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Physical Activity Behavior of Children and Adolescents in Luxembourg - An Accelerometer-based Study

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Abstract Due to the continuous decrease of physical activity of children in industrialized countries physical activity behavior has become a key issue in health-related research. The purpose of this study was to assess objectively the daily physical activity of Luxembourgish children and adolescents and its distribution into school and leisure time. The physical activity behavior of 242 students (108 male students, 134 female students) with an average age of 12.84 years (*SD* = 2.37) was objectively assessed by wearing an accelerometer (ActiGraph GT3X-BT) for seven consecutive days. The average daily time spent in moderate to vigorous physical activity was 47.75 minutes (*SD* = 19.75). 62 students accumulated the recommended 60 minutes per day. 32% of students' total moderate to vigorous physical activity occurred during school time and 63% during leisure time. During physical education, students were engaged in moderate to vigorous physical activity on average for 20.02%, whereas 46.93% of the time was spent being sedentary. Significant gender differences were found for all variables in favor of male students. Equally, physical activity in all areas decreased significantly with age. The Luxembourgish children and adolescents are insufficient physically active and the moderate to vigorous physical activity levels are mainly accounted by leisure time. Therefore, it seems reasonable for schools to create an environment that supports the physical activity throughout the school day to increase the daily physical activity, with special attention to female and older students.

Keywords: *physical activity, children, adolescents, accelerometer, physical education*

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1. Introduction

Regular physical activity (PA) plays a vital role in the maintenance of the health of children and youth and is associated with increased physical fitness and vitality, increased self-confidence, and a reduced risk of obesity and related diseases [1,2]. In this regard, PA is an essential requirement for natural and healthy development with respect to both physical fitness and mental well-being [3]. Furthermore, patterns of PA in adulthood are often established during adolescence, making this stage of life a crucial period for promoting PA [4]. However, despite the obvious and extensive benefits of regular PA, the majority of children and youth in many countries show rather low levels of PA. In fact, studies have revealed a significant trend towards a widely sedentary lifestyle among children and adolescents [5,6,7,8]. Especially in Europe [9] as well as in the US [10], children's PA is continuously declining, whereas associated health problems are increasing. Frequently discussed reasons for this trend are various social developments such as living in large urban areas, the availability and use of electronic media, and the growing number of all-day schools.

According to the recommendations of the World Health Organization (WHO) for PA, children and adolescents should be moderately to vigorously physically active for at least 60 minutes per day [11]. However, the ongoing HBSC study sponsored by the WHO confirmed the generally low PA of children and adolescents and showed that only one third of male students and one quarter of female students fulfill the recommendation to be active for at least 60 minutes per day [12]. In addition, PA has been found to decrease with age; for example, 15-year-olds are significantly less active than 11-year-olds. Comparable with other countries, only 26.6% of male students and 14.6% of female students from Luxembourg meet the WHO guidelines [13]. Similar subjectively measured results were reported already a few years ago by Bös et al. [14], who examined the PA and health status of 1,200 Luxembourgish students at the ages of 9, 14, and 18 and found that only 35% of the male students and 18% of the female students were physically active for 60 minutes or longer per day. With these results, Luxembourg ranks in the bottom third compared with other European countries.

As PA and the amount of time children spend in moderate-to-vigorous PA (MVPA) decreases progressively with age, whereas the percentages of overweight and

obese students and time spent being sedentary increase from primary to secondary school [15,16], the promotion of PA in children and adolescents has been identified as an important task. In this respect, physical education (PE) by far is the most common and promising approach that can be applied during the school day [17]. In addition to everyday activities and club sports, PE contributes to the amount of MVPA per day and, possibly more important, plays a crucial role in promoting PA and teaching the movement skills, knowledge, and attitudes required for an active lifestyle [17]. Nevertheless, studies indicate that the recommendation by the U.S. Department of Health and Human Services [18] and the UK's Association for Physical Education [19] to spend at least 50% of PE time on the MVPA level is only met by 2.9% of male students and 1.8% of female students [20].

However, in the studies mentioned above and in many other studies, too, PA has been assessed subjectively via questionnaires, ignoring the fact that most people tend to overestimate their habitual PA [21]. In recent years, accelerometry has been recognized as the most accurate and reliable method for measuring both the amount and intensity of PA and the amount of sedentary behavior [22]. Therefore, the purpose of this study was to assess the daily PA of Luxembourgish children and adolescents objectively via accelerometer over seven consecutive days and thus to examine how many of them meet the PA guidelines of the WHO. Additional goals were to determine how much of the total amount of children's PA is composed of PA during school and PA during leisure time, to assess PA during regular PE lessons, and finally, to examine the extent to which gender and age predict these variables.

2. Methods

2.1. Participants

A total of 312 students between the ages of 10 and 18 years from four primary and five secondary schools in Luxembourg participated in the study. Schools were randomly selected from the different geographical regions of Luxembourg. Overall, 24 classes from different grades (nine classes from Grade 4 and five classes each from Grades 7, 5, and 3) participated in the study. A total of 242 students (108 male students [44.6%]; 134 female students [55.4%]) with an average age of 12.84 years (SD = 2.37) wore the accelerometer for at least four of the seven days for eight hours per day and thus were included in the analyses. Two students lost the device during the measurement period and were excluded. The study was conducted in accordance with the declaration of Helsinki and the European data protection directive and was approved by the Ethics Review Panel of the University of Luxembourg.

2.2. Apparatus

PA was measured objectively using the accelerometer ActiGraph wGT3X-BT (ActiGraph LLC, Pensacola, FL, USA), a small and easy-to-wear device that measures the acceleration of the body in different spatial dimensions. In recent years, the ActiGraph accelerometer was the most frequently used in research and has shown good validity and reliability in many studies [23].

2.3. Procedure

Before the start of this study, information sessions were held for the PE teachers from the participating classes. They were informed about the study's aims and procedure and were asked to give the PE lessons according to the curriculum and to make sure the children wore the accelerometer.

Each accelerometer was previously initialized at a 30 Hz frequency. Then the accelerometers were distributed by trained personnel to each individual participant during a school lesson. The participants received detailed information about the accelerometer and were instructed to wear it on the right hip for seven consecutive days while awake and to remove it only for water-based activities and while sleeping. Participants' height and weight were measured, and ambiguities were clarified. Additionally, the participants were given stickers to help them remember to wear the accelerometer every day. They were also given a protocol that explained how to record the times when they did not wear the accelerometer and their reasons, the time when they woke up, and the time when they went to sleep.

After one week - or more precisely, on day eight - the accelerometer and the other information they recorded were collected during a school lesson. Both the PE teachers and the students were asked to complete a brief questionnaire about the weather and their health status during the previous week, the exact date and time of the PE lessons and their contents, whether the students had participated normally, and whether the respective PE lesson was similar to their regular PE lessons. The amount of time spent in school was determined on the basis of timetables provided by the schools.

2.4. Data Processing and Analyses

Accelerometer data were downloaded, processed, and analyzed after the seven-day period using the software ActiLife v6.13.4 (Actigraph Inc, USA). Based on the cut-off points given by Evenson, Catellier, Gill, Ondrak, and McMurray [24], the total and daily time spent in MVPA and/or being sedentary were calculated. Time spent not wearing the accelerometer was identified by the algorithm by Choi, Liu, Matthews, and Buchowski [25].

The data were analyzed with SPSS Statistics (version 26). Means and standard deviations were calculated to describe the data. Unpaired t-tests were computed to analyze differences in PA between male and female students. The level of significance was set at $p < .05$. Linear regressions were computed in which gender and age were used to predict the percentages of students who were compliant with the PA guidelines of the WHO.

3. Results

3.1. Participants

Participants' age and anthropometric data are shown in Table 1.

Table 1. Anthropometric data

Sample	Age (years)		Height (cm)		Weight (kg)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Overall (N = 242)	12,84	2,37	159,03	12,79	53,62	17,95
Female students (n = 134)	13,28	2,40	160,28	10,67	55,96	17,22
Male students (n = 108)	12,30	2,24	157,47	14,94	50,71	18,48

M = Mean, SD = Standard Deviation.

3.2. Physical Activity and the WHO Guidelines

On average, students spent 5.95% of the total time they wore the accelerometer in MVPA, which corresponded to 307.59 (*SD* = 135.76) minutes. They spent 21.15% of the total time or 1096.31 minutes (*SD* = 336.10) in light activity and 72.90% or 3822.83 minutes (*SD* = 879.37) in sedentary activity. A regression analysis revealed that age predicted total MVPA (*ß* = -.265, *p* < .001) with the amount of MVPA decreasing with age (Table 2). Furthermore, the regression also revealed that gender was a significant predictor (*ß* = -.326, *p* < .001). Male students accrued significantly (*t*(240) = 6.76, *p* < .001) more MVPA minutes (*M* = 367.94; *SD* = 143.56 minutes) than female students (*M* = 258.95; *SD* = 107.12 minutes).

On average, the daily time spent in MVPA was 47.75 (*SD* = 19.75) minutes, which is below the WHO guideline of at least 60 minutes per day (Figure 1). Only 62 students (25.6%) accumulated the recommended amount of daily MVPA, namely, 17 (12.69%) female students and 45 (41.67%) male students. A significant gender difference was found (*t*(240) = 7.91, *p* < .001) such that male students (*M* = 57.73, *SD* = 20.51 minutes) spent more time in MVPA per day than female students (*M* = 39.70, *SD* = 14.90 minutes). Furthermore, the regression revealed that age (*ß* = -.221, *p* < .001) significantly predicted the average MVPA per day. Thus, the amount of daily MVPA decreased significantly with age.

Table 2. Linear regression analyses with different dependent Variables and the predictors (Intercept) Gender and Age

Dependent Variable	Predictor	Unstandardised B	SE	Standardised Beta	t	p	R^2
Total MVPA							0.257
	Intercept	682.483	44.434		15.360	< .001	
	Gender	-91.190	15.531	-0.335	-5.871	< .001	
	Age	-18.165	3.258	-0.318	-5.575	< .001	
Average daily MVPA							0.282
	Intercept	102.196	6.350		16.094	< .001	
	Gender	-15.737	2.220	-0.397	-7.090	< .001	
	Age	-2.336	0.466	-0.281	-5.018	< .001	
% MVPA in ST							0.231
	Intercept	10.972	0.794		13.821	< .001	
	Gender	-1.801	0.279	-0.395	-6.455	< .001	
	Age	-0.196	0.059	-0.204	-3.328	< .01	
% MVPA in LT							0.247
	Intercept	14.820	1.2034		13.17	< .001	
	Gender	-2.273	0.4026	-0.338	-5.65	< .001	
	Age	-0.294	0.0953	-0.207	-3.09	< .001	
Total MVPA in PE							0.57
	Intercept	22.139	3.797		5.830	< .001	
	Gender	-4.147	1.324	-0.230	-3.133	< .01	
	Age	0.188	0.277	0.029	0.397	.692	
% MVPA in PE							0.178
	Intercept	50.038	5.045		9.919	< .001	
	Gender	-6.634	1.759	-0.259	-3.772	< .001	
	Age	-1.502	0.368	-0.280	-4.086	< .001	

Note: Gender was recoded as 1 = male and 2 = female.

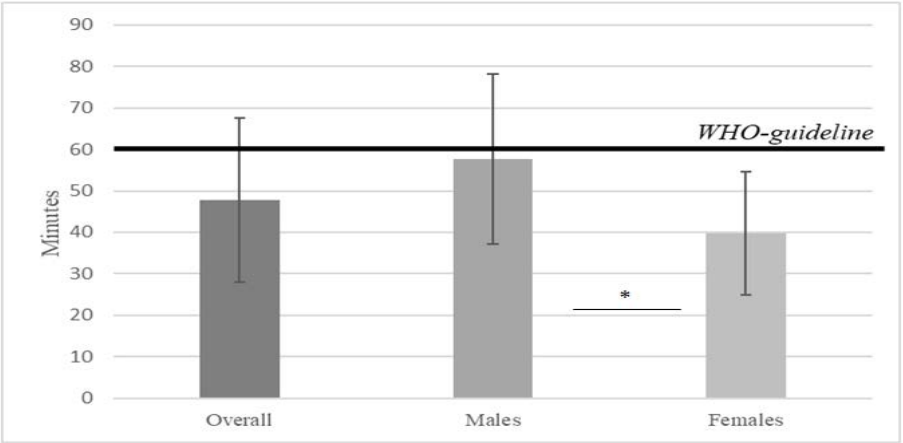

Figure 1. Average MVPA/day

Table 3. MVPA (total and percentage) spent in leisure time (LT), school time (ST), and physical education (PE)

Sample (LT&ST / PE)	LT (min/%)		ST (min/%)		PE (min/%)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Overall (N = 217/187)	190.66 min 5.99 %	110.31 min 3.36 %	98.37 min 5.70 %	40.31 min 2.27 %	14.21 min 20.02 %	8.95 min 12.74 %
Female students (n = 118/106)	151.50 min 4.74 %	82.61 min 2.39 %	83.90 min 4.79 %	35.66 min 1.82 %	12.36 min 16.45 %	7.78 min 10.60 %
Male students (n = 99/81)	237.34 min 7.48 %	120.95 min 10.04 %	115.62 min 6.79 %	38.86 min 2.29 %	16.62 min 24.67 %	9.83 min 13.81 %

M = Mean, SD = Standard Deviation
Note: The percentages refer to the total time spent in leisure time, school time, or physical education.

3.3. School and Leisure Time

Due to missing precise timetables of the participating students of one school, three classes were excluded for the following analyses. Thus, the analyses refer to a reduced sample of 217 students (99 male students [45.6%]; 118 female students [54.4%]).

When the total time was divided into school time and leisure time, 32% of students' total MVPA occurred during school time and 63% during leisure time. This corresponded to 5.70% (*M* = 98.37; *SD* = 40.31 minutes) of total school time and 5.99% (*M* = 190.66; *SD* = 110.31 minutes) of total leisure time (Table 3), whereas 73.99% of school time and 71.90% of leisure time were spent being sedentary. Regression analyses revealed that gender (*ß* = -.394, $p < .001$) and age (*ß* = -.191, $p < .01$) significantly predicted the percentages of MVPA that occurred during school time and during leisure time (Gender: *ß* = -.338, $p < .00$; Age: *ß* = -.207, $p < .001$). In school (6.79%) and during leisure time (7.48%), male students spent a significantly higher percentage of time in MVPA (school time: $t(215) = 7.13$, $p < .001$; leisure time: $t(215) = 6.56$, $p < .001$) than female students (school time: 4.80%; leisure time: 4.74%). The percentage of MVPA decreased as age increased in school and during leisure time.

3.4. Physical Education

Due to the additional requirement that at least one of the valid accelerometer days included a regular PE lesson (no swimming) and the student took part in this lesson, the following analyses refer to a reduced sample of 187 students (81 male students [43.3%]; 106 female students [56.7%]).

On average, PE classes lasted for 77.14 minutes (*SD* = 24.77; Range: 35 to 130 minutes). According to the timetable, 20 children and adolescents had PE twice a week and showed valid data in both units. The remaining 167 children and adolescents participated in PE once or showed valid data in only one unit. During PE, students were engaged in MVPA on average for 20.02% of the time (*MW* = 14.21; *SD* = 8.95 minutes), whereas 46.93% (*MW* = 38.46; *SD* = 21.64 minutes) of the time was spent being sedentary. According to regression analyses, gender significantly predicted the total amount of MVPA minutes during PE (*ß* = -.230, $p < .01$). A significant difference was detected ($t(185) = 3.31$, $p < .01$), whereby male students (*MW* = 16.62; *SD* = 9.83 minutes) accrued more minutes in MVPA than female students (MW = 12.36; *SD* = 7.78 minutes). Age was not a significant predictor of the total number of MVPA minutes during PE. Regarding the percentage of MVPA during PE, regression analyses revealed that both gender (*ß* = -.259, $p < .001$) and age (*ß* = -.280, $p < .001$) were significant predictors, implying that male and female students differed in terms of percentage of MVPA during PE, and the older the children, the less PE time they spent in MVPA. The latter finding was specified by unpaired t-test ($t(185) = 4.62$, $p < .001$) with male students spending significantly more of their PE time (*MW* = 24.67; *SD* = 13.81%) in MVPA than female students (*MW* = 16.45; *SD* = 10.60%). Overall, the recommendation to spend at least 50% of PE in MVPA was fulfilled by 0.5% of the children and adolescents. No female students and only one male student achieved the 50% value of MVPA during PE.

4. Discussion

The purpose of this study was to provide an objective assessment of the daily PA of Luxembourgish children and adolescents and to determine the extent to which the PA recommendation of the WHO has been met. Most previous studies have measured PA only subjectively via questionnaires, and thus, it was important to collect objective data for the first time because it is known that subjective and objective data do not necessarily agree with each other [21]. According to previous investigations in Luxembourg [12,14], the PA of children and adolescents is not sufficient when compared with the recommendation. As we found that only 12.69% of the female students and 41.67% of the male students accumulated the recommended 60 minutes or more of MVPA per day, the previous results of Bös et al. [14] and the HBSC study [12] were essentially confirmed. With a total of only 25.6% of the participating children and adolescents meeting the recommendation, the situation in Luxembourg is worse than, for example, in Germany, where Kettner et al. [26] found that 48% of the children are meeting the guideline. The results of this study are slightly better than the reported data by Guthold et al. [13], where 20.8% of the Luxemburgish children and adolescents are sufficient active. However, these results are based on subjective data.

Across Europe, only 20% of children and adolescents achieve the recommended 60 minutes of MVPA per day [27]. Thus, the results of this study are even slightly better than the European average.

In this study, the average method was used to analyze the MVPA per day. Janssen and LeBlanc [28] pointed out that to maintain good health, at least 60 minutes of MVPA every day might not be required, and therefore, they suggested

that an average would be appropriate for calculating the prevalence of children meeting the PA guidelines.

Another aim of the study was to determine how much of children's total PA time was composed of PA during school and leisure time. According to our data, the MVPA levels of children and adolescents in Luxembourg are mainly accounted by leisure time activities, a finding that is in accordance with other studies [29]. It has to be taken into account that school time also includes breaks and lunchtime. Because of different lengths of break times even within one school, no differentiation was made in this study. Likewise, the ways in which children commuted to and from school were not included in the school time, which could be discussed further because previous studies have also suggested that engaging in active methods of transportation contribute to overall PA [30].

Another aim was to observe the amount of time children spent engaged in PA and the level of PA in PE classes and determine whether the corresponding 50% recommendation was met. Overall, the students participating in this study spent 20.02% of a regular PE class in MVPA. Only one student was found to meet the guideline. This result is similar to other studies, but this represents an even lower proportion than found, for example, by Mooses et al. [31], who computed a little less than 34% of MVPA time during PE. It should be considered that the PA during PE also depends on the curriculum and not every content (e.g., Yoga and TRX) could be measured well by the accelerometer. However, during the survey only a few classes performed corresponding activities in PE and in most PE classes, common and easily measurable sports such as ball games, running, etc. were carried out. The potential of schools and PE classes to provide (and promote) regular PA has apparently not been fully exploited yet but indicates that more attention should be paid to the content and the quality of PE lessons to achieve the recommended 50% of MVPA per lesson [19].

Finally, the impact of gender and age on all measured variables was also examined. For all variables, the female students accrued significant less PA than the male students. Overall, 12.69% of the female and 41.67% of the male students achieved the 60-minute daily PA guideline, which is a clearer gender gap compared with the HBSC study (21% of the female students and 34% of the male students) and with global results (15.3% of the female students and 22.4% of the male students), but the fact that girls are less active than boys is consistent with previous findings [13].

The daily amount of MVPA decreased with age, and the amount of MVPA accrued during school and leisure time decreased just like it did in PE. These results confirm the tendency from previous studies that both daily and in-school PA levels decrease with age [32].

A limitation of the study is that some sports (e.g., swimming) were not included in the analyses because children could not wear the accelerometer during this kind of exercise. Furthermore, although ActiGraph accelerometers are demonstrably suitable for validly measuring the PA of children [33], there are some activities that are not well-detected (e.g., cycling), and thus, the children's actual PA levels could be underestimated. Another aspect to be considered is that although the schools were chosen randomly, organizational aspects and the volunteer of the PE teachers were decisive in the selection of classes. Nevertheless, the classes were well distributed to represent the Luxembourgish students and in addition, the entire classes were measured, not individually selected sportive or non-sportive students.

5. Conclusion

With this first objective assessment of PA, we detected that most of the children and adolescents in Luxembourg do not meet the WHO recommendations for PA; more precisely, only one quarter of them are physically active for at least 60 minutes per day. Because most of the PA takes place during leisure time, there is even less PA in school. Therefore, schools should put more effort into creating an environment that supports and facilitates the PA of children throughout the school day to increase their daily MVPA. Since there have already been projects to increase the PA in Luxembourgish schools (Clever move and Active Learning in Luxemburg), it would be conceivable to conduct further studies which complement these programs by measuring objective PA.

Furthermore, a more detailed analysis of students' after-school time, including any participation in organized sports, should be conducted.

Considering the gender differences found not only in this study, it seems reasonable to also develop PA programs that particularly refer to the needs and goals of girls. Given that there are age effects in all areas, meaning that older students are less active than younger students, it would also make sense to develop specific programs for older students to increase their MVPA levels too.

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Declaration of interest statement

No potential conflict of interest was reported by the authors.

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