of the larger set of FMS. Another limitation of this study is that we only used product oriented measures to analyze FMS. However, it should be noted that process oriented measures are typically used within younger samples and smaller sample sizes.[13] Future studies should analyze associations among PA, ST and a wider range of FMS to determine if other FMS are related to PA and ST. Additionally, future studies could benefit from longer follow-up designs beyond the period of school transition. Lastly, it would be interesting to investigate relationships among type and duration of PA engagement and development of FMS.

5. Conclusion

Our findings demonstrate that girls' MVPA is positively, and ST negatively, associated with leaping skill score during the school transition period. The results of this study also indicate that MVPA, ST, leaping, throwing and catching skills are associated in children between Grade 6 and 7. Supporting girls' to engage in MVPA and leaping skill activities in primary school is strongly recommended. Future studies should analyze associations among MVPA, ST and wider range of FMS to determine if other FMS are related to MVPA and ST.

6. Practical implications

- Special attention should be directed towards facilitating adolescent girls' engagement in MVPA and physical activities involving jumps and takeoffs at primary schools.
- Physical education classes, school recess, extracurricular activities and commuting to and from school are possible contexts to contribute girls' MVPA.
- Dance, rhythmic sport activities and ball games are MVPA activities, which can develop a variety of jumps and takeoffs among girls.

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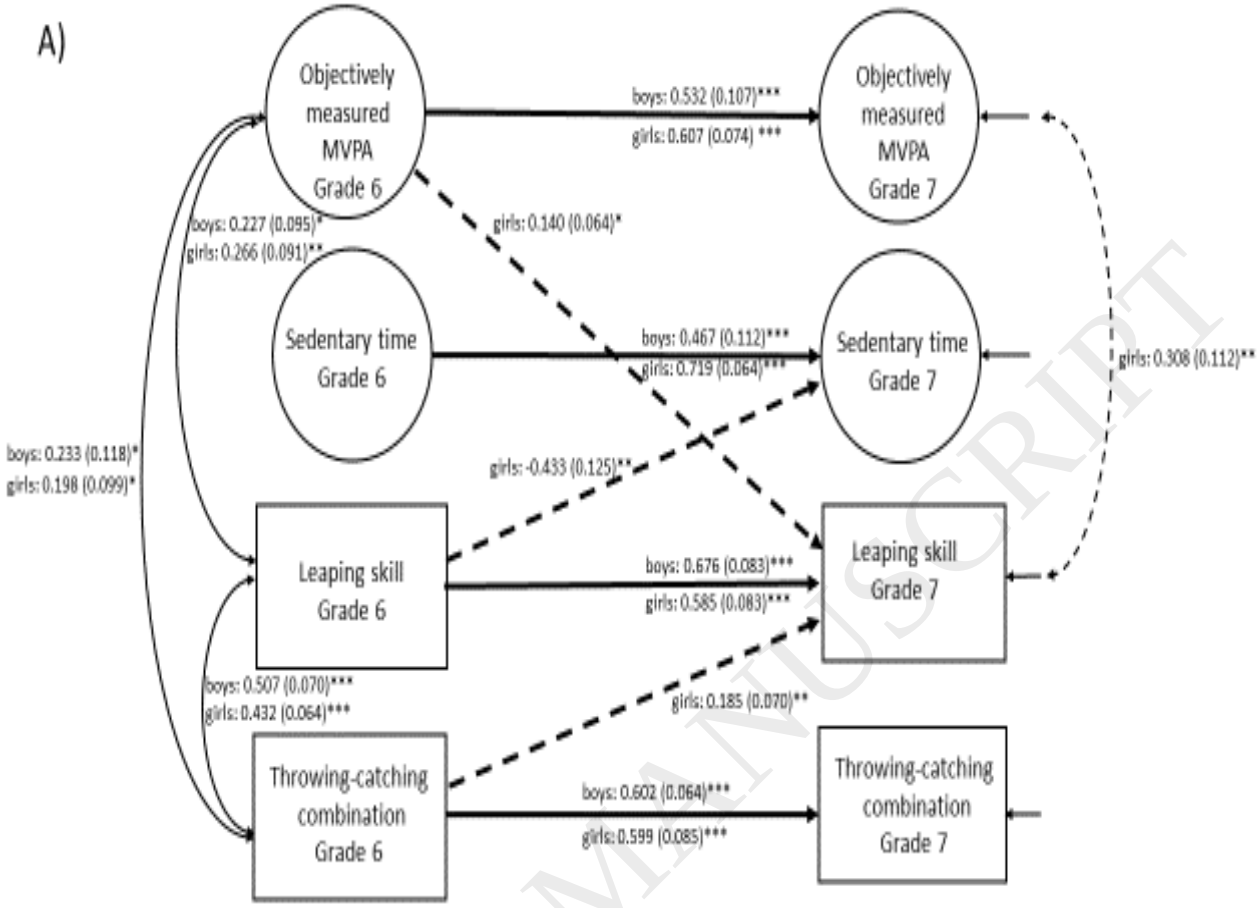

Figure 1. The estimation results of cross-lagged path model for leaping skill, throwing-catching skills, objectively measured moderate-to-vigorous physical activity (MVPA) and sedentary time (ST)(boys: n=153, girls: n=166). Standardized estimates (standard errors) of the significant associations are presented. The highly correlated objectively measured MVPA and sedentary time were entered in the model as latent variables created by using a Cholesky factoring of the predictors. The models were controlled for pubertal stage and body fat percentage.

Note. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 1. Descriptive statistics for the study variables.

	Boys (N= 163)		Girls (N=173)			
	n	Mean (SD)	n	Mean (Sd)	t-value	p-value [a]
Wearing time (Grade 6) (min/day)	98	768.5 (53.9)	128	767.5 (54.6)	0.1	0.885
Wearing time (Grade 7) (min/day)	51	774.3 (61.7)	74	767.4 (53.1)	0.7	0.502
MVPA time (Grade 6) (min/day)	98	61.7 (26.6)	128	47.5 (17.4)	4.9	<0.001
MVPA time (Grade 7) (min/day)	51	57.9 (26.4)	74	41.6 (18.5)	4.1	<0.001
Sedentary time (Grade 6) (%/day)	98	64.2 (6.9)	128	66.4 (5.7)	-2.5	0.010
Sedentary time (Grade 7) (%/day)	51	66.9 (7.1)	74	70.9 (6.1)	-3.3	<0.001
Throwing-catching skills (Grade 6) (reps.)	142	14.8 (4.7)	159	13.9 (4.6)	1.7	0.088
Throwing-catching skills (Grade 7) (reps.)	116	13.2 (4.6)	123	12.9 (4.5)	0.6	0.569
Leaping skill (Grade 6) (m)	136	8.5 (1.2)	159	8.2 (0.9)	2.7	0.008
Leaping skill (Grade 7) (m)	115	9.0 (1.2)	120	8.3 (0.9)	4.7	<0.001
Body fat percentage (%)	141	15.5 (8.5)	160	21.0 (6.9)	-6.1	<0.001
Pubertal stage (range 1-5)	142	2.7 (0.9)	159	2.7 (0.8)	0.0	0.966

MVPA, moderate-to-vigorous physical activity; PA, physical activity

Grade 6, measurement at 6th grade; Grade 7, measurement at

7th Grade

[a] p value for gender difference

Table 2. Correlation coefficients for the study variables among boys (upper triangle) and among girls (lower triangle).

	1	2	3	4	5	6	7	8
1 MVPA time (Grade 6)	--	0.577***	-0.782***	-0.376**	0.247*	0.302**	0.216*	0.182
2 MVPA time (Grade 7)	0.622***	--	-0.533**	-0.658**	0.230*	0.265**	0.248*	0.209
3 Sedentary time (Grade 6)	-0.604***	-0.379**	--	0.597**	-0.162	-0.146	-0.050	0.001
4 Sedentary time (Grade 7)	-0.480***	-0.694**	-0.673**	--	0.051	-0.089	0.060	0.058
5 Throwing-catching skills (Grade 6)	0.183	0.124	-0.142	-0.151	--	0.699***	0.511***	0.398***
6 Throwing-catching skills (Grade 7)	0.131	0.018	-0.059	-0.059	0.617***	--	0.484***	0.475***
7 Leaping skill (Grade 6)	0.240**	0.105	-0.056	-0.257*	0.437***	0.366***	--	0.812***
8 Leaping skill (Grade 7)	0.323**	0.256*	-0.208*	-0.364**	0.451***	0.437***	0.779***	--

*** p < 0.001, ** p < 0.01, *p < 0.05; Grade 6, measurement at 6th grade; Grade 7, measurement at 7th grade.