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Assessment of physical activity with a pedometer and its relationship with VO_2max among adolescents in Switzerland

Summary

Objectives: In the absence of a gold standard, the assessment of physical activity in children remains difficult. To record physical activity with a pedometer and to examine to what extent it is correlated with VO_2max.

Methods: Survey on physical activity and fitness; 233 Swiss adolescents aged 11 to 15 carried a pedometer (Pedoboy®) during seven consecutive days. VO_2max was estimated through an endurance shuttle run test.

Results: The physical activity recorded by the pedometer did not vary from one day to the other ($p > 0.05$). The physical activity was higher among boys than among girls ($p < 0.001$) and higher among younger adolescents (6^{th} versus 8^{th} grade; $p < 0.001$). The correlation between physical activity and estimated VO_2max was 0.30 ($p < 0.01$).

Conclusions: The use of a pedometer to assess physical activity over one entire week is feasible among adolescents. The record provided by the pedometer gives an objective measure of the usual physical activity and, as such, is relatively well correlated with aerobic capacity.

Keywords: Adolescents – Survey – Physical activity – Fitness – Pedometer endurance.

Over the last 20 years, there has been a growing interest in the measurement of physical as well as sports activity among adults and children, owing to the potential beneficial effect of regular physical activity and fitness on general and cardiovascular health (Berenson et al. 1998; Rowland & Freedson 1994; Baranovski et al. 1992; Perry et al. 1994; Sothern et al. 1999; Rowland 2001). Different authors have assessed the physical activity of children, both within descriptive epidemiological surveys and as an evaluation criterion of prevention programmes (Glenmark et al. 1994; Van Mechelen et al. 2000; Brownson et al. 2000; Tell & Velar 1988; Webber et al. 1996; Prochaska et al. 2001; Myers et al. 1996; Ferron et al. 1997). However, the assessment of physical activity – especially among children – is linked to conceptual problems (Trost 2001; Pate 1993; Kowalski et al. 1997; Welk et al. 2000; Sallis & Saelens 2000; Fox & Riddoch 2000): some authors focus on "habitual physical activity" or "daily physical activity", that is all the physical activities of the everyday life which induce energy expenditure, including sports and leisure activities. Others target more specifically the so-called "moderate-to-vigorous activity" (Shepherd et al. 1999; Blair & Conelly 1996), that is the activity of a level which induce an increase in energy expenditure (e.g., sweating, rapid heart rate or breath rate). The methods which have been used to assess these different dimensions of physical activity have varied accordingly:

- Several surveys rely on *self-reported* physical activity: self-administered questionnaires on usual sports and physical activities (Tell & Velar 1988; Kowalski et al. 1997), one-day or several-day recalls (Rowland 2001; Kowalski et al. 1997; Kimiecik et al. 1996; Simons-Morton et al. 1990; Sirard & Pate 2000). Questionnaires and recalls are subject to memory biases, and some authors propose to rely on diaries (Trost 2001; Fox & Riddoch 2000; Sallis et al. 1992) or face-to-face interviews (Brownson et al. 2000; Kowalski et al. 1997; Simons-Morton et al. 1990; Sallis et al. 1992). Moreover, most of these measures do not capture the intensity of physical activity.
- Other methods involve *objective measures* such as direct observation (Kimiecik et al. 1996; Sallis et al. 1996; Dishman et al. 1992) or more often heart rate monitoring (Welk

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et al. 2000; Sirard & Pate 2000; Freedson & Miller 2000) or actometers (Brownson et al. 2000; Kowalski et al. 1997; Fox & Riddoch 2000; Saris 1985; Blair & Conelly 1996; Sallis et al. 1992; Freedson & Miller 2000; Rowlands et al. 1997; Sallis et al. 1990; Sequeira et al. 1995; Bassett et al. 1996; Freedson 1991), which record body movements. These devices are worn on the wrist or the waist for several hours/days and record uni- or multidimensional movements of the body and, to a large extent, give a fair picture of the everyday total physical activity. The more complicated the device, the less robust, the more expensive, the less usable it becomes on a large scale, especially among children, who may be less compliant or more careless than adults. With one exception (Blair & Conelly 1996), pedometers have usually been used among small samples or for short periods of time among children and adolescents (Brownson et al. 2000; Sallis et al. 1992; Rowlands et al. 1997).

As part of a larger survey on physical activity and fitness of adolescents nine to 19 years in the western part of Switzerland, we conducted an in-depth survey among a subsample of youngsters 11 to 15 years, including different measures of physical activity and fitness. The objectives were:

- To test the feasibility of using a pedometer among a relatively large sample of young adolescents over a sustained period of time, i.e., an entire week.
- To compare the physical activity by gender and age, and to examine its variability over one week.
- To measure the correlation between the physical activity as assessed by the pedometer and an estimation of cardiovascular endurance (VO_2max).

Material and methods

Sample and design

The survey on physical fitness and sports activity of children and adolescents was conducted from September 1996 to March 1997 in the schools of the canton of Vaud. A two-step cluster sampling procedure was used to select classes from the 4th, 6th, 8th, 10th and 11th grades (nine to 19-year-old pupils) Sampling stratification was performed by region and school curriculum: schools were selected in groups of schools classified in three types of region, based on the geographic density of the population. The same number of classes were selected from a unique group of 4th grade, from the three main curricula in the 6th and in the 8th grades and from high schools and vocational schools separately, in the 10th and in the 11th grades.

A subgroup of adolescent boys and girls from grade 6 and 8 were randomly[1] selected from the total sample to participate for a whole week in the present study (n = 233). The use of a seven-day period (used by other authors (Trost 2001; Blair & Connelly 1996; Sirard & Pate 2000; Sallis et al. 1996; Sallis et al. 1990)) enabled to address the whole range of habitual activities participants engage in, including weekdays and the weekend. After receiving detailed information about the aims and the design of the study, all the adolescents and their parents gave written consent. Those who refused participation (33%) were replaced by other pupils next on the list until the target size of around 250 individuals was attained.

Participants were divided into eight groups of 30 subjects. On the first day of the study, each group received a detailed description of the objective of the study and of the way the pedometer had to be carried during the following seven days. The groups were convened over the whole range of weekdays (Monday through Friday) in a special quiet location within the school, at the beginning of the day. During the course of the seven-day period, each subject was contacted by telephone by one of the investigators (M.C.), usually on day three, in order to address queries and to improve the compliance with the use of the pedometer. On the last day of the seven-day recording period, subjects were met again early in the morning: the number of counts recorded by the pedometer (and reported each day by the subject on a sheet) were checked and registered.

The same day, the subjects took part in the larger survey with the rest of their classmates (whole school sample). They answered a self-administered questionnaire including items related to sports and physical activities, lifestyles and sociodemographic characteristics. The reported amount of daily moderate to vigorous physical activity was assessed in one question.[2] The reported amount of sports activity was assessed through a retrospective dairy assessing the number of sports practiced each day over one week: participants had to quote, within a list of 38 sports, the ones they had engaged in every day. Given the age of the respondents, there was no attempt at quantifying the amount of time devoted to each sport each day. The global amount of sports activity was computed over the entire week (number of sports × number of days they were practised).

[1] Randomly: every four individuals on the list of pupils within the involved classes.

[2] If you think of a normal day, outside the time you spend within your school, how much time do you spend in activities which make you sweat and make your heart beat quickly? a) three hours or more; b) about two hours; c) about an hour; d) about 30 minutes; e) less than 30 minutes.

The same day, within a special 45 mn. duration fitness test session, they performed an endurance shuttle run test, designed by Léger and Lambert (1982), which allows to assess aerobic capacity: pupils are requested to run between two borders at progressively increasing paces (which correspond to the various levels of maximum aerobic speed) and to quit when they are exhausted. The results are first expressed by the level of stage attained; then, VO_2max is estimated, using the mathematical formula given by the author (Léger 1985). The correlation between the results of the shuttle run test and VO_2max assessed by ergometric methods among children varies between 0.8 to 0.9 (Léger 1985). The planning and the progress of the tests were carefully supervised by specially trained monitors. After the test session, anthropometric measurements were performed by two trained nurses (the same during the whole survey): Weight was measured with a beam balance to the nearest 0.1 kg, the pupils being lightly dressed (training/t-shirts); height was measured with a Harpenden® portable stadiometer, at ± 0.1 cm. The protocol was reviewed by the Ethics Committee of the University of Lausanne Medical School.

Measurement of physical activity

In the present study, a small, resistant and inexpensive instrument, a Pedoboy® (Barrigo GmbH, Schwenningen, Germany) was used. This mechanic device records the vertical acceleration produced by the body's centre of gravitation; its characteristics have been described in detail in an earlier publication (Sallis et al. 1990). All the subjects were advised to keep wearing their Pedoboy® on their waist all day long, especially during periods of physical activity, and to remove it *only* during some sports such as judo or swimming, which can damage the instrument. The device was sealed with tape to avoid any manipulations. It features a dial which shows the amount of movements (of "steps") in kilometres (km). The cumulative value displayed by the dial was recorded each day by the subject and reported on a diary, at bedtime. Like for the use of other actometers (Saris 1985; Freedson & Miller 2000; Narring et al. 1999), the Pedoboy® expresses its results in km instead of a count of the movements: each motion is converted into a step and then fixed numbers of steps are converted into km (Saris 1985; Freedson & Miller 2000). To allow for valid inter-individual comparisons, correction factors were calculated for each instrument in comparison to one standard instrument which had been submitted to a standard number of 10 000 vertical movements (Freedson & Miller 2000; Rowlands et al. 1997; Sallis et al. 1990).

Data analyses

Differences between subgroups (by sex and by age) were calculated using either Student t-test or one way covariance ANOVA procedures. Correlation between physical activity as assessed by the pedometer and estimated VO_2max were estimated using Pearson's correlation coefficients. All the tests were performed by the SPSS programme.

Results

A total of 340 children and parents were contacted, a third of which refused to take part in the study. Among the 248 adolescents included in the study, 15 (6%) could not be included in the analyses: One pedometer was lost, two records were unusable and twelve younger pupils – all aged twelve or under – were not able to adequately fill in their diary (reporting the results of the pedometer as well as their physical activities). As shown in Table 1, the results are based on a sample of 119 girls and 114 boys (grade 6: 50 girls and 51 boys; grade 8: 66 girls and 56 boys). For all 233 subjects we obtained the detailed results of the pedometer as well as the data on the fitness tests. There were no statistical differences between boys and girls, with the exception of estimated VO_2max, which is higher among boys than among girls.

We first tested whether there was a „novelty effect" in using the pedometer (pupils shaking their pedometer to boost their scores, in assessing potential differences in km between the records of the first, the following and the last day).

Table 1 Main demographic, anthropometric and endurance characteristics of the sample (means and standard deviations)

	Girls (n = 119)		Boys (n = 114)		p values**
	Values	Standard deviation	Values	Standard deviation	
Age (years)	13.0	1.2	12.9	1.3	0.95
Weight (kg)	48.8	9.9	49.1	13.1	0.98
Height (cm)	158.1	8.4	158.7	11.7	0.72
Body mass index (kg/m²)	19.4	2.9	19.2	3.7	0.96
VO_2max (ml/kg · min)*	43.5	4.4	48.4	4.9	0.01

* As derived from the Léger test (Léger & Lambert 1982); ** p values calculated by means of an two-tailed anova test.

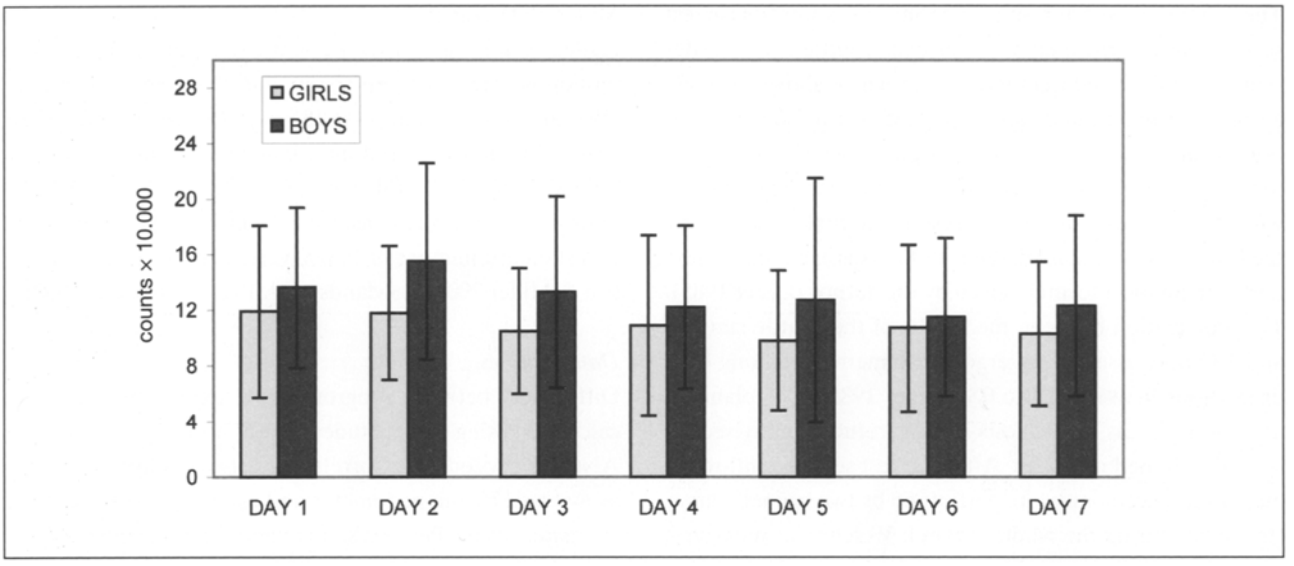

Figure 1 Mean daily physical activity recorded with the pedometer (counts x 103) along the seven-day period of the study, by gender (day 6 and 7 do *not* necessarily mean week-end)

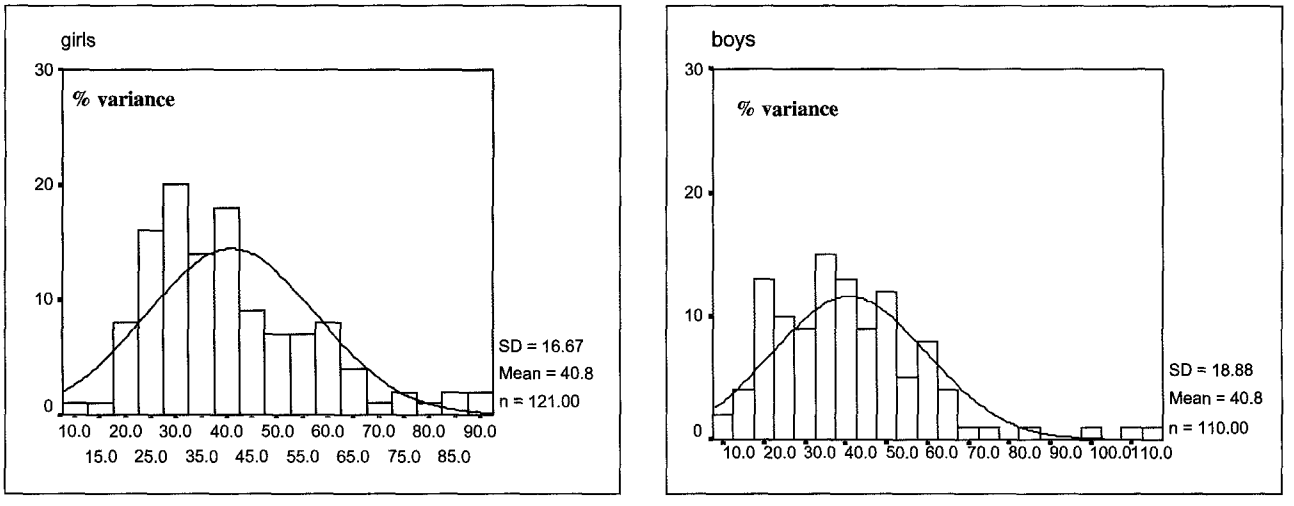

Figure 2 Intra-individual variability of the counts measurement (percentages of subjects displaying different amounts of variation over the seven days)

Figure 1 shows that this is not the case, i.e., scores among girls as well as among boys do not significantly vary from one day to another. We also calculated intra-individual variations from one day to another, as shown in Figure 2. This varies from 10 to 110% (some participants have the same amount of activity over the seven days whereas other exhibit important variations over time).

The daily physical activity recorded by the Pedoboy® is provided in Table 2, by gender and by grade. The *total activity* (total number of counts) over the seven days (TA_7) is higher among boys than among girls. The *mean daily activity* (DA_7) is also higher among boys than among girls. It is higher among younger adolescents (6th grade versus 8th grade) and is *lower* during the weekend (DA_2) than during the week (DA_5). Based on the reported time spent in activities inducing sweating, we divided our sample into two groups with higher and lower level of reported physical activity: the total physical activity as measured by the pedometer is significantly different between these two groups (respectively 78 versus 69, $p < 0.001$). We also correlated the measured physical activity with the number of sports episodes reported by the participants in their dairies. As shown in Figure 3, the correlation between these two variables is insignificant (0.15, $p < 0.07$). On the other hand, estimated VO_2max, derived from the Léger test, is positively correlated with the recorded physical activity as measured over the entire week ($r = 0.30$,

Table 2 Amount of physical activity recorded by the pedometer, by gender and grade

	Girls (n = 119)		Boys (n = 114)		p	6th Grade		8th Grade		p
	Values	S.D.	Values	S.D.		Values	S.D.	Values	S.D.	
Total weekly										
Total TA_7 (counts x 10^3) Sum of counts over the seven days	74.0	22.7	88.4	29.0	< 0.01	85.9	26.5	77.5	26.6	< 0.05
Mean daily activity										
DA_7 (counts x 10^3/d) Mean daily number of counts over the 7 days of the week	10.8	3.2	13.0	4.1	< 0.01	12.3	3.8	11.0	3.8	< 0.01
DA_5 (counts x 10^3/d) Mean daily number of the counts from Monday to Friday	11.2	3.4	13.4	4.1	< 0.01	12.9	4.1	11.8	3.6	< 0.05
DA_2 (counts x 10^3/d) Mean daily number of the counts during the weekend	9.0	4.6	11.2	6.5	< 0.01	10.6	5.3	9.7	6.0	0.07

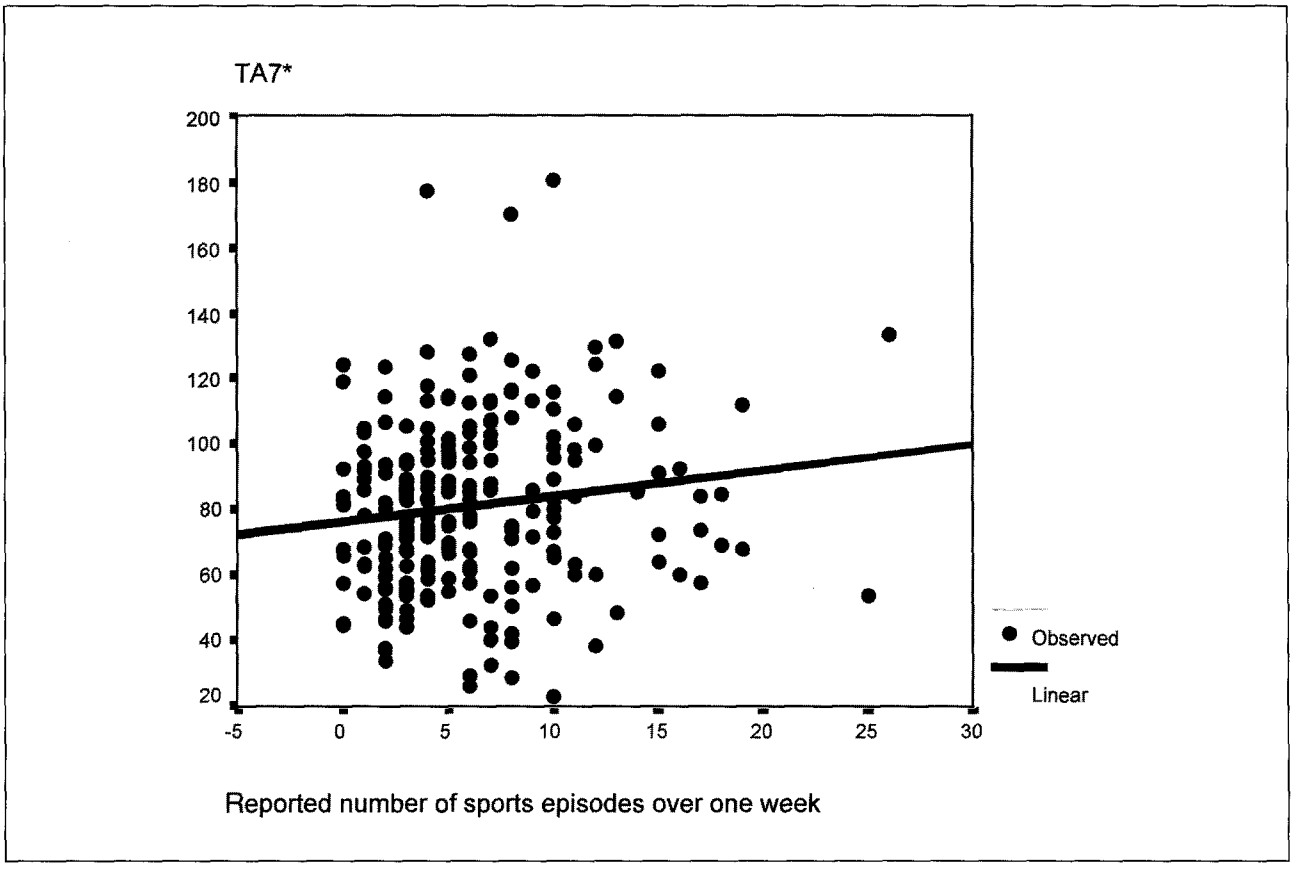

Figure 3 Correlation between measured physical activity (total number of pedometer counts over one week) with the number of sports episodes reported by the participants in their weekly dairies (R = 0.15; p < 0.07)

$p < 0.1$), over the weekdays ($r = 0.29$, $p < 0.1$) and the weekend ($r = 0.21$, $p < 0.1$); it is in fact higher than the correlation with the weekly number of sports episodes (0.11; $p < 0.02$).

Discussion and implications

The present study shows that it is possible to use a pedometer on a relatively large sample of young adolescents for a longer period of time than previously thought (Pate 1993; Kowalski et al. 1996; Welk et al. 2000; Sallis & Saelens 2000). The subjects were very compliant, since data were unusable for only 6% of the subjects, whereas the percentage was nearly 50% in another study involving adolescents (Kowalski et al. 1996). This difference may be attributable to the way in which the study was presented to the participants at the beginning of the week and may have improved motivation. It was not possible to assess the participants' energy expenditure over the week (Kcal/METS) since available algorithms have been derived from studies conducted in the adult population, thus not suitable for growing subjects (Freedson & Miller 2000; Freedson 1991). However, it is still possible to discuss some issues related to the number of counts registered: as in other similar studies focusing on physical activity measured by actometer (Brownson et al. 2000; Blair & Connelly 1996), the number of movements was higher among boys than among girls. One interesting result is the fact that the recorded physical activity was lower during the weekend than during the weekdays: we are unaware of any other study reporting such a discrepancy among adolescents. Among adults, studies have reported contradictory results, with some displaying higher level of physical activity during the weekend (Sequeira et al. 1995), while others indicate lower level during the weekend, especially among men engaging in high intensity physical activity on their job (Sallis et al. 1990). The lower physical activity during the weekend in our sample could be explained by the fact that the weekend, even if it includes longer periods of sports activity for some participants, also implies getting out of bed later in the morning or spending more time in front of the television or quiet in a living room, reading magazines or chatting, so that the total amount of physical activity, irrespective of its intensity, is actually lower on Saturday and Sunday (the pedometer counts every displacement in the vertical position, but not the intensity of the movement). The fact that the habitual physical activity is lower during the weekend than during the week should be taken into account in the future since many of the available surveys involving the use of actometer among children and adolescents to date include records of weekdays only (Brownson et al. 2000; Kowalski et al. 1997; Sallis et al. 1992; Sallis et al. 1990).

As expected, the extent of reported physical activity is correlated to the amount of physical activity as assessed by the pedometer. However, we found no significant relationship between the extent of formal sports activity and the measures of the pedometer. Moreover, while the estimated VO_2max correlated fairly well with the records of the pedometer, it did not correlate significantly with the reported amount of formal sports activity. The extent of the correlation between VO_2max and our measure of physical activity is greater than in other similar research by Sallis et al. (Pearson's correlation: 0.11 (1988) and by Tell and Velar (Pearson's correlation: 0.11 (1988), which would mean that an objective assessment such as the pedometer is a more valid measure than the questionnaires used in other studies. Interestingly, participation in formal sports activity is less correlated with VO_2max than physical activity. Although other research has shown a correlation between habitual physical activity and VO_2max (Weymans & Reybrouck 1989; Taylor & Baranowski 1991), we do not know of any research which has compared the correlation of physical vs sports activity with VO_2max. It may be that children, when asked to report on sports activity, tend to focus on quite formal encounters and omit to disclose the numerous episodes of informal sports they engage in during their leisure time, while the pedometer is able to assess more globally the amount of formal and informal sports activity as well as activities not at all considered as sports but which can potentially have an effect on the children's fitness, such as riding to school, using the staircase instead of an elevator, etc.

Some limitations to this study should be mentioned. Some of the younger participants were excluded from the research because they could not fill in the diary and/or forgot to wear their pedometer. The total rate of invalid records is very low (6%), and was limited to children less than 12 years old: it should thus be kept in mind that the pedometer is probably not suitable for children under 12 years of age. Secondly, as some parents and children refused to participate, we can imagine that those who accepted to participate were more interested in sports and more active and compliant than those who did not participate would have been.

Even if the low fluctuations of records from one day to another show that the participants did not forget to wear the instrument for extended periods of time, we cannot discard the fact that some may have under-used their pedometer on certain occasions and that the pedometer cannot be carried rigorously all day long (i.e., when getting up in the morning, during the daily shower/bath etc.). Also, as the pedometer essentially records changes of position in the vertical axis, it is less sensitive to activities like biking or rowing, and cannot be used in the swimming pool. In fact, the results of the

questions addressing the kind of sports practiced by the participants (Sequeira et al. 1995) suggest that very few of them engaged in these sports. Actually, we have totaled pedometer counts among those practicing or not practicing sports such as swimming and judo and have found no difference at all between the two groups.

Finally, the pedometer does not measure the intensity of physical activity and as such represents a good measure of ordinary physical activity but a less valid assessment of total energy expenditure and exercise: surveys comparing estimated physical activity through actometers and through diaries focusing on sports activities have various degrees of correlation ranging from 0.14 to 0.57, depending on the age of the subjects and the type of actometer (Blair & Connelly 1996; Sallis et al. 1992; Sallis et al. 1990; Rowlands et al. 1997).

What are the implications of our findings? A pedometer provides good information on habitual physical activity in older children and adolescents, and can be used over a longer period of time than previously described. The Pedoboy® is inexpensive, well tolerated by most of the participants. As our results show that the habitual physical activity is higher during the week than during the weekend, future studies focusing on the physical activity of children and adolescents should include measurement over both weekdays and weekend. Also in our study, the pedometer data correlates well with estimated VO_2max: overall physical activity and physical fitness may be better correlated than previously thought (Pate et al. 1995; Payne & Morrow 1993). It may thus be useful, in the assessment of children's and adolescents' physical activity as well as when counselling them, to rely not only on formal sports activity, but also to habitual physical activity, like means of transportation to school or time spent in informal play with friends.

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Zusammenfassung

Eine Messung von der physischen Aktivität und ihre Zusammenhänge mit VO_2max bei schweizerischen Jugendlichen

Fragestellung: Mangels einer allgemein akzeptierten Wertskala verbleibt die Schätzung der physischen Aktivität der Kinder schwierig. Physische Aktivität mittels eines Pedometers zu messen und feststellen, in welchem Ausmass diese Aktivität mit VO_2max in Zusammenhang steht.

Methoden: Untersuchung über physische Aktivität und körperliche Verfassung; 233 schweizerische Jugendliche im Alter von 11 bis 15 Jahren trugen einen Pedometer (Pedoboy®) während sieben aufeinanderfolgenden Tagen. VO_2max wurde durch einen Dauerlauftest bewertet.

Resultate: Die vom Pedometer registrierte physische Aktivität änderte sich nicht von einem Tag zum anderen ($p > 0.05$). Die physische Aktivität war bei den jungen Männern höher als bei den jungen Frauen ($p < 0.001$) und höher je jünger die Jugendlichen waren (6. Klassenstufe versus 8. Klassenstufe; $p < 0.01$). Der Zusammenhang zwischen physischer Aktivität und geschätzte VO_2max war 0.30 ($p < 0.01$).

Schlussfolgerungen: Der Gebrauch eines Pedometers, um während einer ganzen Woche die physische Aktivität Jugendlicher zu schätzen, ist durchaus möglich. Die vom Pedometer registrierten Daten geben einen objektiven Anhaltspunkt für die normale physische Aktivität und stimmen mit der Aerobic-Kapazität einigermassen überein.

Résumé

Une mesure de l'activite physique par pédomètre et ses relations avec la VO_2max chez des adolescents en Suisse

Objectifs: En l'absence d'une méthode de référence acceptée par tous, l'évaluation de l'activité physique chez les enfants est difficile. Evaluer l'activité physique à l'aide d'un pédomètre et analyser la corrélation entre activité physique et VO_2max.

Méthodes: Enquête sur l'activité et la condition physique; 233 adolescents suisses de 11 à 15 ans ont porté un pédomètre (Pedoboy®) pendant sept jours consécutifs. La VO_2max a été calculée grâce au test d'endurance de course navette.

Résultats: L'activité physique enregistrée par le pédomètre ne varie pas d'un jour à l'autre ($p > 0.05$). Le niveau d'activité physique est plus élevé chez les garçons que chez les filles ($p < 0.001$) et parmi les adolescents les plus jeunes (comparaison entre la 6ème année et la 8ème année; $p < 0.001$). Le coefficient de corrélation entre l'activité physique mesurée par le pédomètre et la VO_2max est de 0.30 ($p < 0.01$).

Conclusions: Il est possible d'utiliser le pédomètre chez les adolescents pour évaluer l'activité physique sur une durée d'une semaine entière. Les données enregistrées par le pédomètre donnent une mesure objective du niveau d'activité et sont relativement bien corrélées avec la capacité aérobie.

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