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Review Paper

Level of physical activity among children and adolescents in Europe: a review of physical activity assessed objectively by accelerometry

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SUMMARY

This study explored the proportion of European youth who are sufficiently active according to physical activity (PA) recommendations, based exclusively on objective assessment through accelerometers. A systematic electronic search of studies published up to March 2012 was conducted. PubMed was used to identify accelerometry-assessed PA studies that involved European youth. Within the 131 European studies, only 35 clearly reported the proportion of youth meeting the PA recommendations. Different thresholds lying between 1000 and 4000 counts/min (cpm) were used to define moderate-to-vigorous PA (MVPA). Overall, up to 100% of youth may be sufficiently active when using a threshold of approximately >1000–1500 cpm. With the most cited cut-off point (i.e. >2000 cpm), up to 87% of European youth might be considered physically active with reference to the current recommendations. Alternatively, with a cut-off point >3000 cpm, no more than 3–5% of them appeared to achieve these recommendations. The large discrepancy in outcomes released by accelerometer data is mainly due to the variety of cut-off points for MVPA among youth, hindering the definition of a clear goal towards PA promotion in Europe. Standardization of methods is urgently required.

Introduction

Among children and adolescents (4–12 and 13–18 year olds), physical inactivity may increase the risk of numerous non-communicable chronic diseases. Many of these diseases, including metabolic syndrome/insulin resistance, type 2 diabetes and hypertension, have a direct relationship with paediatric obesity.[1] In most Westernized countries, the number of overweight and obese youth has more than doubled in the past 20 years.[2] The establishment of healthy patterns of physical activity (PA) during childhood and adolescence appears to be an important contributor to the prevention of

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obesity and its related diseases. As PA is gaining recognition for its impact on the health of populations, stakeholders and governmental organizations have increasingly echoed PA recommendations for children. These recommendations state that children aged 5–18 years should engage in moderate-to-vigorous PA (MVPA) for a minimum of 60 min on a daily basis.[3] Published in 2005, these guidelines stem from a systematic review of data by an expert panel, and are in line with existing and/or updated guidelines from several countries, including Australia,[4] Canada,[5,6] the UK[7–9] and the USA.[10] These recommendations are currently endorsed by the European Commission[11] and the World Health Organization (WHO).[12] Obviously, the next step beyond writing the guidelines is to quantify the number of children who actually meet these recommendations. Given the investment of millions of Euros on prevention programmes or health-enhancing PA strategies, long-term surveillance and evaluation are required. These are needed to facilitate adjustment of the targeted goals.

Together with monitoring the prevalence and incidence of physical-inactivity-related diseases and with the determination of behavioural determinants of PA, a central function in PA epidemiology is assessment of the prevalence of and changes in PA patterns.[13] In particular, policy makers require, at least, prevalence estimates as a prime answer to fundamental questions in public health, such as: 'How many children and adolescents need to be targeted for physical inactivity and its related morbid conditions?', 'Is that number being significantly reduced by funded interventions such as education, prevention, screening, training and treatment?' Such data are important to boost promotional efforts, to allocate limited resources and to develop policies.[13] As reported previously, the question about the utility of frequency estimates for policy decisions is complex.[14,15] Aside from the issues related to the joint consideration of the severity of a health condition or a morbid state, prevalence estimates are threatened by difficulties for policy makers in clearly defining the presence or absence of PA behaviour in youngsters. Consequently, public health decisions and practices may be hampered or biased by inaccuracies in the measurement of PA, as found with the use of a PA questionnaire in the UK surveillance system.[16] In fact, reporting one's own activity through questionnaires is cognitively difficult for adults and much more so for children or adolescents, even in large-scale studies where large sample sizes are expected to compensate for weaknesses associated with subjectivity.[17] Thus, even the most popular and sophisticated PA questionnaires, such as those used in the WHO Health Behaviour in Schoolchildren Survey[18] or the Youth Risk Behaviour Survey in the USA,[19,20] may be prone to recall bias, social desirability and misinterpretation. Ideally, questionnaires should be involved in the assessment of perceptual dimensions and/or the context of the activities that children perform. However, given the technological progress made over the last 5–10 years, questionnaires appear much too imprecise in the assessment of activity behaviour *per se*[16,21–23] to be favoured in large-scale studies or for surveillance systems.[24,25] Alternatively, indirect calorimetry and double-labelled water (DLW), heart rate monitors, pedometers or accelerometers are feasible objective methods, with accelerometers used in large-scale epidemiological studies as exemplified by several recent data from the USA,[26,27] Canada,[28,29] the UK[30,31] and Europe.[32–34] Among these objective methods, the DLW technique is recognized as the reference method or 'gold standard' for measuring energy expenditure under free-living conditions.[35] However, energy expenditure is only a physiological result of PA, and not all dimensions of PA should be summed up into energy expenditure. As shown in earlier studies, PA and energy expenditure are two distinct constructs and not synonymous.[36,37] For instance, PA may cause an elevation in metabolic rate that persists long after cessation of observable movement.[36] Furthermore, the DLW technique is limited by its excessive cost for use in large-scale studies. Finally, the DLW is blind to information related to the pattern of PA behaviour.[38] Thus, although accelerometers are less accurate for the estimation of PA-related energy expenditure compared with DLW, they are better in depicting the pattern of PA in terms of assessing the frequency, intensity and duration of PA.[38] For monitoring and surveillance purposes, this technique seems to provide a reasonable trade-off between validity/reliability, ease of administration, ethics and cost.[39] Accelerometry is presently viewed as the reference method for measuring movement behaviours of children in free-living conditions.[40] Nonetheless, due to the long-standing lack of objective data in Europe, the most important official reports and fact sheets[41,42] about activity levels in European youth have been based on data obtained through questionnaires. Despite the merit of these reports, self-reported activity data are prone to hinder and/or distort decisions regarding the establishment of priorities for promoting PA among youth.

The aim of this study was to describe the published data on compliance of children and adolescents in Europe with PA recommendations using data measured objectively through accelerometry.

Methods

Search strategy

A systematic electronic database search was conducted for studies published up to March 2012. This computerized search was performed using PubMed. A two-level search strategy was set up (see Fig. 1). The first level included all studies published about accelerometry-assessed PA in the world. The second level consisted of published studies that involved European youth. The search terms included the following: (1) 'children', 'adolescents' or 'youth' used for the youth; (2) 'physical activity', 'exercise' or 'sport' used for PA; (3) 'accelerom*' or 'acceleromet*', alternately used for accelerometry or accelerometer; and (4) 'Europe*' or 'Europ*' for Europe. Terms from (1) were primarily combined with those from (2) and (3) using 'AND' as the link. Next, terms from (1), (2), (3) and (4) were combined to identify studies performed solely in Europe, including multicentre studies. In all cases, duplicates were removed. In addition to the computerized literature search, the reference lists of relevant papers were searched manually for other pertinent articles. If multiple articles were identified from the same cohort study, they were all considered for inclusion.

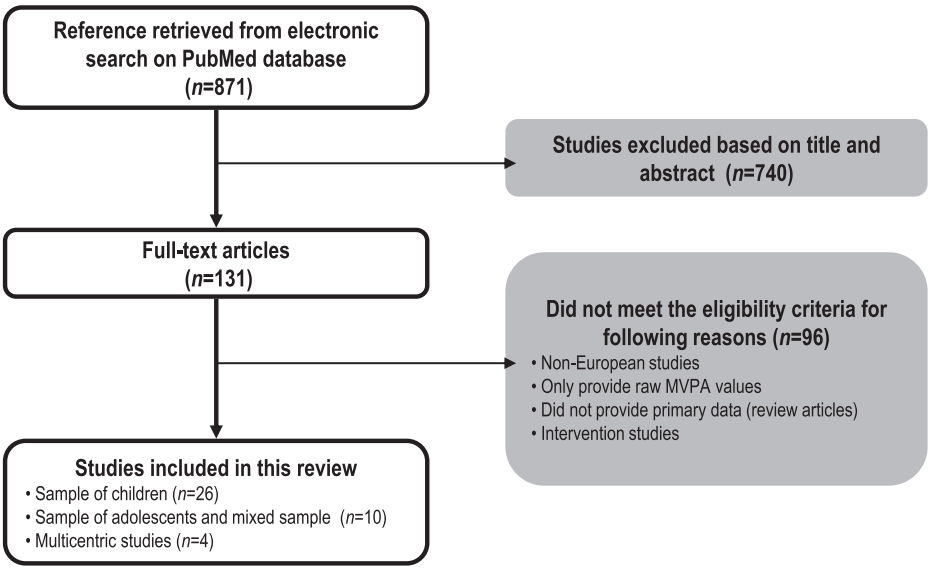

Fig. 1 – Process through the stages of study selection.

Eligibility criteria

Only studies about youth that were published in English and met the following criteria were included in this review. The studies were required to have been carried out in one or more countries (e.g. multicentre studies) from the European continent. Participants consisted of children (age ≤12 years) and adolescents (age 13–18 years) living in Europe. Eligible studies included cross-sectional observations and prospective cohort studies. In the prospective studies, prevalence values were considered at each measurement point as long as the children's ages conformed to the inclusion criteria. Conversely, intervention studies were not included in this review due to potential bias related to the sample selection (e.g. inactive children).

Studies were only included in the review when they explicitly reported the proportion of children who met the PA guidelines. In other words, the main outcome from the included studies was the proportion of children who engaged in MVPA for at least 60 min/day. Otherwise, the prevalence of PA was drawn from the primary authors' comments. Commonly, as the average time spent in MVPA greatly exceeded 100 min/day, 100% of children involved in the targeted studies were deemed as meeting the PA recommendations in such cases. Studies were not included if the mean, median and standard deviations of MVPA were the sole reported statistics, and the proportion of children achieving the PA guidelines was not described.

Data extraction

All retrieved references were screened for possible inclusion using the title and abstract. References that met the inclusion criteria based on the abstract were retained if they were deemed appropriate. A structured form was developed to collect information related to the country (or set of countries for multicentre studies) where the study had been implemented, the data collection period(s), the sample characteristics (age of participants, sample size and sex ratio), the PA measurement procedure [type of accelerometer, selected epoch length, data reduction criteria and cut-off point(s) to define MVPA]. To facilitate the interpretation and comparability of the selected studies, the cut-off points for MVPA expressed in metabolic equivalent tasks (METs) in the papers have been converted to their nearest values in counts/min (cpm).

Results

Fig. 1 displays the process of study selection. Based on titles and abstracts retrieved from the electronic search strategy, 131 European references were judged to merit further evaluation and were therefore assessed as full-text articles. Of these 131 publications from Europe, 96 did not meet the eligibility criteria, and only 35 clearly reported the proportion of youth meeting the PA recommendations. Within the suitable studies that were included in this review, 26 studies involved a sample of children exclusively[16,31,43–61] or both children and adolescents analysed separately,[62–66] and five studies involved adolescents or a mixed analysis of children and adolescent pooled together (Table 1).[67–71] Notably, 11% of the studies were multicentre studies encompassing several European countries (Table 2).[33,34,72,73]

Variability in the cut-off points for MVPA and the selection of epochs

Almost all the studies included in this review used the MTI Actigraph accelerometer (MTI Actigraph LLC: Pensacola, FL, USA) (Models 7164, GT-256, GT1M or GT3X). Only one study also considered another model of accelerometer.[73] Using the same model of accelerometer may be perceived as facilitating the comparison between the studies, but the selected cut-off points

to define MVPA and the epoch definition still differed between studies. Seven studies[34,44,47,48,58,67,70] used the age- and gender-specific equation by Freedson et al.[74] that translates into approximately 1000 cpm for children and approximately 1500 cpm for adolescents with three METs as the energy requirement for moderate-intensity PA. Fifteen studies[33,45,49,53,55,56,59,60,62–65,68,72,75] were based on a cut-off point of approximately 2000 cpm, four studies used a cut-off point >3000 cpm,[31,43,63,66] and one study used a cut-off point of 4000 cpm.[76] Only five studies[46,51,54,61,71] used multiple cut-off points for a comparison purpose. Overall, five different epochs (i.e. 60 s, 30 s, 15 s, 10 s and 5 s) were adopted in studies to collect activity data. The most commonly used epoch interval was 60 s (48% of cases), followed by 15 s (24% of cases). The lowest epoch (5 s) was only used in 19% of cases. More precisely, six studies[45,49,56,59,60,64] collected data using a 5-s epoch, three studies used a 10-s epoch,[47,48,52] six studies used a 15-s epoch,[16,33,43,62,63,73] one study used a 30-s epoch,[61] and 16 studies used a 60-s epoch.[31,34,44,46,51–55,58,65–67,70,72,76] In one study, data were collected with a 60-s epoch and then with a 10-s epoch (Table 1).[52]

Proportion of children engaged in sufficient PA

The proportion of children (age ≤12 years) who met the PA recommendations ranged from 1% to 100% depending mainly on the cut-off point(s) used to define their activity level. Approximately 78–100% of children were found to comply with the PA recommendations of a cpm cut-off point equivalent to three METs (Tables 1 and 2). Fewer children (36–87%) achieved the PA recommendations with a cut-off point of approximately 2000 cpm. Between 3% and 9% of European children were found to meet these guidelines when MVPA was computed using a cut-off point >3000 cpm. Only 1% of children were sufficiently active according to guidelines with a cut-off point of 4000 cpm (Table 1).[76] Apart from data obtained with the 1000 cpm cut-off point, boys met the recommendations more frequently (between 1.3 and 12.8 times) than girls. Finally, a study found that children suffering from chronic conditions (e.g. obesity, juvenile idiopathic arthritis or type 1 diabetes) adhered to the guidelines less often than their healthy peers.[53]

Between 4% and 100% of adolescents were found to achieve the PA recommendations, once again depending on the cut-off point(s) used (Tables 1 and 2). With the three METs cpm equivalent from Freedson et al.,[74] at least four in 10 adolescents (range 44–66%) complied with the PA guidelines. This proportion was in the range of 20–71% with a cut-off point of approximately 2000 cpm, and was <10% (range 4–9%) with a cut-off point >3000 cpm. On the whole, adolescent boys met the recommendations more frequently (between 1.1 and 11.3 times) than adolescent girls. However, as a paradox, in one study involving Swedish adolescents, girls achieved the recommendations 1.3 times more often than boys (Table 1).[70] Finally, and just as among children, chronic conditions such as overweight status and obesity have been found to impair the ability of adolescents to achieve the recommendations.[33] Forty-two percent of normal-weight adolescents met the PA recommendations compared with 38% and 32% of their overweight and obese counterparts, respectively (Table 2).[33]

Discussion

This study sought to draw attention to the proportion of European youth who are sufficiently active according to the current PA recommendations, and whose activity is based exclusively on accelerometry data. In total, approximately 20,000 children and adolescents in Europe have been involved in local non-representative studies, and >4000 have been involved in the current two important European multicentre studies (the ENERGY, EYHS and HELENA studies). A more stringent the low end to define moderate-intensity PA, the lower the proportion of youth meeting the PA recommendations. For instance, up to 100% of youth may be sufficiently active when their MVPA is computed with a cut-off point of approximately three METs (or its corresponding counts conversion, i.e. ~1000–1500 cpm), while proportions as high as 93% and 14% are obtained with the higher cut-off points of >2000 cpm and >3000 cpm, respectively. The second lesson from these European data is that regardless of the MVPA cut-off point, the results confirm the lower probability of girls being physically active (as low as 0.4%) compared with boys (as low as 5.1%). Finally, the association between age and achievement of PA recommendations is not clear, although previously, age was thought to be related to a decline in PA. In fact, the proportions of active children (≤12 years) were as high as 100%, 87% and 9% with cut-off points of >1000 cpm, >2000 cpm and >3000 cpm, respectively. The corresponding values for adolescents (13–18 years) were 100%, 66% and 9% with similar cut-off points (Tables 1 and 2).

One particular feature of these European data is the use of the same type of accelerometer, models of the Actigraph, which may theoretically enhance and/or ease comparability of findings. However, the most appropriate lower limit cut-off point of MVPA of children and adolescents is currently debated. This issue has been addressed by several previous studies, which have suggested favouring cut-off points between 3000 and 3600 cpm among children.[77,78] A recent analysis also proposed the use of cut-off points in the range between 2000 and 3500 cpm.[79] Meanwhile, Guinhouya et al.[80] suggested that caution should be exercised when using cut-off points <3000 cpm among children due to biomechanical and physiological specificities of the growing bodies of youth. Nevertheless, until a consensus is reached on the basis of further robust validation studies, the use of multiple cut-off points as suggested by Ekelund et al.[79] may represent a reasonable analytic trade-off for the interpretation of accelerometer data.

Most existing comparative prevalence data are from North America. Thus, with a similar model of accelerometer (i.e. Actigraph) and by adopting a cut-off point >2000 cpm, only 42% of 6–11 year olds and 8% of 12–15 year olds in the USA have been found to have accumulated at least 60 min of MVPA per day.[27] This is lower than was observed in the current study in European youth of comparable age. Using an Actical accelerometer on Canadian children aged 6–19 years, Colley et al.[28] reported that 7% (9% of boys and 4% of girls) accumulated 60 min of MVPA on at least 6 days/week. These findings are difficult to compare directly with the current study due to a difference in the type of accelerometer used, but the results are close to data obtained among European youth with cut-off

points >3000 cpm. Nevertheless, comparisons may improve when using the corresponding cut-off points for the two types of accelerometers. In a calibration study during which children wore two accelerometers (i.e. Actigraph and Actical) simultaneously when exercising, values >2296 cpm and >2032 cpm were found as the lower limit for MVPA with the Actigraph and Actical accelerometers (Phillips – Respironics, Oregon, USA), respectively.[81] If this association is applied to the currently available data, it may be suggested that European youth meet the PA recommendations more frequently (up to 12 times) than their Canadian peers. However, one should take into account the fact that the Canadian study used a lower cut-off point (i.e. >1600 cpm).[28,82] Just as for the Actigraph accelerometer, there is also concern about the non-equivalence of cut-off points with the Actical accelerometer. Indeed, the cut-off point reported by Colley and Tremblay[82] is in agreement with that of Puyau et al.,[83] who set the lower end of moderate-intensity PA at 3200 cpm using a similar study design.[84] It may be obvious that comparisons between studies using the same accelerometer are difficult, but comparisons between studies using different accelerometers are even more dangerous. Such a debate, however, is beyond the scope of the current article.

When assessing youth PA through accelerometry, the selection of epoch length may also be an important consideration. Although there are few studies on this topic to date, some earlier data underscored differences in PA estimates between short (e.g. 1 s) and longer (e.g. 60 s) epochs at high intensities.[85,86] More recently, a difference of approximately 16 min (62%) was found in the time that preschoolers spent in MVPA when a 5-s epoch was considered in comparison with a 60-s epoch.[87] Among the studies included in the current analysis, the only study that used both short and long epochs during a five-year longitudinal follow-up revealed an increase in the time spent in MVPA and in the proportion of children meeting the recommendations (+5%), especially the boys.[52] The authors hypothesized that the average activity level of these children had increased over years,[52] while such an increase may also simply be the result of using a shorter epoch length during the second wave of evaluation. On the other hand, when the issue related to epoch length definition has been tested empirically among school-aged children,[78] the results have indicated a significant difference in MVPA (i.e. a difference of 65% in MVPA with a 15-s epoch compared with MVPA with a 60-s epoch) that may not be of biological meaningful. Thus, these authors concluded that 'despite a widespread perception that shorter epochs are essential to measure PA in children, the empirical evidence on the topic is limited and does not support the notion that 'short' epochs are essential. One exception to this conclusion might be in circumstances where the outcome of interest is vigorous-intensity PA'.[78] Going against this reassuring statement, the impact of the epoch length definition on the MVPA of youths should not be ruled out completely as it is capable of amplifying the effect due by the cut-off point selection in one direction or the other. This is exemplified by recent findings, which suggested that the importance of the effect of epoch length increases with the stringency of the selected cut-off point.[88,89] In children, when MVPA obtained with short epochs (e.g. 10 or 15 s) is compared with MVPA with a 60-s epoch, differences of 7% (10 vs 60 s)[88] to up to 38% (15 vs 60 s)[89] have been found with an Actigraph-based cut-off point >2000 cpm. The corresponding differences with a cut-off point >3000 cpm were approximately 26% (10 vs 60 s)[88] and 62% (15 vs 60 s).[89] Even if, with the current data, no clear pattern flowed from data processed with different epoch lengths and using a given cut-off point on children of comparable age group (e.g. cut-off point >2000 cpm on 6–11-year-old children), the epoch length definition should be viewed as being as important as the cut-off point selection.

One of the strengths of the studies included in this review is the relatively heterogeneous and high number of youth involved in all the studies pooled together. This strength may allow this study to present the most realistic picture of activity behaviour in European youth. However, only 15 countries (i.e. Austria, Belgium, England, Estonia, France, Greece, Hungary, Iceland, Italy, Norway, Portugal, Spain, Sweden, Switzerland and The Netherlands) in all of Europe provided some data about the compliance of youth with PA recommendations; England produced more than 40% of the data about children, and Portugal produced 30% of the data about adolescents or mixed sample studies. Thus, generalization of the current findings to other paediatric populations in Europe should be performed with caution. Data from Eastern Europe are severely lacking. Likewise, objective data on the PA of young people are still lacking at national level in some Western Europe countries, such as Luxembourg,[36] which is characterized by a multi-ethnic population with potentially interesting variability in PA behaviour. Nevertheless, it should be acknowledged that the dearth of PA prevalence data does not mean that no studies have been performed in some countries. For instance, PA data exist on preschoolers from Germany,[90] although no PA prevalence data can be gathered. This discrepancy may simply reflect the fact that this parameter (i.e. PA prevalence) is not yet unanimously viewed as one the most powerful decision support indicators in PA epidemiology, and is not systematically computed as it should be. Thus, researchers from Europe and throughout the world should be encouraged to systematically add the proportion of individuals who meet PA guidelines, even as a secondary statistic, when reporting their surveys.

This review has a few limitations. The first relies on the impossibility to include several European studies due to the lack of prevalence data. This may hinder the generalization of the present observations to the whole European paediatric population. Additionally, apart from a robust validation study and/or a consensus conference based on evidence regarding the most appropriate cut-off point to define the lower limit of moderate-intensity PA among young people, no clear estimates of the proportion of sufficiently active children can be provided. Accordingly, support for public health decisions towards the promotion of PA among youth may still be debatable. Meanwhile, as recommended elsewhere,[79] using multiple cut-off points for MVPA in epidemiological studies may be wise.

At best, with the most used cut-off point for MVPA among youth (i.e. 2000 cpm), 87% of European children and adolescents meet the PA recommendations. The corresponding prevalence with cut-off points >3000 cpm is 71%. At worst, only 3–5% of young people in Europe may reach these recommendations. Standardization of accelerometry data treatment regarding both cut-off point selection and epoch definition is needed urgently to provide more solid foundations for decisions towards PA promotion policies in Europe.

Table 1 – Local studies in Europe describing the adherence of children and adolescents in Europe to physical activity (PA) guidelines.

Country	Region	Authors (date)	Data collection period	Sample characteristics			Characteristics of PA measurement				Prevalence		
				Age (years)	Sample size	Sex ratio: male/female	Accelerometer	Epoch	Inclusion criteria	MVPA cut-off point(s)	Overall	Boys	Girls
Sample of children (≤12 years)													
Belgium (Flanders)	West	Cardon and Bourdeaudhuij (2007)[43]	Dec. 2005–Jan. 2006	4–6	76	0.95	Actigraph MTI 7164	15-s	4 days/week and ≥8.6 h/day	≥3248/3564 cpm	8%	–	–
England	North	Fisher et al. (2011)[50]	–	8–10	100	1.04	Actigraph MTI GT1M	60-s	≥3 days/week and ≥10 h/day	≥4000 cpm	1%	–	–
		Basterfield et al. (2008)[16]	Oct. 2006–Dec. 2007	6–8	405	0.98	Actigraph MTI GT1M	15-s	≥3 days/week and ≥6 h/day	≥3200 cpm	6%	–	–
		Corder et al. (2010)[45]	Apr.–July 2007	9–10	844	0.71	Actigraph MTI GT1M	5-s	≥3 days/week and ≥8 h/day	≥2000 cpm	70%	–	–
		Fairclough and Ridgers (2010)[49]	Oct.–Dec. 2008	10–11	175	0.80	Actigraph MTI GT1M	5-s	5 days/week and ≥10 h/day	≥2000 cpm	45%	63%	30%
		McLure et al. (2009)[54]	–	9–10	255	0.76	Actigraph MTI GT-256	60-s	≥3 days/week and ≥10 h/day	≥1100 cpm ≥3200 cpm	97% 7%	97% 13%	97% 2%
		Owen et al. (2009)[56]	Jan. 2006–Feb. 2007	9–10	2071	0.92	Actigraph MTI GT1M	5-s	≥1 day/week and ≥10 h/day	≥2000 cpm	64%	76%	53%
		Steele et al. (2009)[57]	Apr.–July 2007	9–10	1862	0.77	Actigraph MTI GT1M	5-s	≥3 days/week and ≥8 h/day	≥2000 cpm	69%	82%	59%
		MetCalf et al. (2008)[55]	Jan. 2000–Jan. 2001	5	212	1.14	Actigraph MTI 7164	60-s	7 days/week and 13 h/day	≥2500 cpm	28%	42%	11%
		Van Sluijs et al. (2008)[60]	April–July 2007	9–10	1868	0.79	Actigraph MTI GT1M	5-s	≥3 days/week and ≥8 h/day	≥2000 cpm	69%	80%	60%
		Riddoch et al. (2007)[31]	Jan. 2003–Jan. 2005	11–12	5595	0.91	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	≥3600 cpm	3%	5%	0.4%
		Trayers et al. (2006)[58]	Mar. and July 2004	8–12	52	1.00	Actigraph MTI 7164	60-s	≥4 days/week and ≥10 h/day	≥1000 cpm	100%	100%	100%
		Cooper et al. (2003)[44]	May–June 2002	10	114	1.07	Actigraph MTI 7164	60-s	≥4 days/week and 10 h/day	≥1000 cpm	91%	98%	83%
France	West	Apété et al. (2012)[61]	Sept. 2005–Mar. 2006 and Nov. 2007–Mar. 2008	8–11	252	1.19	Actigraph MTI 7164	30-s	≥3 days/week and 13 h/day	≥1000 cpm ≥3200 cpm ≥3600 cpm	99% 9% 5%	99% 14% 8%	99% 3% 1%
		Blaes et al. (2011)[64]	–	4–5 9	94 156	0.88 0.90	Actigraph MTI GT1M	5-s	≥6 days/week and 13 h/day	≥2170 cpm	83% 87%	95% 99%	73% 76%
		Guinhouya et al. (2006)[51]	Sept. 2004–	8–11	45	1.37	Actigraph MTI 7164	60-s	3 days/week and 13 h/day	≥1000 cpm ≥3200 cpm	100% 9%	– –	– –
Iceland	North	Magnusson et al. (2011)[66]	Sept. 2003 and Jan. 2004	9	176	0.85	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day -	≥3400 cpm	5%	9%	2%
Norway	North	Kolle et al. (2010)[65]	2005–2006	9	1291	1.16	Actigraph MTI 7164	60-s	≥2 days/week and ≥8 h/day	≥2000 cpm	83%	91%	75%
		Kolle et al. (2009)[52,75]	1999–2000 2005	9.7 9.8	340 378	1.07 1.24	Actigraph MTI 7164	60-s 10-s	≥3 days/week and ≥8 h/day	≥2000 cpm	81% 87%	87% 93%	76% 79%

Portugal	South	Vale et al. (2010)[59]	Feb. 2008–May 2009	4–6	245	1.33	Actigraph MTI GT1M	5-s	≥4 days/week and ≥10 h/day	>1680 cpm	Wk: 94% We: 78%	Wk: 96% We: 89%	Wk: 84% We: 78%
		Baptista et al. (2012)[63]	2006–2008	10–11	800	0.92	Actigraph MTI GT1M	15-s	≥3 days/week and ≥10 h/day	≥2059 cpm	36%	52%	23%
Spain	South	Aznar et al. (2010)[62]	–	9	136	1.00	Actigraph MTI GTM1	15-s	≥4 days/week and ≥10 h/day	≥2000 cpm	47%	60%	34%
Sweden	North	Dencker et al. (2006)[47]	Aug.–Dec.	8–11	248	1.30	Actigraph MTI 7164	10-s	≥3 days/week and ≥8 h/day	≥1000 cpm	100%	100%	100%
		Dencker et al. (2007)	–	8–11	225	1.23	Actigraph MTI 7164	10-s	≥3 days/week and ≥8 h/day	≥1000 cpm	100%	100%	100%
Switzerland	West	Maggio et al. (2010)[53]	–	9–11	209	–	Actigraph MTI 7164	60-s	≥4 days/week and ≥10 h/day	≥2000 cpm	60% (HC) 52% (OB) 38% JIA 39% (T1DM)	–	–
The Netherlands	West	De Vries et al. (2009)[46]	Oct. 2004–Jan. 2005	6–11	51	0.46	Actigraph MTI 7164	60-s	≥4 days/week and ≥8 h/day	>600–1000 cpm >2000–3000 cpm	100% 16%	100% 38%	100% 6%
Sample of adolescents (13–19 years) or mixed sample (e.g. 8–15 years)													
Belgium (Flanders)	West	Ottevaere et al. (2011)[71]	–	15	213	0.71	Actigraph MTI 7164	15-s	≥3 days/week and 8–10 h/day	≥1700 cpm ≥2000 cpm ≥2000 cpm	45% 24% 5%	51% 33% 9%	27% 11% 0.8%
France	West	Blaes et al. (2011)[64]	–	12–13	111	0.82	Actigraph MTI GT1M	5-s	≥6 days/week and 13 h/day	≥1944 cpm	44%	60%	31%
Iceland	North	Magnusson et al. (2011)[66]	Sept. 2003 and Jan. 2004	15	162	1.25	Actigraph MTI 7164	–	–	≥3400 cpm	9%	15%	2%
Norway	North	Kolle et al. (2010)[65]	2005-2006	15	975	1.08	Actigraph MTI 7164	60-s	≥2 days/week and ≥8 h/day	≥2000 cpm	52%	54%	50%
Portugal	South	Lopes et al. (2006)	–	6–14	405	0.97	Actigraph MTI 7164	60-s	7 days/week	>1000–1500 cpm	100%	100%	100%
		Mota et al. (2003)[69]	April–May 2001	8–15	84	0.56	Actigraph MTI 7164	60-s	≥3 days/week and 13 h/day	>1000–1500 cpm	100%	100%	100%
		Baptista et al. (2012)[63]	2006–2008	16–17	444	0.75	Actigraph MTI GT1M	15-s	≥3 days/week and ≥10 h/day	≥3239 cpm	4%	8%	1%
Spain	South	Martinez-Gomez et al. (2009)[68]	Nov. 2007–Feb. 2008	13–16	214	1.00	Actigraph MTI GTM1	15-s	≥4 days/week and ≥10 h/day	≥1700 cpm	71%	82%	61%
		Aznar et al. (2010)[62]	–	15	85	1.36	Actigraph MTI GTM1	15-s	≥4 days/week and ≥10 h/day	≥2000 cpm	20%	29%	9%
Sweden	North	Ortega et al. (2008)[70]	–	14–16	472	0.89	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	>1500–1800 cpm	66%	61%	70%

MVPA, moderate-to-vigorous physical activity; Wk, weekday; We, weekend day; HC, healthy children; OB, obesity; JIA, juvenile idiopathic arthritis; T1DM, type 1 diabetes mellitus.

Table 2 – European multicentre studies describing the adherence of children and adolescents in Europe to physical activity (PA) guidelines.

Countries	Authors (date)	Data collection period	Sample characteristics			Characteristics of PA measurement				Prevalence		
			Age (years)	Sample size	Sex ratio: male/female	Accelerometer	Epoch	Inclusion criteria	MVPA cut-off point(s)	Overall	Boys	Girls
Sample of children (≤12 years)												
EYHS: Denmark (D), Portugal (P), Estonia (E), Norway (N)	Nilsson et al. (2009)[72]	–	9	1184	1.01	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	≥2000 cpm	Wk: 60% (D) Wk: 65% (P) Wk: 70% (E) Wk: 90% (N) We: 45% (D) We: 60% (P) We: 60% (E) We: 60% (N)	–	–
EYHS: Denmark, Portugal, Estonia, Norway	Riddoch et al. (2004)[34]	–	9		–	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	≥1000 cpm	–	97%	98%
ENERGY: Belgium, Greece, Hungary, The Netherlands, Switzerland	Verloigne et al. (2012)[73]	Mar.–Sept. 2010	10–12	686	0.89	Actigraph MTI GT1M/ GT3X Actitrainer		≥3 days/week and 8–10 h/day	≥3000 cpm	10%	17%	5%
Sample of adolescents (13–19 years)												
HELENA: Austria, Belgium, France, Germany, Greece, Hungary, Italy, Spain, Sweden	Martinez-Gomez et al. (2010) [32,33]	2006–2007	12.5–17.5	2094	0.89	Actigraph MTI GT1M	15-s	≥3 days/week and ≥8 h/day	≥2000 cpm	42% (NW) 38% (OV) 32% (OB)	59% (NW) 51% (OV) 45% (OB)	28% (NW) 26% (OV) 14% (OB)
EYHS: Denmark (D), Portugal (P), Estonia (E), Norway (N)	Nilsson et al. (2009)[72]		15	770	0.72	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	≥2000 cpm	Wk: 20% (D) Wk: 50% (P) Wk: 58% (E) Wk: 68% (N) We: 12% (D) We: 38% (P) We: 38% (E) We: 38% (N)	–	–
EYHS: Denmark, Portugal, Estonia, Norway	Riddoch et al. (2004)[34]	–	15	2185	–	Actigraph MTI 7164	60-s	≥3 days/week and ≥10 h/day	≥1500 cpm	–	82%	62%

MVPA, moderate-to-vigorous physical activity; NW, normal-weight children; OV, overweight children; OB, obese children; D, Denmark; P, Portugal; E, Estonia; N, Norway.

Key points

What is already known

- Among youth, physical inactivity may increase the risk of numerous non-communicable chronic diseases that are directly related to paediatric obesity.
- Children are commonly recommended to engage in MVPA for a minimum of 60 min on a daily basis.
- In Europe, the proportion of young people who comply with these recommendations is not actually known because most official reports and fact sheets about activity levels of youth are based on outcomes from subjective methods that are prone to important errors.

What this study adds

- Within the 131 European studies involving children and adolescents that use an accelerometer to assess PA behaviour, only 35 have clearly reported the proportion of youth meeting the PA recommendations.
- Only 15 countries in Europe have provided data about the compliance of youth with the PA recommendations. England produced >40% of data about children, and Portugal produced >30% of data about adolescents.
- Depending on the accelerometry cut-off point used to define MVPA, current data show that, at best, 71–87% of European youth meet the PA recommendations. At worst, 3–5% of young people in Europe comply with these recommendations.
- To reach a more consistent result about the proportion of sufficiently active children in Europe, a consensus about the actual cut-off point for MVPA for this group is urgently required.

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REFERENCES

1. Guinhouya BC. *L'activité physique au cours du développement de l'enfant*. [*Physical activity during growth*]. Paris: Lavoisier: Médecine-Sciences; 2012.
2. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Ped Obes* 2006;**1**:11–25.
3. Strong WB, Malina R, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pirvarnik JM, Rowland T, Trost SG, Trudeau F. Evidence based physical activity for school-age youth. *J Pediatr* 2005;**146**:732–7.
4. CDHA. *Commonwealth Department of Health and Ageing. Australia's physical activity recommendations for 5–12 year olds*. Canberra: Commonwealth of Australia; 2004.
5. Janssen I. Physical activity guidelines for children and youth. *Appl Physiol Nutr Metab* 2007;**32**:S109–21.
6. Tremblay MS, Warburton DE, Janssen I, Paterson DH, Latimer AE, Rhodes RE, Kho ME, Hicks A, Leblanc AG, Zehr L, Murumets K, Duggan M. New Canadian physical activity guidelines. *Appl Physiol Nutr Metab* 2011;**36**(1):36–58.
7. Biddle S, Sallis JF, Cavill NA. *Young and active?Young people and health enhancing physical activity: Evidence and implications*. London: Health Education Authority; 1998.
8. Cavill N, Biddle S, Sallis JF. Health enhancing physical activity for young people: Statement of the United Kingdom Expert Consensus Conference. *Ped Exerc Sci* 2001;**13**:12–25.
9. O'Donovan G, Blazevich AJ, Boreham C, Cooper AR, Crank H, Ekelund U, Fox KR, Gately P, Giles-Corti B, Gill JM, Hamer M, McDermott I, Murphy M, Mutrie N, Reilly JJ, Saxton JM, Stamatakis E. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci* 2010 Apr;**28**(6):573–91.
10. USDHHS. *Physical Activity Guidelines Advisory Committee*. Physical Activity Guidelines Advisory Committee Report. Washington, DC: U.S. Department of Health and Human Services 2008; 2008.
11. EU. European Union (EU) Working Group. "*Sport & Health*". *EU Physical Activity Guidelines*. Recommended Policy Actions in Support of Health-Enhancing Physical Activity. Brussels: EU commission; 2008.
12. WHO. *Global recommendations on physical activity for health*. Geneva: World Health Organization (WHO); 2010.
13. Caspersen CJ, Nixon PA, DuRant RH. Physical activity epidemiology applied to children and adolescents. *Exerc Sport Sci Rev* 1998;**26**(341-403):341.
14. Kessler RC, Merikangas KR, Berglund P, Eaton WW, Koretz DS, Walters MS. Mild disorders should not be eliminated from the DSM-V. *Arch Gen Psychiatry* 2003;**60**:1117–22.
15. Mechanic D. Is the prevalence of mental disorders a goog measure of the need of services. *Health Aff* 2003;**22**:8–20.
16. Basterfield L, Adamson AJ, Parkinson KN, Maute U, Li P-X, Reilly JJ. Surveillance of physical activity in the UK is flawed: validation of the health survey for England physical activity questionnaire. *Arch Dis Child* 2008;**93**(12):1054–8.
17. Janz KF. Physical activity in epidemiology: moving from questionnaire to objective measurement. *Br J Sports Med* 2006;**40**:191–2.
18. Booth ML, Okely AD, Chey T, Bauman A. The reliability and validity of the physical activity questions in the WHO health behaviour in schoolchildren (HBSC) survey: a population study. *Br J Sports Med* 2001;**35**(4):263–7.
19. Kolbe LJ. Am epidemiological surveillance system to monitor the prevalence of youth behaviors that most affect health. *Health Educ* 1990;**21**:44–8.
20. Kolbe LJ, Kann L, Collins JL. Overview of the Youth Risk Behavior Surveillance system. *Public Health Rep* 1993; **108**(suppl 1):S2–10.
21. Adamo KB, Prince SA, Tricco AC, Connor-Gorber S, Tremblay M. A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: a systematic review. *Int J Ped Obes* 2009;**4**(2):2–27.
22. Corder K, van Sluijs EM, Wright A, Whincup P, Wareham NJ, Ekelund U. Is it possible to assess free-living physical activity and energy expenditure in young people by self-report? *Am J Clin Nutr* 2009;**89**(3):862–70.
23. LeBlanc AG, Janssen I. Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity in youth. *Pediatr Exerc Sci* 2010;**22**(4):523–34.

24. Troiano E. Large-scale applications of accelerometers: New frontier and new questions. *Med Sci Sport Exerc* 2007;**39**(9):1501.
25. Troiano RP. Can there be a single best measure of reported physical activity? *Am J Clin Nutr* 2009;**89**(3):736–7.
26. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA* 2008;**300**(3):295–305.
27. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the US measured by accelerometer. *Med Sci Sports Exerc* 2008;**40**:181–8.
28. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep* 2011;**22**(1):15–23.
29. Craig CL, Cameron C, Griffiths JM, Tudor-Locke C. Descriptive epidemiology of youth pedometer-determined physical activity: CANPLAY. *Med Sci Sports Exerc* 2010;**42**(9):1639–43.
30. Ness AR, Leary SD, Mattocks C, Blair SN, Reilly JJ, Wells J, Ingle S, Tilling K, Smith GD, Riddoch C. Objectively measured physical activity and fat mass in a large cohort of children. *PLoS Med* 2007;**4**(3):e97.
31. Riddoch CJ, Mattocks C, Deere K, Saunders J, Kirkby J, Tilling K, Leary SD, Blair SN, Ness AR. Objective measurement of levels and patterns of physical activity. *Arch Dis Child* 2007;**92**(11):963–9.
32. Martinez-Gomez D, Ruiz JR, Ortega FB, Casajus JA, Veiga OL, Widhalm K, Manios Y, Beghin L, Gonzalez-Gross M, Kafatos A, Espana-Romero V, Molnar D, Moreno LA, Marcos A, Castillo MJ, Sjostrom M. Recommended levels and intensities of physical activity to avoid low-cardiorespiratory fitness in European adolescents: The HELENA study. *Am J Hum Biol* 2010;**22**(6):750–6.
33. Martinez-Gomez D, Ruiz JR, Ortega FB, Veiga OL, Moliner-Urdiales D, Mauro B, Galfo M, Manios Y, Widhalm K, Beghin L, Moreno LA, Molnar D, Marcos A, Sjostrom M. Recommended levels of physical activity to avoid an excess of body fat in European adolescents: the HELENA Study. *Am J Prev Med* 2010;**39**(3):203–11.
34. Riddoch C, Andersen L-B, Wedderkopp N, Harro M, Klasson-Heggebo L, Sardinha LB, Cooper AR, Ekelund U. Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc* 2004;**36**(1):86–92.
35. Plasqui G, Westerterp KR. Physical activity assessment with accelerometers: an evaluation against doubly labeled water. *Obesity* 2007;**15**:2371–9.
36. Armstrong N, Welsman JR. The physical activity patterns of european youth with reference to methods of assessment. *Sports Med* 2006;**36**(12):1–20.
37. Montoye HJ, Kemper HCG, Saris WHM, Wasburn RA. *Measuring physical activity and energy expenditure*. Champaign, IL: Human Kinetics; 1996.
38. Trost SG. Measurement of physical activity in children and adolescents. *Am J Lifestyle Med* 2007;**1**(4):299–314.
39. Guinhouya BC, Apété GK, Hubert H. Evaluation of habitual physical activity of children during clinical and epidemiological trials.[Evaluation de l'activité physique habituelle des enfants lors d'études cliniques et épidémiologiques]. *Sante Publique* 2009;**21**(5):465–78.
40. Bornstein DB, Beets MW, Byun W, McIver K. Accelerometer-derived physical activity levels of preschoolers: a meta-analysis. *J Sci Med Sport* 2011;**14**(6):504–11.
41. Carroquino-Salto MJ. *Percentage of physically active children and adolescents*. Fact Sheet 2.4. Bonn: WHO Regional Office for Europe & the European Environment and Health Information System (ENHIS); 2009. Report No.: RPG2_Hous_Ex1.
42. Cavill N, Kahlmeier S, Racioppi F. *Physical activity and health in Europe: evidence for action*. Copenhagen: WHO Regional Office for Europe; 2006.
43. Cardon G, de Bourdeaudhuij I. Comparison of pedometer and accelerometer measures of physical activity in preschool children. *Ped Exerc Sci* 2007;**19**:93–102.
44. Cooper AR, Page AS, Foster LJ, Qahwaji D. Commuting to school: Are children who walk more physically active? *Am J Prev Med* 2003;**25**(4):273–6.
45. Corder K, van Sluijs EM, McMinn AM, Ekelund U, Cassidy A, Griffin SJ. Perception versus reality awareness of physical activity levels of British children. *Am J Prev Med* 2010;**38**(1):1–8.
46. de Vries SI, Hopman-Rock M, Bakker I, van Mechelen W. Meeting the 60-min physical activity guideline: Effect of operationalization. *Med Sci Sport Exerc* 2009;**41**(1):81–6.
47. Dencker M, Thorsson O, Karlsson MK, Lindén C, Svensson J, Wollmer P, Andersen LB. Daily physical activity in Swedish children aged 8-11 years. *Scand J Med Sci Sports* 2006;**16**:252–7.
48. Dencker M, Thorsson O, Karlsson MK, Linden C, Wollmer P, Andersen LB. Daily physical activity related to aerobic fitness and body fat in an urban sample of children. *Scand J Med Sci Sports* 2008;**18**(6):728–35.
49. Fairclough SJ, Ridgers ND. Relationships between maturity status, physical activity, and physical self-perceptions in primary school children. *J Sports Sci* 2010;**28**(1):1–9.
50. Fisher A, Saxton J, Hill C, Webber L, Purslow L, Wardle J. Psychosocial correlates of objectively measured physical activity in children. *Eur J Public Health* 2011;**21**(2):145–50.
51. Guinhouya CB, Hubert H, Soubrier S, Vilhelm C, Lemdani M, Durocher A. Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points. *Obesity* 2006;**14**(5):774–7.
52. Kolle E, Steene-Johannessen J, Klasson-Heggebo L, Andersen LB, Anderssen SA. A 5-yr change in Norwegian 9-yr-olds' objectively assessed physical activity level. *Med Sci Sport Exerc* 2009;**41**(7):1368–73.
53. Maggio ABR, Höfer MF, Martin XE, Marchand LM, Beghetti M, Farpour-Lambert NJ. Reduced physical activity level and cardiorespiratory fitness in children with chronic diseases. *Eur J Public Health* 2010;**169**:1187–93.
54. McLure SA, Summerbell CD, Reilly JJ. Objectively measured habitual physical activity in a highly obesogenic environment. *Child Care Health Dev* 2009;**35**(3):369–75.
55. Metcalf BS, Voss LD, Hosking J, Jeffery AN, Wilkin TJ. Physical activity at the government-recommended level and obesity-related health outcomes: a longitudinal study (Early Bird 37). *Arch Dis Child* 2008;**93**(9):772–7.
56. Owen CG, Nightingale CM, Rudnicka AR, Cook DG, Ekelund U, Whincup PH. Ethnic and gender differences in physical activty levels among 9-10-year-old children of white European, South Asian and African-Caribbean origin: the Child Heart Health Study in England (CHASE study). *Int J Epidemiol* 2009;**38**(4):1082–93.
57. Steele RM, van Sluijs EM, Cassidy A, Griffin SJ, Ekelund U. Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children. *Am J Clin Nutr* 2009;**90**(5):1185–92.
58. Trayers T, Cooper AR, Riddoch CJ, Ness AR, Fox KR, Deem R, Lawlor DA. Do children from an inner city British school meet the recommended levels of physical activity? Results from a cross sectional survey using objective measurements of physical activity. *Arch Dis Child* 2006;**91**(2):175–6.
59. Vale S, Silva P, Santos R, Soares-Miranda L, Mota J. Compliance with physical activity guidelines in preschool children. *J Sport Sci* 2010;**28**(6):603–8.
60. van Sluijs EM, Skidmore PML, Mwanza K, Jones AP, Callaghan AM, Ekelund U, Harrison F, Harvey I, Panter J, Wareham NJ, Cassidy A, Griffin SJ. Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity

and Eating Behaviour: Environmental determinants in young people). *BMC Public Health* 2008;**8**(388):1–12.
61. Apété GK, Zitouni D, Hubert H, Guinhouya BC. Compliance of children in northern France with physical activity recommendations. *Perspect Public Health* 2012;**132**(2):81–8.
62. Aznar S, Naylor PJ, Silva P, Pérez M, Angulo T, Laguna M, Lara MT, Lopez-Chicharro J. Patterns of physical activity in Spanish children: a descriptive pilot study. *Child Care Health Dev* 2011;**37**(3):322–8.
63. Baptista F, Santos DA, Silva AM, Mota J, Santos R, Vale S, Ferreira JP, Raimundo AM, Moreira H, Sardinha LB. Prevalence of the portuguese population attaining sufficient physical activity. *Med Sci Sports Exerc* 2012;**44**:466–73.
64. Blaes A, Baquet G, van Praagh E, Berthoin S. Physical activity patterns in French youth - From childhood to adolescence - monitored with high-frequency accelerometry. *Am J Hum Biol* 2011;**23**(3):353–8.
65. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Objectively assessed physical activity and aerobic fitness in a population-based sample of Norweigian 9- and 15-year-olds. *Scand J Med Sci Sports* 2010;**20**:e41–7.
66. Magnusson KT, Arngrimsson SA, Sveinsson T, Johannsson E. Physical activity of 9 and 15 year-old Icelandic children - Public health objectives and relations of physical activity to gender, age, anthropometry and area of living. *Laeknabladid* 2011;**97**(2):75–81.
67. Lopes VP, Vasques CMS, Maia JAR, Ferreira JCV. Habitual physical activity levels in childhood and adolescence assessed with accelerometry. *J Sports Med Phys Fitness* 2007;**47**:217–22.
68. Martinez-Gomez D, Welk GJ, Calle ME, Marcos A, Veiga OL. Preliminary evidence of physical activity levels measured by accelerometer in Spanish adolescents; The AFINOS study. *Nutr Hosp* 2009;**24**(2):226–32.
69. Mota J, Santos MP, Guerra S, Ribeiro JC, Duarte JA. Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biology* 2003;**15**:547–53.
70. Ortega FB, Ruiz JR, Hurtig-Wennlöf A, Sjöström M. Physically active adolescents are more likely to have a healthier cardiovascular fitness level independently of their adiposity status. The European youth heart study. *Rev Esp Cardiol* 2008;**61**(2):123–9.
71. Ottevaere C, Huybrechts I, de Meester F, de Bourdeaudhuij I, Cuenca-Garcia M, de Henauw S. The use of accelerometer in adolescents and its implementation with non-wear time activity diaries in free-living conditions. *J Sport Sci* 2011;**29**(1):103–13.
72. Nilsson A, Anderssen SA, Andersen LB, Froberg K, Riddoch C, Sardinha LB, Ekelund U. Between- and within-day variability in physical activity and inactivity in 9- and 15-year-old European children. *Scand J Med Sci Sports* 2009;**19**:10–8.
73. Verloigne M, Van Lippevelde W, Maes L, Yildirim M, Chinapaw M, Manios Y, Androutsos O, Kovacs E, Bringolf-Isler B, Brug J, de Bourdeaudhuij I. Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project. *Int J Behav Nutr Phys Act* 2012;**9**(1):34.
74. Freedson PS, Sirard J, Debold E, Pate RR, Dowda M, Trost S, Sallis JF. Calibartion of the Computer Science and Applications, Inc. (CSA) Accelerometer. *Med Sci Sports Exerc* 1997;**29**(Suppl):S45.
75. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: a cross-sectional study. *Int J behav Nutr Phys Act* 2009;**6**(36):1–9.
76. Fisher A, Hill C, Webber L, Purslow L, Wardle J. MVPA Is Associated with lower weight Gain in 8-10 Year old children: A prospective study with 1 year follow-up. *PLoS One* 2011;**6**(4):e18576.
77. Guinhouya CB, Hubert H. Incoherence with studies using Actigraph MTI among children aged 6-12 yr. *Med Sci Sports Exerc* 2008;**40**(5):979–80.
78. Reilly JJ, Penpraze V, Hislop J, Davies G, Grant S, Paton JY. Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child* 2008;**93**(7):614–9.
79. Ekelund U, Tomkinson G, Armstrong N. What proportion of youth are physically active? Measurement issues, levels and recent time trends. *Br J Sports Med* 2011;**45**(11):859–65.
80. Guinhouya BC, Hubert H, Zitouni D. Need for an unbiased computation of the moderate-intensity physical activity of youths in epidemiologic studies. *Am J Prev Med* 2011;**41**(1):e1–2.
81. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008;**26**(14):1557–65.
82. Colley RC, Tremblay MS. Moderate and vigorous physical activity intensity cut-points for the Actical accelerometer. *J Sports Sci* 2011;**29**(8):783–9.
83. Puyau MR, Adolph AL, Vohra FA, Zakeri I, Butte NF. Prediction of activity energy expenditure using accelerometers in children. *Med Sci Sports Exerc* 2004;**36**:1625–31.
84. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. *Obesity Res* 2002;**10**(3):150–7.
85. Nilsson A, Ekelunf U, Yngve A, Sjöström M. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Ped Exerc Sci* 2002;**14**:75–84.
86. Rowlands AV, Powell SM, Humphries R, Eston RG. The effect of accelerometer epoch on physical activity output measures. *J Exerc Sci Fit* 2006;**4**:52–8.
87. Vale S, Santos R, Silva P, Soares-Miranda L, Mota J. Preschool children physical activity measurement: importance of epoch length choice. *Pediatr Exerc Sci* 2009;**21**(4):413–20.
88. Dencker M, Svensson J, El-Naaman B, Bugge A, Andersen L-B. Importance of epoch length and registration time on accelerometer measurements in younger children. *J Sports Med Phys Fitness* 2012;**52**(2):115–21.
89. Kim Y, Beets MW, Pate RR, Blair SN. The effect of reintegrating Actigraph accelerometer counts in preschool children: Comparison using different epoch lengths. *J Sci Med Sport* 2013;**16**:129–34.
90. Toschke JA, von Kries R, Rosenfeld E, Toschke AM. Reliability of physical activity measures from accelerometry among preschoolers in free-living conditions. *Clin Nutr* 2007;**26**(4):416–20.