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original article

Correlation between physical activity measured by accelerometry and BMI in adolescents

Prática de atividade física mensurada por acelerometria associada ao IMC em adolescentes

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Abstract – The aim of this study was to investigate the correlation between physical activity measured by accelerometry and excess weight in schoolchildren. Three hundred and ninety one school-age adolescents (10 to 18 years old) participated in the study. The cut-off points used to estimate time spent in physical activity were: moderate ≥3.0 METs and vigorous ≥6.0 METs. Student's t-test and Pearson product-moment correlation coefficient were used to verify statistical differences and correlations between physical activity and body mass index (BMI). Statistical significance was set at $p<0.05$. Male schoolchildren spent more time in moderate (96.1 ± 39.6 $min \cdot day^{-1}$) and vigorous (9.7 ± 8.8 $min \cdot day^{-1}$) physical activity than their female peers (moderate: 73.7 ± 37.7 $min \cdot day^{-1}$; vigorous: 6.1 ± 6.8 $min \cdot day^{-1}$). For both sexes, younger schoolchildren (10 to 14 years old) were more physically active than older ones (14 to 18 years old). Time spent in moderate-vigorous physical activity was inversely related to BMI. These findings suggest that regular physical activity (RPA) is related to body weight reduction in schoolchildren. Therefore, RPA can be used as an obesity prevention strategy in elementary school.

Key words: Excess weight; Lifestyle; Schoolchildren.

Resumo – *O objetivo do presente estudo foi investigar a associação da atividade física medida pelo acelerômetro com o excesso de peso corporal em escolares. Trezentos e noventa e um adolescentes em idade escolar (10 a 18 anos) participaram deste estudo. Os pontos de corte utilizados para determinar o tempo gasto em atividade física foram: moderada ≥ 3,0 METs e vigorosa ≥ 6,0 METs. Teste t de Student e coeficiente de correlação produto-momento de Pearson foram utilizados para verificar diferenças estatísticas e associações entre atividade física e IMC. A significância estatística foi fixada em p <0,05. Escolares do sexo masculino passaram mais tempo em atividade física moderada (96,1 ± 39,6 min/dia) e vigorosa (9,7 ± 8,8 min/dia) do que o sexo feminino (moderado: 73,7 ± 37,7 min/dia; vigorosa: 6,1 ± 6,8 min/dia). Para ambos os sexos, os escolares mais jovens (10 a <14 anos) foram mais ativos fisicamente do que os escolares mais velhos (14 a <18 anos). Tempo despendido em atividade física moderada e vigorosa foi inversamente relacionado ao IMC. Estes achados sugerem que a prática regular de atividade física está relacionada a redução do peso corporal em escolares. Por conseguinte, pode ser usado como uma estratégia de prevenção da obesidade na escola elementar.*

Palavras-chave: *Escolares; Estilo de vida; Excesso de peso*

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INTRODUCTION

The increasing prevalence of overweight and obesity among children and adolescents has been observed in many countries all around the world, becoming a serious public health problem. Excess weight is associated with several risk factors to non-transferable chronic degenerative diseases, including diabetes, hypertension and atherosclerosis[1].

In view of this, taking physical activity as a tool for obesity prevention and health promotion, the World Health Organization has recently launched Global Recommendations on Physical Activity for Health[2], which recommends that adults should engage in moderate-intensity physical activity for at least 150 minutes a week, equivalent to 30 minutes a day for five days a week. For children and adolescents the recommendation is that they should engage in moderate-vigorous physical activity for at least 60 minutes a day.

Nevertheless, what we have seen is a gradual increase in rates of sedentarism in several countries, including Brazil. Currently, available data suggest that 31% of the world's population do not meet the minimum recommended amount of physical activity[3].

Studies conducted among young individuals in disparate countries show a similar pattern: boys are more physically active than girls in all age groups and physical activity, particularly of vigorous intensity, declines significantly with advancing age in both sexes[4-6].

One of the difficulties in defining the exactly behavior of physical activity, in large part, is due to the difficulty in accurately measure levels of physical activity in the general population, since most studies have used reminders or self-administered physical activity diaries. These methods, although they are valid and widespread, present limitations on the individuals' ability to effectively recall the type, intensity, frequency and duration of physical activities[7]. Moreover, among younger individuals, another intervening factor has to be consider with respect to the use of subjective methods, because young people's habitual activities, most of the time, are done in the form of short-term intermittent activities, besides they have difficulty in perceiving intensity levels of physical activity[8]. In Brazil, due to the high cost and the time taken for data collection, there is no information available in the literature on levels of physical activity from objective measurements on representative samples of schoolchildren.

In view of these aspects, this study aimed to compare physical activity measured by accelerometry between both sexes and different age groups of schoolchildren aged between 10 and 18 years, as well as to analyze the correlation between physical activity and values of body mass index (BMI).

METHODOLOGICAL PROCEDURES

The probabilistic sample by conglomerates was composed of schoolchildren of both sexes, aged between 10 and 18 years, enrolled in public and private schools in the city of Jacarezinho, PR.

Jacarezinho is located in the northern region of the state of Paraná, known as "Mesoregion of Pioneer Northern Paraná", with average human development index (HDI) of 0.782, similar to those HDI observed in other mesoregions of Paraná, except the large Curitiba and the metropolitan region of Curitiba. According to the census conducted in 2010 by Instituto Brasileiro de Geografia e Estatística, the city of Jacarezinho has 38,580 inhabitants.

According to information provided by Núcleo Regional de Educação de Jacarezinho, PR, in the 2010 school year there were 5242 enrolled children from the 5th grade to 3rd grade of high school. In view of this, the sample size was calculated according to the following criteria: a) the total number of schoolchildren, b) confidence interval of 95%, c) sample error of 5%, and prevalence of 20%[9].

The minimum sample size calculated based on information from Secretaria Municipal de Educação and Núcleo Regional de Ensino was 235 schoolchildren. To estimate the design effect we used the value of 1.5 as a correction to the sample by conglomerates design[9]. In addition, we added another 5% of individuals to avoid problems due to loss of data and defect in the physical activity measuring equipment. The considered sample size was 370 schoolchildren. At the end of data collection, 391 adolescents had valid information and took part in this study.

Under the authorization of Núcleo Regional de Educação all the 18 schools were invited to participate of the study. Classrooms were randomly selected from the list containing the number of rooms from 5th to 8th grade and 1st to 3rd years of high school provided by each school, participating in evaluations always two classes of each grade, totaling 14 classes. Before evaluations, schoolchildren who agreed to participate in the study received a "term of free and informed consent", which was completed and signed by their parents or guardians, authorizing the use of their data. This study was approved by the Research with Humans Ethics Committee of Universidade Estadual de Maringá (UEM), Opinion Nº 668/2010, which is in accordance with the Declaration of Helsinki and the Resolution 196/96-CNS/MS.

Physical activity was objectively measured, using a Actigraph multiaxial accelerometer (GT3X; Pensacola, Florida, USA), designed to measure and record body accelerations in the vertical plane at a magnitude from 0.05 to 2.0G and a frequency of responses from 0.25 to 2.50 Hz. Accelerations in counts, which represent the amount and magnitude of accelerations, are filtered and counts are summed over a pre-determined time interval or epoch. Accelerometers were programmed to record data at 60-second (1 minute) epoch intervals. Participants were instructed to set the equipment in their hip, using an elastic band at the height of the anterior iliac spine, on the opposite side of the dominant arm for seven consecutive days. The accelerometer should be removed only for bathing (or other activities in a liquid environment) and to sleep.

After information was transferred to the computer, the first day of measurement was disregarded, since the specialized literature suggests a possible reactivity that may overestimate the habitual physical activity by approximately 3%[8]. Then, reduction of data was performed using Mahuffe 1903 software, in which null values of counts/min for 30 continuous minutes were excluded from the analysis, assuming that the device was not in use at this time.

Subjects who did not have at least 4 full days of data, i.e. ≥ 10 hours per day record, with at least a valid day on the weekend, were excluded from analyses[10]. The accelerometer has proven validity and reliability for measuring physical activity in adolescents during activities both in laboratory and outdoor[11-13].

Counts obtained in different activities were converted into metabolic equivalents (METs), using the equation developed and validated by Freedson et al.[14] for children and adolescents aged from 6 to 18 years: METs = 2.757 + (0.0015 x counts/min) – (0.08957 x age) – (0.000038 x counts/min x age). The cut-off points adopted for different physical activity intensity levels are shown in Table 1. These cut-off points have been used in previous studies conducted with samples of children and adolescents[4,14-16].

Table 1. Cut-off points in counts/min for different physical activity intensity levels.

Activity category	METs
Sedentary	< 1.5
Light	≥ 1.5 e < 3.0
Moderate	≥ 3.0 e < 6.0
Vigorous	≥ 6.0

For measuring the height of schoolchildren we used a WCS portable vertical stadiometer, scaled in 0.1 cm. During evaluation subjects were barefoot and posted in anatomical position on the base of the stadiometer, forming a right angle with the vertical edge of the device. Subjects' body mass should be distributed on both feet, and their head positioned in the Frankfurt plane. Arms freely loose along their trunk and palms facing their thighs. Subjects should keep their heels together, touching the vertical edge of the stadiometer. The device cursor was placed at the highest point of their head during inspiratory apnea at the time of the measuring[17].

For body mass assessment we used a Plena portable digital scale with a 100g resolution. During evaluation subjects were barefoot and wearing only light clothes, standing on the center of the scale platform and with their back to the scale, in anatomic position, and their body weight evenly distributed on both feet[17].

Body mass index (BMI) was calculated using the formula BMI = body mass / height^2, in order to determine schoolchildren's nutritional status according to BMI percentiles: normal weight (BMI <85th percentile); overweight (BMI ≥ 85th and < 95th percentile); obesity (BMI ≥ 95th percentile). Subjects were classified using reference tables developed according to sex and age group by the National Center for Health Statistics[18] for individuals aged from 2 to 20 years.

Data were tabulated and stored in a database developed on Access 2007. Data were analyzed using SPSS for Windows version 15.0, with a significance level set at p<0.05 for all analyses. We used descriptive statistics (mean and standard deviation) for sample characterization. Then, for comparing rates of physical activity between sexes and age groups we used the Student's t test for independent samples. To verify the normality of data we used the Kolmogorov-Smirnov test. Correlations between physical activity and BMI were determined using Pearson correlation coefficients.

RESULTS

Information about characteristics of the sample according to sex and age group are showed in Table 2. Boys were significantly taller and with lower BMI than girls in the group aged from 14 to 18 years.

Table 2. Participant's characteristics according to sex and age group.

			10 < 14 years n=211		14 < 18 years n=180		Total n=391	
	Sex	n	Mean	SD	Mean	SD	Mean	SD
Age (years)	Male	194	12.5	0.8	15.8*	1.4	13.3	1.7
	Female	197	12.3	0.9	15.6*	1.1	13.1	1.7
Height (cm)	Male	194	154.0	8.6	171.6*+	7.3	158.3	11.2
	Female	197	153.6	7.7	161.7*	6.0	155.8	8.1
Body Mass (kg)	Male	194	47.1	12.2	59.0*	9.2	50.0	12.6
	Female	197	47.7	11.6	58.6*	10.9	50.6	12.3
BMI (Kg/m^2)	Male	194	19.6	3.9	20.0	2.6	19.7	3.6
	Female	197	20.2	4.2	22.3*+	3.8	20.7	4.2

* Significant difference between age groups p<0.05; + Significant difference between sexes.

Data regarding the time spent in different physical activity intensity levels showed that boys are more physically active than girls with respect to the time spent in moderate-vigorous physical activity and counts/min in both age groups (Table 3). No significant differences were observed between sexes in daily time recorded (time per day using the accelerometer) and light-intensity physical activity.

Both sexes had significantly reduction in minutes/day engaged in physical activity of light, moderate and vigorous intensity, and in the mean of counts/min in the group aged from 14 to 18 years compared with the one aged from 10 to 14 years.

Regarding to physical activity, 30.3% of schoolchildren are not engaged in a 60 minutes/day moderate-vigorous physical activity (males: 17.6%, female: 38.2%) (data not shown). A higher occurrence of individuals who do not meet the recommended 60 minutes/day of MVPA was observed in the group aged from 14 to 18 years (73.5%) compared with the one aged from 10 to 14 years (18%).

Regarding to schoolchildren's nutritional status, 16.5% of them were overweight (male: 14.9%, female: 17.5%) and 9.3% were obese (males: 7%, female: 10.7%). When compared between age groups, among schoolchildren aged from 10 to 14 years, 15.7% and 10.2% were overweight and obese, respectively. Among schoolchildren aged from 14 to 18 years, 18.7% were overweight and 6.7% obese (data not shown).

Table 3. Physical activity according to sex and age group.

			10 < 14 years n=211		14 < 18 years n=180		Total n=391	
	Sex	n	Mean	SD	Mean	SD	Mean	SD
Time recorded (minutes/day)	Male	194	837.8	181.1	789.6	100.6	827.0	167.2
	Female	197	888.5	168.2	820.2	149.0	873.4	166.1
LPA (minutes/day)	Male	194	295.9	60.4	251.3*	86.2	285.9	69.0
	Female	197	291.9	56.8	247.4*	80.1	281.7	65.3
MPA (minutes/day)	Male	194	106.1	35.1	61.3*	35.3	96.1	39.6
	Female	197	82.0†	36.5	44.4*†	24.9	73.7†	37.7
VPA (minutes/day)	Male	194	11.2	9.3	4.6*	3.9	9.7	8.8
	Female	197	7.3†	7.3	1.9*†	2.8	6.1†	6.8
MVPA (minutes/ day)	Male	194	117.2	38.8	66.0*	38.1	105.8	44.0
	Female	197	89.3†	40.7	46.4*†	25.9	79.8†	41.8
Physical activity (counts/min)	Male	194	497.1	174.0	403.2*	157.4	476.15	174.0
	Female	197	388.6†	150.0	319.1*†	150.0	373.32†	152.2

* Significant difference between age groups $p<0.05$; † Significant difference between sexes. LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; MVPA: moderate-vigorous physical activity.

Correlation coefficients between physical activity intensity levels and BMI are showed in Table 4. We observed a significant inverse correlation between time spent in moderate-vigorous physical activity and BMI.

Table 4. Correlation coefficients between physical activity and body mass index.

		10 < 14 years n=211	14 < 18 years n=180	Total n=391
	Sex	R	R	R
LPA	Male	0.033	-0.185	-0.087
	Female	0.069	-0.115	-0.059
MPA	Male	-0.053	-0.226*	-0.164*
	Female	-0.024	0.066	-0.134
VPA	Male	-0.070	-0.190	-0.130
	Female	-0.165	-0.305*	-0.244*
MVPA	Male	-0.065	-0.229*	-0.174*
	Female	-0.050	-0.096	-0.160*

* $p<0.05$; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; MVPA: moderate-vigorous physical activity.

DISCUSSION

This is the first study in Brazil, with a school-based sample, that objectively assessed physical activity in schoolchildren. This study's findings go against previous evidences that boys are more physically active than girls and that physical activity is lower in older adolescents compared with their younger peers. So, even this sample being from of a specific region of Brazil, this study's findings regarding physical activity behavior proved to be consistent when compared with other studies' findings in several states and countries[4,19-21].

From 1986 to 2002 Samdal et al.[5] assessed secular trends in adolescents' physical activity behavior and showed that in all countries (Austria, Finland, Hungary, Norway, Scotland and Sweden) boys reported more time spent in moderate-vigorous activities than girls. Likewise, Hallal et al.[22] found a prevalence rate of sedentarism of 49% in males and 67% in females.

Kimm et al.[6] objectively measured physical activity in adolescents and reported a 21% reduction in the level of physical activity from 11 to 14 years old. Likewise, Narder et al.[4] longitudinally assessed physical activity by accelerometry in 1032 American adolescents, using as a criterion to determine physical activity intensity levels the same cut-off points used in this study (≥ 60 minutes/day of MVPA). After the monitoring, authors observed a significant linear reduction of time engaged in MVPA from 9 to 15 years old. This reduction was of 38 minutes/day, per year, on weekdays and 41minutes/day, per year, in weekends.

When authors analyzed the proportion of adolescents who met the recommended 60minutes/day of MVPA, they observed that at the age of 9 years old virtually all subjects met that recommendation. However, with the reduction of time spent in MVPA with advancing age in both sexes, girls with 13.1 and boys with 14.7 years old fail to meet the recommended physical activity levels[4]. These results are similar to our findings, in which the proportion of schoolchildren who meet the recommended 60 minutes/day of MVPA drops to approximately 25% in the group aged from 14 to 18 years.

The fact that males, from very young, are more physically active than females, still generates curiosity in the scientific community, since there is still no universally accepted biological plausibility to explain this phenomenon. Social factors seem to have an undoubted impact in this context, because boys, from very young, are encouraged by parents and teachers to practice sports, while girls are motivated to low-intensity activities or even sedentary ones.

Thus, in view of this reality, as scientific as empirical, physical education teachers should encourage their students to engage in regular physical activity as a means of promoting health. Another point of consensus among several studies[19-21] is that adolescents, with advancing age, regardless of gender, show a significant reduction in habitual physical activity. This fact is often due to the new skills and priorities that are envisioned with the arrival of adulthood, such as increasing the time devoted to studies preparing for the university admission test, as well as the entry into the labor market.

Regarding to correlations between time spent in different physical activity intensity levels and BMI values we observed significant inverse correlations between time engaged in moderate-vigorous physical activity and BMI. The same did not occur with light-intensity activities.

Silva et al.[23] assessed correlations between physical activity, BMI and sedentary behaviors in 5208 adolescents from the state of Santa Catarina and showed that the chance of having excess weight was 74% higher among low-active boys when compared with the active ones.

In a longitudinal study conducted by Moore et al.[24], children with a habitual high level of physical activity had consistently smaller gains in BMI. In another study conducted with adolescents from 34 countries, the chance of overweight decreased as physical activity increased (trend observed in 29 of the 34 countries) and excess weight was less prevalent when the time spent watching TV decreased[25]. Likewise, Hancox et al.[26] showed that the greater the number of hours watching TV, the higher the BMI of adolescents.

In contrast, the study conducted by Guedes et al.[19] showed that insufficient physical activity was not associated with excess weight assessed by BMI.

It is known that excess weight is a combined result of excessive food intake and low physical activity energy expenditure. Levin et al.[27] reported that adolescents with higher BMI are less engaged in physical activity than adolescents with lower BMI values. Thus, as adolescents with normal weight and low physical activity level may develop overweight, those who are already obese have more difficulty to engage in regular physical activity programs due to their excessive weight.

Disagreement among studies on correlations between physical activity and BMI is often due to the method used to assess physical activity, since most subjective methods do not provide accurate information about the time spent in different physical activity intensity levels. In this sense, what should be highlighted in the assessment of physical activity in young people is the importance of using specific cut-off points for each age to determine physical activity intensity levels, because it takes into account differences in energy savings and resting metabolic rate related to each age, which allows us to estimate accurately the young people participation in physical activity of light, moderate and vigorous intensity.

It should be mentioned, as a limiting factor of this study, that accelerometers are not accurate for measuring certain activities such as biking, activities in a liquid environment, weight training, which, in a way, may underestimate the habitual physical activity of young people. Furthermore, future studies in this area should examine how much is the optimal amount of physical activity for weight control in children and adolescents, since the cross-sectional design of the study does not guarantee the temporal precedence of variables and limits the extrapolation of findings.

CONCLUSION

Corroborating other reports in the literature, this study showed that boys are more physically active than girls. Moreover, in both sexes, younger subjects (10 to 14 years old) spend more time per day engaged in moderate-vigorous physical activity than their peers in the group aged from 14 to 18 years. Furthermore, results of this study reinforce previous evidence that moderate-vigorous physical activity is inversely related to excess weight in schoolchildren. Finally, prevention strategies should be developed to increase regular physical activity in the pediatric population, especially in female schoolchildren aged from 14 to 18 years, for individuals to maintain a physically active lifestyle for all life.

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