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OBJECTIVELY MEASURED PHYSICAL ACTIVITY IN CHILDREN AGED FROM 5 TO 8 YEARS

OBJEKTIVNO IZMERJENA GIBALNA AKTIVNOST OD PET- DO OSEMLETNIH OTROK

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Abstract

Objective: *Today, a majority of the world population is dealing with physical inactivity and related health problems. Moreover, while various interventions are being adopted to increase children's physical activity, these are mostly less- or even un-successful. One of the possible reasons for this could be the wrong timing for their instalment. Therefore, the purpose of our study is to analyse between-day and within-day physical activity in 5- to 8-year old children.*
Methods: *Using accelerometers we monitored 97 Slovenian children (49 males) for five consecutive days.*
Results: *We found that 5- to 8- year old Slovenian children are physically active on average between 689 and 795 counts per minute, with age and gender significant factors, however both with low effect size. The average data was in line with the trends of the world's population. Time spent in moderate-to-vigorous physical activity was never measured in 5- to 8- year old children and we found it to be significantly longer than in slightly older children. Furthermore, we have defined the time periods with the lowest physical activity, which is in the morning, after the breakfast. Additionally, there are some age differences, with 5-year olds being most active before lunch but less physically active in the early afternoon.*
Conclusions: *In conclusion we have to emphasize and implicate to next generation studies to indicate time periods with the lowest physical activity and to promote physical activity interventions in those periods to achieve the greatest impact.*

Key words: physical activity, health, intervention, sedentary life style

Izvirni znanstveni članek
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Izvleček

Namen: *Gibalna neaktivnost in z njo povezane zdravstvene težave so problem današnjega modernega sveta. Veliko je bilo poskusov, da bi z intervencijami dosegli povečanje gibalne aktivnosti otrok, vendar so bili ti večinoma manj uspešni ali celo neuspešni. Eden izmed glavnih razlogov za to je verjetno v neučinkovitem časovnem dizajnu intervencije. Zato smo si za cilj postavili analizo meddnevne in znotrajdnevne gibalne aktivnosti od pet do osem let starih otrok.*
Metode: *Z merilnikom pospeška smo izmerili gibalno aktivnost 97 slovenskih otrok (49 dečkov) v petih zaporednih dneh med tednom in ob koncu tedna.*
Rezultati: *Ugotovili smo, da je povprečna gibalna aktivnost od pet do osem let starih slovenskih otrok med 689 in 795 sunkov na minuto, pri čemer sta starost in spol značilna faktorja, vendar z nizko stopnjo učinka. Ta ugotovitev sovpada s trendom drugih držav. Vendar čas, ki ga otroci preživijo v srednji in visoki gibalni aktivnosti, do danes za to starost še ni bil izmerjen in smo ugotovili, da je bistveno daljši kot pri nekoliko starejših otrocih. Analiza variabilnosti gibalne aktivnosti je pokazala, da imajo otroci najnižjo gibalno aktivnost po obrokih (zajtrk in kosilo). Ugotovili smo tudi razlike glede na starost, pri čemer imajo petletni otroci najvišjo gibalno aktivnost pred kosilom, a najnižjo v zgodnjem popoldnevu.*

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Zaključek: V zaključku lahko poudarimo in priporočamo pomen tovrstnih študij pri dimenzioniranju prihodnjih intervencij za dvig gibalne aktivnosti otrok za kar najboljši učinek.

Ključne besede: gibalna aktivnost, zdravje, intervencija, sedeči življenjski slog

1 INTRODUCTION

Appropriate and regular physical activity enables the morphological and motor development of children, as it prevents an overweight body mass and obesity and promotes muscle development (1). To further stress the importance of adequate physical activity, the relevant literature emphasises that children's physical activity is solely statistically important for the regulation of body fat (2-5). There is limited evidence that physical activity in childhood is directly related to health status in adulthood, however there is plenty of proof that childhood physical activity is (negatively) related to childhood obesity (6, 7), hypertension, insulin resistance and diabetes type 2 (8), and metabolic syndrome (9).

Today, researches aim to evaluate efficient interventions to increase the quantity and intensity of children's physical activity as the results of many studies confirm that a large number of children have had a low quantity and intensity of physical activity in the last ten years (10) and that quantity and intensity largely decrease by age (11, 12) and the majority of children do not achieve the suggested daily recommendations for physical activity (13).

Until 2007, a total of 3045 physical activity intervention studies have been reported. Less than 2% of them met the criteria for scientific excellence (14). Furthermore, published intervention studies rarely evaluated their success in follow-ups. Most of them mainly just examine the prevention of obesity as the outcome measure (15-18). These studies mainly include the adult population (19-21) and evaluate the effects of intervention programmes in children and adolescents together rather than separately (22-24); they are methodologically less qualitative as well (22-26) and do not include a control group (22-25). The effectiveness of intervention studies is hard to evaluate due to the heterogeneity of the interventions, their settings, participants and outcome measures.

The systematic review of van Slujis et al. (14) examines the effectiveness of physical activity interventions in children and adolescents. Their literature search included 3045 intervention studies and identified 57 studies for further meta-analysis: 33 aimed at children and 24 at adolescents. Twenty four studies were of high methodological quality, including 13 studies in children. Interventions that were found to be effective achieved increases ranging from an additional 2.6 minutes to 283 minutes in weekly physical activity. Among children, limited evidence for a significant effect was found for interventions targeting children from low socioeconomic populations, and environmental interventions. Strong evidence was found that school-based interventions with the involvement of the family or community and multicomponent interventions can increase physical activity in adolescents. Their conclusion was that for adolescents, multicomponent interventions and interventions including both school and family or community involvements have the potential to make important differences to the levels of physical activity and should be promoted. However, a lack of high quality evaluation hampers the conclusions concerning effectiveness, especially among children.

Another aspect for achieving successful physical activity intervention setting is weekly and daily variations in physical activity. There have been significant variations documented within and between days (27-29). Therefore, we could suppose that the next generation interventions should aim at the most appropriate daily and weekly timing for their instalment. By this we mean time periods with a lack of habitual physical activity.

Therefore, the aim of our study was to measure the quantity and intensity of physical activity in 5- to 8- year old Slovenian children and to determine the age and gender statistical effect. Furthermore, we also aimed to compare Slovenian children with others from the world's population. And lastly, we identified the time variation of physical activity with an identification of the time periods where physical activity is lowest.

2 METHODS

2.1 Participants

This study was conducted along with the target-research project of the Slovenian Research Agency and the Slovenian Ministry of Education and Sport entitled "Children Amidst the Influences of Modern Lifestyle – the Motor Abilities, Physical Characteristics and Health Status of Slovene Children" and coordinated by the Institute of Kinesiology Research, Science and Research Centre of Koper, University of Primorska. The research included 97 kindergarten and school children (49 boys) aged from 5 to 8 years from three

Slovenian cities: Koper, Ljubljana and Maribor. From these regions, we included the eight biggest schools and six kindergartens in the study. Furthermore, we use a random selection of children from these schools and kindergartens. The children's age distribution and basic morphological data can be seen in Table 1. Children and parents were pre-informed of the protocol concerning wearing accelerometers and a written consent was obtained from parents. All procedures conformed to the 1964 Declaration of Helsinki.

2.2 Instruments

The quantity of physical activity was measured using Actigraph GT1M accelerometers (Actilife, USA). Every child was wearing an accelerometer for five consecutive days during the same week, namely three days during week days (from Wednesday to Friday) and both days during the weekend. The week was randomly selected during the May and June period. In the beginning we demonstrated how to fasten and unfasten the accelerometer. The children wore the accelerometer on the right hip all the time except when sleeping, swimming or taking a shower or bath.

2.3 Data Processing

The accelerometer was saving the average quantity of physical activity for every minute's interval. The unit used is '*counts per minute'* (cpm). For valid daily analyses, we took into account data collected from 8:00 to 20:00 (12 hours) on condition that the child wore the accelerometer for at least 9.6 hours a day (30). Valid final result was determined with at least two valid days during the week and at least one valid day during the weekend. Physical activity cut-off points for preschool children were determined by van Cauwenberghe et al (31) and Pate et al. (32), being 0 – 1488, 1489 – 2336, 2337 – 3520 and > 3521 for sedentary, light, moderate and vigorous physical activity, respectively.

A meta-analysis of the overall physical activity (Figure 1) consists of 57 foreign studies (found in PubMed, SpringerLink) that were combined with our results of Slovenian children. We only selected studies that measured the physical activity in children aged between 2 and 18 years, using the Actigraph GT1M accelerometer worn on the hip for at least 3 valid days with more than 6 hours of daily wearing time.

2.4 Statistics

All the data passed normality and homogeneity tests. The data is presented in average values and standard deviation. Data was analysed using Microsoft Excel (Microsoft Co., USA) and the SPSS statistic packet (SPSS Inc., USA). Two-way ANOVA was used for gender and age effect. Repeated ANOVA measurements for weekday and weekend day comparison. Linear regression lines were modelled for age and physical activity relationships in both genders. The statistical significance was set at $P < 0.05$.

3 RESULTS

From 120 children, 97 valid measurements were obtained and further analysed. See table 1, the description of the valid children sample. One child complained about a skin rash and itching beneath the elastic strap and therefore we excluded him after the second day of measurement. Three children decided not to wear the accelerometer after the first day and we excluded them. Furthermore, 19 measurements were excluded from analysis because due to missing data.

Table 1 presents the average morphological and physical activity data for all four age groups and both genders. Two-way ANOVA confirmed the age and gender to be significant factors of overall (P_{AGE} = 0.047; P_{GENDER} = 0.036), sedentary (P_{AGE} = 0.044; P_{GENDER} = 0.018), light (P_{AGE} = 0.004; P_{GENDER} = 0.013) physical activity. However, gender only significantly affects moderate (P_{GENDER} = 0.004) and moderate to vigorous (P_{AGE} = 0.049) physical activity. While age only significantly affect vigorous (P_{AGE} = 0.012) physical activity. More or less 21% to 67% of all the children achieve more than the 60 minutes of moderate to vigorous physical activity recommended for a healthy lifestyle.

In Figure 1 we presented an overview of the children's overall physical activity from fifty-seven selected studies from all over the world in combination with our data. We modelled a linear declining trend for boys and girls from the age of three to eighteen years. The decline in overall physical activity at the age of 18 is 45% for boys and girls. We could conclude that our data is in trend with the model and that there is wide variability between studies.

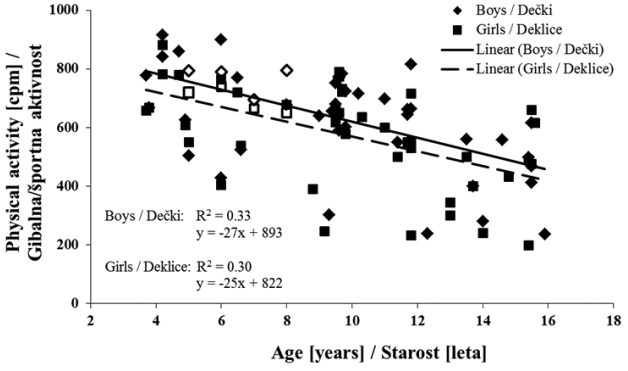
Table 1. Physical characteristics and main physical activity variables.
Tabela 1. Morfološke in glavne značilnosti gibalne/športne aktivnosti otrok.

	Boys / Dečki				**Girls / Deklice**			
	5 years / let	**6 years / let**	**7 years / let**	**8 years / let**	**5 years / let**	**6 years / let**	**7 years / let**	**8 years / let**
N	14	11	10	14	11	11	14	12
Body height / Telesna višina [cm]	117±8	126±5	132±4	137±6	118±5	126±5	131±6	136±6
Body mass / Telesna masa [kg]	22.4±4.3	26.2±6.0	30.8±5.3	33.7±4.1	23.9±4.8	25.9±5.1	29.2±5.7	32.1±5.5
Body mass index / Indeks telesne mase [kg/m^2]	15.8±1.9	16.8±2.9	17.2±2.3	17.9±2.6	16.0±2.0	16.4±2.6	16.9±2.5	17.4±2.6
Fat mass / Maščobna masa [%]	17.4±2.6	18.8±4.4	22.1±5.5	21.1±5.9	19.2±3.4	19.0±5.1	21.0±5.9	22.5±6.1
Overall PA [counts/min] / Celokupna G/ŠA [sunkov/min] [G, A]	794±163	784±181	689±113	795±150	720±157	740±169	673±119	669±168
Sedentary PA [min/day] / Gibalna neaktivnost [min/dan] [G, A]	583±42	586±38	608±13	579±34	606±39	601±39	615±25	608±80
Light PA [min/day] / Lahka G/ŠA [min/dan] [G, A]	78±21	65±13	59±5 [#]	64±11 [#]	65±18	60±15	57±11	53±11
Moderate PA [min/day] / Srednja G/ŠA [min/dan] [G]	44±18	46±16	38±7	51±17	35±16	36±16	32±11	37±13
Vigorous PA (min/day) / Visoka G/ŠA [min/dan] [A]	15±8	23±12 [#]	15±6	26±15	15±9	23±13	15±6	21±12
MVPA [min/day] / Srednja in visoka G/ŠA [min/dan] [G]	60±24	69±27	52±12	77±29	50±25	59±27	48±17	58±22
Children > 60min MVPA [%] / Otroci > 60min srednje in visoke G/ŠA [%]	50	67	30	61	27	36	21	58

Legends: N – Participants; PA – physical activity; MVPA – moderate to vigorous physical activity; [G] – significant gender effect at P < 0.05; [A] – significant age effect at P < 0.05; [#] – Statistically significant from age of 5 years at P < 0.05
Legenda: N – število preiskovancev; G/ŠA – gibalna/športna aktivnost; [G] – Značilen vpliv spola pri P < 0.05; [A] – Značilen vpliv starosti pri P < 0.05; [#] – Statistično značilno odstopanje od starosti 5 let pri P < 0.05

Figure 1. The age effect on overall physical activity (in counts per minute – cpm) estimated from 57 selected international studies (full trapeziums and squares) including our Slovenian study (empty trapeziums and squares).

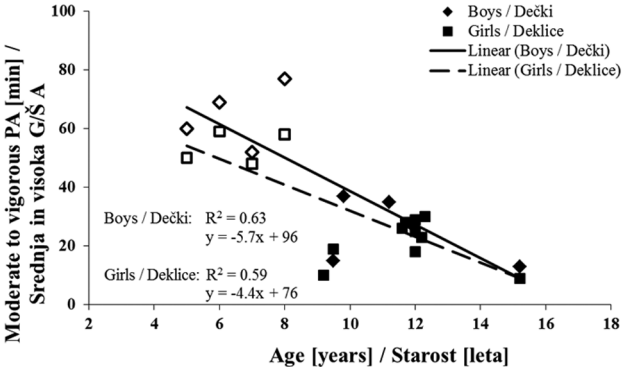
Slika 1. Učinek starosti in spola na gibalno/športno aktivnost (v sunkih na minuto) otrok. Podatki so pridobljeni iz 57 izbranih mednarodnih študij (polni trapezi in kvadrati), vključujoč našo (prazni trapezi in kvadrati).



In Figure 2 we present an overview of the children's time spent in moderate to vigorous physical activity from ten selected studies from all over the world in combination with our data. We modelled a linear declining trend for boys and girls aged from five to sixteen years. Our data fills the gap in the trend under the age of nine years. The decline in moderate to vigorous physical activity is higher in boys than in girls, though there is evidently a huge variability in the results. Furthermore, in the figure, we only presented studies that used the same accelerometer (Actigraph, USA) and had similar cut-of points as we used.

Figure 2. The age effect on time spent in moderate to vigorous physical activity (PA) estimated from 10 selected international studies (full trapeziums and squares) including our Slovenian study (empty trapeziums and squares).

Slika 2. Učinek starosti in spola na srednjo in visoko gibalno/športno aktivnost (G/ŠA) otrok. Podatki so pridobljeni iz 10 izbranih mednarodnih študij (polni trapezi in kvadrati), vključujoč našo (prazni trapezi in kvadrati).



In Table 2 we presented a comparison of the overall, sedentary and moderate to vigorous physical activity between an average weekday and weekend day. We could not confirm any differences and therefore we could conclude that there is no week/weekend day effect on physical activity in children.

Table 2. Comparison of the overall physical activity (in counts per minute – cpm), the time of sedentary physical activity and the time of moderate to vigorous physical activity during an average weekday and weekend day.

Tabela 2. Primerjava celokupne gibalna/športna aktivnost (G/ŠA, v sunkih na minuto), čas, preživet v gibalni neaktivnosti ter čas, preživet v srednji in visoki G/ŠA, med povprečnim dnevom v tednu in vikendu.

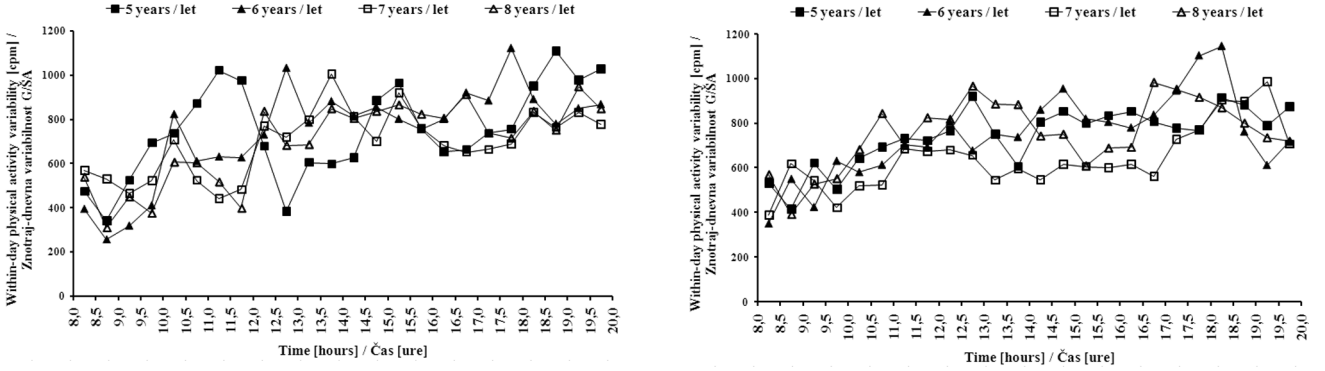
	Weekday / Med tednom	**Weekend day / Med vikendom**	**P**
Overall physical activity [cpm] / Celokupna G/ŠA [sunkov/min]	725±139	743±244	0.499
5 years / let	757±156	771±235	0.735
6 years / let	759±156	761±232	0.962
7 years / let	697±107	658±135	0.205
8 years / let	695±135	784±331	0.189
Sedentary physical activity [min/day] / Neaktivnost [min/dan]	599±32	598±56	0.959
5 years / let	593±40	591±59	0.832
6 years / let	591±35	599±51	0.433
7 years/ let	606±24	621±30	0.052
8 years / let	602±28	583±72	0.193
MVPA [min/day] / Srednja in visoka G/ŠA [min/dan]	59±22	58±40	0.746
5 years / let	56±23	53±33	0.654
6 years / let	65±26	61±36	0.537
7 years / let	53±18	44±20	0.064
8 years / let	62±20	73±59	0.353

Figure 3 displays the within-day physical activity variability. We can see that during the average weekday (Figure 3, upper graph), children have lower physical activity in the mornings (typically from 8:30 and 10:30 o'clock). Later on, school children face another decrease in physical activity, while preschool children have an increase in physical activity. However, after 12 o'clock (and before 15 o'clock) a significant drop in physical activity is evident in 5-year olds as well, probably due to lunch time and post lunch sleep. All children achieve the highest physical activity after school time.

During the average weekend day (Figure 3, lower graph), the lowest physical activity was observed in the morning hours, between 8 and 13 o'clock. A marked increase in physical activity could be observed in all children between 17 o'clock and 19 o'clock.

Figure 3. The within-day physical activity variability during an average weekday (upper graph) and an average weekend day (lower graph).

Slika 3. Znotraj-dnevna variabilnost gibalne/športne aktivnosti (G/ŠA) med povprečnim dnevom tedna (zgornji graf) in povprečnim dnevom vikenda (spodnji graf).



4 DISCUSSION

We have found that daily physical activity declines with the children's age (Figure 1), which is in line with the studies of others (12, 33, 34). Moreover, boys and girls spent more time in sedentary physical activity and less in light physical activity (35). Interestingly, we found that children are involved in moderate to vigorous physical activity independently of their age, though in each age and gender group just 30% to 60% children are involved in moderate to vigorous physical activity for more than 60 minutes. Studies by Biddle et al. (10) and Roberts et al. (13) confirm our findings, saying that most children do not meet the minimal standards of moderate to vigorous physical activity.

The output of the accelerometer are counts of mechanical vibrations that are measured on the body. By Newton's law, acceleration must be initiated by muscle work (i.e. physical activity). To have more interpretable information on physical activity, we could calculate the physiological indexes as metabolic equivalent, oxygen consumption and energy consumption (36). A higher value of counts per minute equals a greater intensity of physical activity in the measured subject. Therefore, the cut-off points were set to distinguish between different intensities of physical activity. We have come across of several calibration studies that defined cut-off points (37-41). However, there are some discrepancies between their findings that could have a huge effect in the valid and reliable measurement of physical activity using an accelerometer. The physical inactivity cut-off point is set from [0, 99] cpm to [0, 799] cpm; light physical activity is set from [100, 999] cpm to [799, 3599] cpm; moderate physical activity is set from [1000, 4135] cpm to [3600, 8199] cpm; and vigorous physical activity is set from >4136 cpm to >8200 cpm. The cut-off points serves as estimators of the time spent in each physical activity intensity level. Even though this is a very important measure of physical activity, there is considerable variation allowed if different cut-off points are used. Furthermore, most of the calibration studies are measured in adults (38, 42), only few of them were performed using children (39). The decision on the appropriate cut-off point's usage is very important for our study and we made a detailed consideration on this issue. Physical activity cut-off points for school children were identified by many authors and in many accelerometers. The values are approximately the same as for pre-school children with high between study variability (43). The systematic review was recently

performed (44) and outlined further research on this field. Therefore, we used the same cut-off points as in pre-school children to allow direct comparison on the grounds of slight possible discrepancies in validity. Some authors found significant differences between week and weekend days (45, 28, 29). We have also presented the structure of overall, sedentary and moderate to vigorous physical activity durations on both an average weekday and weekend day. We found no significant differences and therefore we could conclude that there is no week/weekend day effect on physical activity in children (Table 2). In the study by Jackson et al. (45), they found similar results in 3- and 4- year old children. They confirmed low variability in physical activity between days. However, some other European studies (27-29), measured using heart rate monitors established that children aged between 6 and 11 years are physically more active during weekdays than during weekend days. There are some discrepancies between studies performed with accelerometers where Page (33) found that 10- and 11- year old children are more physically active during the weekend than during weekdays. Furthermore, Simons-Morton et al. (46) found that American children are more physically active after school and even more during the weekend. However, the main aim of our study was to establish within-day variability in physical activity during an average weekday and weekend day (Figure 3). The motivation of our work was to research time-dependent possibilities for intervention instalments. We defined daily periods when physical activity is at its lowest, which is when intervention could bring the biggest effect. During the average week day, the lowest physical activity of school children is in the morning hours, until 12.30 o'clock, while children are engaged in school settings. Similarly, though just until 10.30, physical activity is also lowest in preschool children, however with a marked increase in physical activity before lunch time followed by a significant decrease after it. The morning spike of physical activity in preschool children could be explained by play time between breakfast and lunch, which is in the daily schedule of almost every kindergarten. Interestingly, on the average weekend day, we did not find an increase in physical activity (Table 2). Furthermore, within-day analysis demonstrated the lowest physical activity was again in the morning hours, between 8 and 13 o'clock, systematically for all children. The highest physical activity was between 17 and 19 o'clock. The absolute values were similar to average week days, when children are engaged in school settings, which makes as think that a lot of seated and low intensity physical activities must also be performed during the weekend. We could conclude that during weekday and weekend day morning time (between 8:30 to 12:30 o'clock) is not the most appropriate time for intervention programmes. This is the time when some studies have already suggested interventions that could be installed: active transport to school, an active school break and an extra hour of physical education. Review of Faulkner et al. (47) included 13 studies and nine of them demonstrated that children who actively commute to school accumulate significantly more physical activity. Studies of active school breaks as an intervention programme found increased daily physical activity (48-50). Similar results are also found in other studies. However, there are discrepancies when extra hours of physical education could increase physical activity predominantly in boys (43) or predominantly in girls (51).

Our findings are of great importance in the objective assessment of physical activity in Slovenian children. The major limitation of the study is the sample size, which in our study could not be enlarged due to limited devices (20 pcs), 5-days of wearing time and the limited time children are available in the spring season period. However, future independent research will show any possible sampling error or bias that might blur the real results. Another limitation we can see is not assessing water-based physical activities as the accelerometers are not waterproof. In the future, additional research could be performed by manually assessing those periods. The same goes for the possibility accelerometers may underestimate certain physical activities (i.e. cycling, uphill walk/run, extra weight bearing activities, etc.). Therefore, future research should go in at least two directions. Firstly, in improving (or finding new) sensors for physical activity, even better at physical activity recognition from the acquired signals. Secondly, in developing a sensor for the assessment of physical inactivity (i.e. sitting), which could be applied very easily with high validity. But nevertheless our results are trustworthy and in accordance with others.

In conclusion, we must agree with several reported methodological difficulties when measuring physical activity (e.g. subjective factors, objective instrument validity and reliability – cut-off points, etc.). However, not only is more physical activity is important for our health, less physical activity is as well. However there are easier ways to determine physical inactivity (e.g. sitting time). We proposed that greatest effect on children's health and motor would be when periods of physical inactivity are directly substituted with physical activity periods. We believe that the promotion of

physical activity in the school setting is an excellent intervention programme. Therefore, the goal of every school should be to develop and promote an attractive physical environment for relaxing children. Furthermore, parents should be aware of the opportunities they have to increase the involvement of their children in suitable physical activity during the whole day.

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