Pedometer-Measured Physical Activity Patterns of Youth

A 13-Country Review

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Context: Insufficient physical activity among young people aged 5–18 years is a global public health issue, with considerable disparities among countries. A systematic review was conducted to identify studies reporting pedometer daily steps (steps·day^{-1}) in order to compile comparative, global cross-sectional data on youth physical activity patterns.

Evidence acquisition: Articles were included if they were in English, published by April 2009, and reported steps·day^{-1} for boys and girls, separately, and reported steps·day^{-1} for age groupings of no more than 4 years (e.g., 5–8 years) or combined no more than three grade levels (e.g., third- to fifth-graders). Studies could have been intervention-based but had to have reported baseline steps·day^{-1}, which would reflect unadulterated physical activity steps·day^{-1} estimates. Inverse variance weighted estimates (steps·day^{-1w}) were calculated for each country, and random effects models were estimated. Analyses were conducted in May and June 2009.

Evidence synthesis: Forty-three studies, representing young people in 13 countries (N=14,200), were included. The majority of studies were from the U.S. (17/43). Overall, there was considerable variation within and among countries in steps·day^{-1w}. Boys and girls from European and Western Pacific regions had significantly more steps·day^{-1w} than young people from the U.S. and Canada. Significantly lower steps·day^{-1w} estimates for girls were observed for studies that combined measured steps·day^{-1} for weekdays and weekend days, in comparison to weekdays only.

Conclusions: Limited sample sizes and non–population-based data preclude definitive statements regarding projected steps·day^{-1} within countries. Nevertheless, these findings provide preliminary information for policymakers and researchers on the extent of the disparities among countries in the physical activity patterns of young people.
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Introduction

The global health burden of physical inactivity is increasingly recognized as a major public health problem for both developing and developed countries.[1,2] Declines in physical activity are intricately linked to increases in childhood and adolescent obesity[3–7] and metabolic syndrome,[8] and they parallel the rapid secular decline in youth cardiovascular fitness.[9] Worldwide, 1.9 million deaths annually are attributable to noninfectious diseases related to physical inactivity.[2] Although there is little doubt that physical activity plays an important role in reversing these trends, public health practitioners, despite best efforts, have made little headway.[10,11]

Globally, the prevalence of young people (aged 5–18 years) who are physically inactive, in conjunction with the soaring prevalence of obesity, is a major threat to health in the 21st century.[2] However, considerable disparity exists among countries in the physical activity levels of young people. In some countries, physical activity levels are notably high, and hence, the young people are on average healthier.[12,13] Conversely, in some countries, young people consistently demonstrate low levels of

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physical activity, high levels of obesity, and hence are on average less healthy.[3,12–14] The focus here is not on whether the former countries should be emulated, but rather on important lessons gleaned from their experience that may benefit "less healthy" countries.

Public health advocates and policymakers gain from cross-national comparisons in several important ways. Comparisons help identify global rankings of physical activity and inactivity patterns. These rankings assist with establishing priorities for improving physical activity levels and serve as a benchmark for physical activity within individual countries. Population-level data can also serve to inform policymakers regarding trends in physical activity and inactivity patterns over time. As mentioned previously, comparisons afford the opportunity to identify model countries that can inform public health planning in less-active countries. Yet, aside from a few studies,[12,13,15–17] not many global comparisons of physical activity patterns are available.

Global problems require global solutions, or at a minimum, global studies.[18] Often the spark that ignites global awareness of the magnitude of an issue is the compilation of existing studies.[6,13,19] Comprehensive reviews, therefore, provide useful information regarding the patterning of physical activity among countries.[13] Efforts to compile such reviews, however, are complicated by the many forms of measurement used in physical activity data. In the absence of standardized instrumentation (e.g., the International Physical Activity Questionnaire [IPAQ]),[16] aggregating activity levels from either self-report or objective measures (e.g., accelerometers) is methodologically difficult because of differences in the units reported (e.g., estimated energy expenditure from varying formulas, differences among accelerometer cutpoints).[13,20,21] Thus, there is little information on global patterns of youth physical activity.

The use of pedometers to quantify physical activity has grown over the past decade. Pedometers also provide one of the few forms of physical activity assessment with a standard metric (most commonly, steps·day^{-1}). Pedometers, therefore, are one of the few valid and reliable objective measures of youth physical activity[22] that allow direct comparisons across studies. This aspect of pedometer use has led to a growing body of literature reporting daily physical activity levels of young people among numerous countries, in addition to the development of guidelines for recommended steps·day^{-1} for young people. Recommendations range from 11,000 to 16,500 steps·day^{-1} for boys and girls.[23–26] Data on the extent to which young people from various countries achieve recommended pedometer activity levels are limited, however, and comparisons among countries are relatively few.[12,25] The purpose of the current study was to compile and explore physical activity patterns of young people (≤18 years) from studies that measured physical activity via pedometery from around the world.

Evidence Acquisition

A systematic review of the literature was conducted between December 2008 and April 2009 to identify all peer-reviewed papers published by April 2009 that reported daily pedometer-derived steps (i.e., steps·day^{-1}) of children and adolescents (≤18 years). A Boolean search for relevant articles was conducted in PubMed, EBSCOhost, and Google Scholar with pedomet* and the following combination of keywords: child*, adolesc*, and youth*. Additional searches were carried out on citations of included papers and published reviews on youth physical activity and pedometers. Articles were included if they were published prior to May 2009 and reported steps·day^{-1} for boys and girls, separately, for age groupings of no more than 4 years (e.g., 5–8 years) or combined no more than three grade levels (e.g., third- to fifth-graders). Studies could have been intervention based but had to have reported baseline steps·day^{-1}, which would reflect physical activity steps·day^{-1} estimates that were unaffected by an intervention. Analyses were conducted in May and June 2009.

Studies were excluded if they reported only steps·day^{-1} for youth divided into BMI categories (i.e., overweight versus healthy weight)[25,27]; data were previously published and analyzed for a secondary purpose[28]; data represented overweight youth only; data for age ranges were combined for more than 4 years or three grade levels; data for boys and girls were combined[29]; data were collected for less than 1 complete day (e.g., physical education class or recess only); or data were collected on youth from a special population (e.g., indigenous peoples, Amish).[30,31]

Information was extracted from identified articles, and data were entered into specially designed templates for analysis. The following information was extracted from each article: country; days on which data were monitored (i.e., weekdays, weekend days, or weekdays plus weekend days); sample size; age; gender; type of pedometer used; and mean steps·day^{-1} and SD. Articles in which seasonal variations were of interest, the spring/fall season was selected as representative and was included in the review, because most data collection occurs during these times.

Aggregation of Data and Statistical Analysis

For ease of interpretation, when studies reported the mean age of the sample, age was rounded to the nearest whole year (e.g., 9.5 to 10 years; 11.4 to 11 years). Where age of the sample was not reported, grade level was used to infer the average expected age for a given grade-level range. For studies within each country, the mean steps·day^{-1}; sample size (n); and SD were used to create an inverse variance sample-weighted estimated steps·day^{-1w} by weighting the contribution of each study's mean steps·day^{-1} by the sample size divided by the variance (i.e., square of the SD).[32] For studies where the SDs of steps·day^{-1} were not reported (6/43 studies), the SD was estimated by predicting the sample-weighted coefficient of variance (CV) for all studies with the mean steps·day^{-1}, gender, and age. The predicted CV was then used to determine the SD of those studies by multiplying the mean steps·day^{-1} by the predicted CV. For countries where multiple studies reported mean steps·day^{-1} for a single age and gender (e.g., girls aged 8 years), the reported steps·day^{-1} value was multiplied by its respective inverse variance weight; then the values were summed and divided by the sum of the weights to arrive at the steps·day^{-1w} estimate. Studies were divided based on the inclusion of weekend days in the total steps·day^{-1} versus weekdays only. Across studies within a country for a given age (whole years), steps·day^{-1w} were calculated and plotted versus age.

Random effects models, accounting for the clustering of reported steps·day^{-1} within studies (i.e., a single study could have reported multiple age–gender steps·day^{-1} values), were used to estimate the average sample-weighted steps·day^{-1w} across the age range (5–18 years) for all studies for boys and girls, and for weekdays versus weekdays plus weekend days, separately. Age, age squared, and the square root of age were included in the models to account for the nonlinear change in steps·day^{-1} from 5 to 18 years. Random effects models were used to test the difference in weekday only versus weekday plus weekend-day data collection. Tests of significance were also conducted to determine if there was a difference in steps·day^{-1w} for length of pedometer assessment (i.e., number of days). In addition, steps·day^{-1w} for each age–gender strata within each country were compared to established pedometer steps·day^{-1} guidelines for young people aged 5–12 years[24–26] and those aged 5–19 years.[23]

Comparisons among individual countries were not possible because of the limited sample sizes and ages represented in the majority of the studies. Therefore, countries were placed into regional groupings based on WHO[33] regional distributions in order to compare steps·day^{-1w}. The groupings were as follows: Western Pacific (Australia and New Zealand); Europe (Sweden, Switzerland, Belgium, France, Greece, Czech Republic, and the United Kingdom); and the Americas (Canada and the U.S.). Two countries (China and Saudi Arabia) were the only ones from their WHO regions (Southeast Asia and Eastern Mediterranean, respectively) and therefore were grouped together in an "Other" category in the models. Regional groupings were dummy-coded and entered into the random effects models. The region containing the U.S. and Canada was used as the reference group for these analyses because, in general, it produced some of the lowest steps·day^{-1w} values across age–gender comparisons. All analyses were conducted using Mplus, version 5.2 (www.statmodel.com).

Evidence Synthesis

The database searches yielded a total of 356 hits across all combinations of keywords. After excluding articles that did not meet inclusion criteria (see above), a total of 43 studies, representing 13 countries and approximately

Table 1. Included country characteristics and representation

Region	Country	No. of studies	References	Ages represented (years)														Sample size
				5	6	7	8	9	10	11	12	13	14	15	16	17	18	
North America	Canada	1	34						●	●								133
	U.S.	17	26, 35–50		●	●	●	●	●	●	●	●	●	●	●	●	●	4,228
Europe	Belgium	1	51	●														122
	Czech Republic	1	52		●	●												176
	France	1	53						●		●	●	●	●	●			478
	Greece	1	54								●	●						221
	Sweden	4	55–58			●	●	●	●	●	●	●	●		●		●	1,845
	Switzerland	1	59									●						233
	United Kingdom	6	60–65					●	●									1,255
Other	China	1	66									●	●	●				144
	Saudi Arabia	2	67, 68	●				●	●		●							520
Western Pacific	Australia	4	69–72				●		●		●		●	●	●			2,222
	New Zealand	3	73–75		●	●		●		●		●		●				2,623
Total		43		●	●	●	●	●	●	●	●	●	●	●	●	●	●	14,200

14,200 young people, were retained for analysis. The primary brand of pedometer used across studies was the Digiwalker (66%). The final summary of included articles is presented in Table 1. The majority of the studies (17/43) were from the U.S., 30% of the total sample. Regional representation consisted of the following proportions: Other (5%); Europe (30%); Western Pacific (34%); and Americas (31%). The median number of days physical activity was monitored was 4. The length of monitoring of steps·day^{-1} had no significant effect on any of the estimates.

Results from the random effects models comparing steps·day^{-1w} from studies reporting weekday only versus weekday plus weekend steps·day^{-1w} indicated that for those aged 5–18 years, steps·day^{-1w} measured during weekdays only were approximately 1050 steps·day^{-1w} (95% CI=741, 2522) more for girls in comparison to the value for weekdays plus weekend days. The results of the comparison for weekdays versus weekdays plus weekend days for boys was inconclusive (974 steps·day^{-1w}; 95% CI=−203, 2150).

The final weighted steps·day^{-1w} estimates for boys and girls by age (whole years) are presented in Figure 1 (weekdays only) and Figure 2 (weekdays plus weekend days). Considerable variation among countries in steps·day^{-1w} can be seen for both genders and monitoring time frames (see Figures 1 and 2).

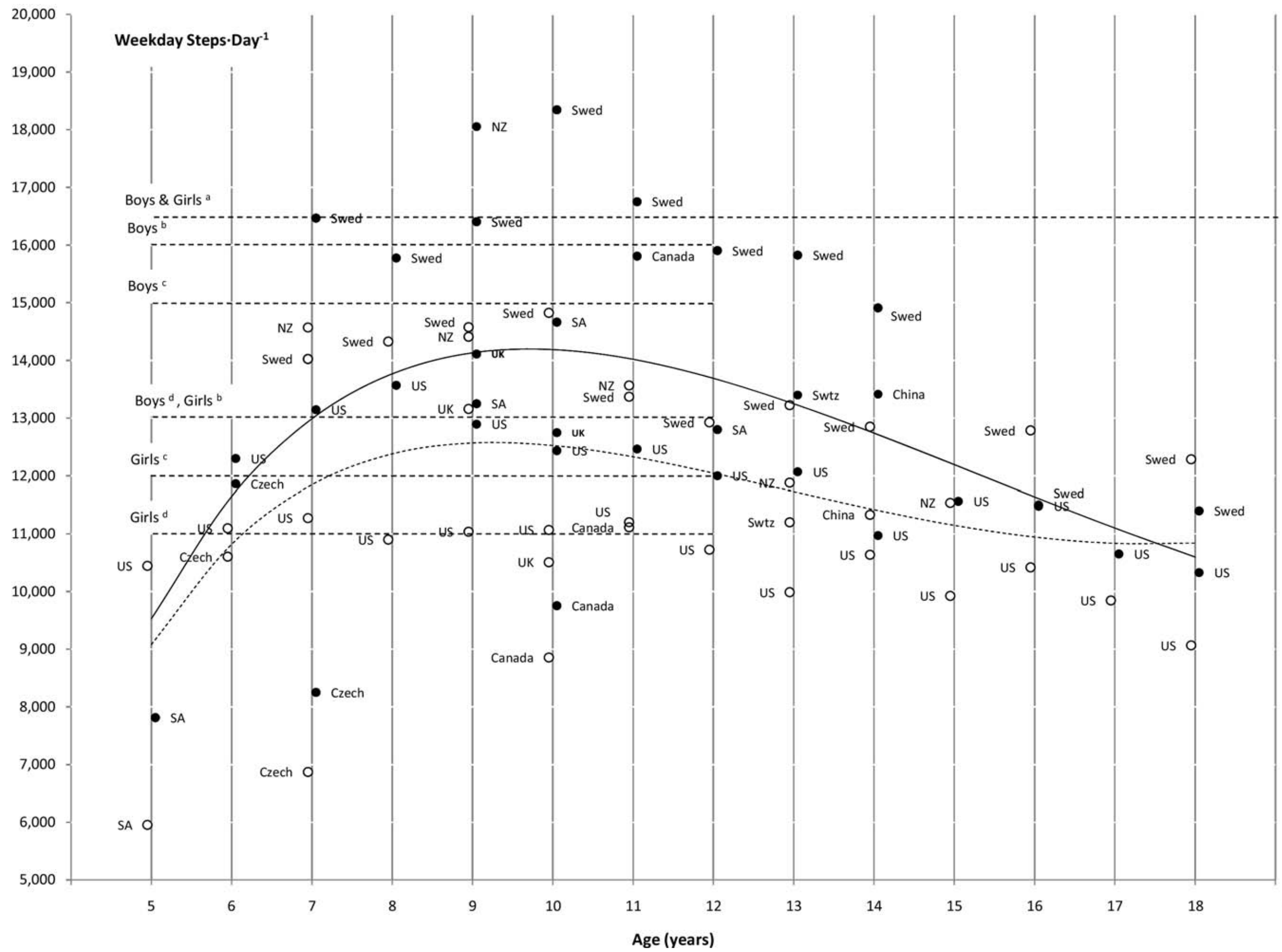

Figure 1. Weighted steps·day^{-1w} for studies reporting weekday steps across countries by age for boys (●, black circles) and girls (○, white circles), separately

Note: Curved lines represent the estimated average steps·day^{-1w} from all studies for boys (–, solid line) and girls (---, dashed line), separately.

[a]Steps·day^{-1} guidelines (from Canada[23]) for boys and girls aged 5–19 years, based on an equivalence to 90 minutes of moderate to vigorous physical activity

[b]Steps·day^{-1} guidelines (from New Zealand[24]) for boys and girls aged 5–12 years, based on bioelectric impedance body fat percentage

[c]Steps·day^{-1} guidelines (from Sweden, Australia, and the U.S.[28]) for boys and girls aged 5–12 years, based on BMI

[d]Steps·day^{-1} guidelines (from the U.S.[26]) for boys and girls aged 5–12 years, based on mean values

Czech, Czech Republic; NZ, New Zealand; SA, Saudi Arabia; Swtz, Switzerland; Swed, Sweden; UK, United Kingdom

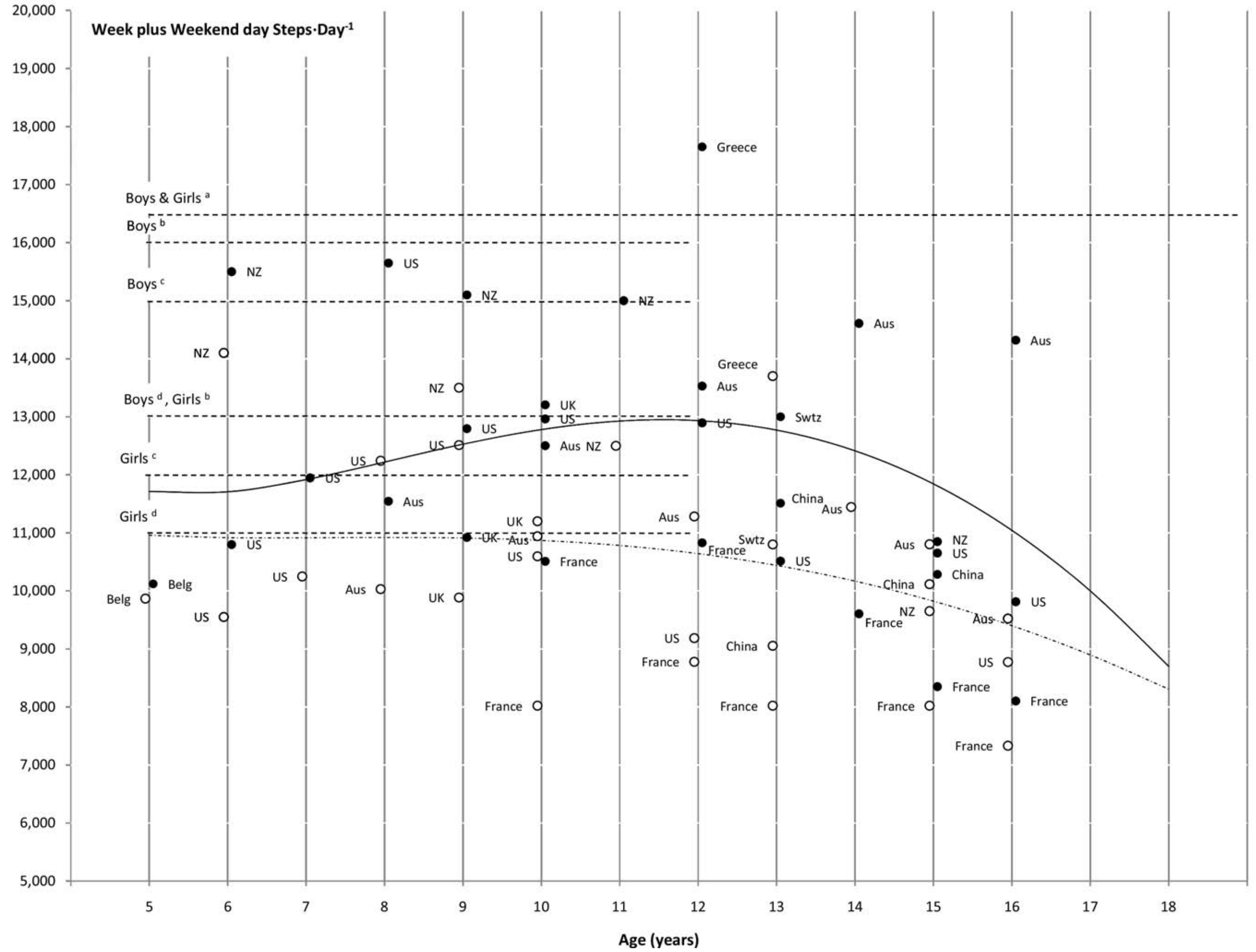

Figure 2. Weighted steps·day^{-1w} for studies reporting weekday plus weekend-day steps across countries by age for boys (●, black circles) and girls (○, white circles), separately
Note: Curved lines represent the estimated average steps·day^{-1w} from all studies for boys (–, solid line) and girls (---, dashed line), separately.
[a]Steps·day^{-1} guidelines (from Canada[23]) for boys and girls aged 5–19 years, based on an equivalence to 90 minutes of moderate to vigorous physical activity
[b]Steps·day^{-1} guidelines (from New Zealand[24]) for boys and girls aged 5–12 years, based on bioelectric impedance body fat percentage
[c]Steps·day^{-1} guidelines (from Sweden, Australia, and the U.S.[28]) for boys and girls aged 5–12 years, based on BMI
[d]Steps·day^{-1} guidelines (from the U.S.[26]) for boys and girls aged 5–12 years, based on mean values
Czech, Czech Republic; NZ, New Zealand; SA, Saudi Arabia; Swtz, Switzerland; Swed, Sweden; UK, United Kingdom

For weekday steps·day^{-1w} (Figure 1), a notable difference was observed for boys from Sweden, where steps·day^{-1w} are greater than they are in almost all other countries, apart from one (New Zealand, for those aged 9 years). For girls, a similar pattern is observed. In addition, boys and girls from the U.S. have, across the age continuum, the lowest or next-to-lowest steps·day^{-1w} values in comparison to all other countries. Random effects models comparing differences among regions supported these observations, with boys and girls from European countries, on average, taking, respectively, on average 2389 and 2375 steps·day^{-1w} more than young people from the U.S. and Canada. In addition, Western Pacific girls took 3340 steps·day^{-1w} more than girls from the U.S. and Canada. No comparisons among boys from the Western Pacific region could be made for weekday steps·day^{-1w} because of insufficient representation of boys from this region. No difference was observed between young people from the Other region and those from the U.S. and Canada.

For weekday plus weekend-day steps·day^{-1w} estimates, the ordering of countries was less clear (Figure 2). Boys from Australia and New Zealand consistently demonstrated some of the highest steps·day^{-1w} values in compari-

Table 2. Weighted steps·day^{-1w} comparisons for studies reporting weekdays only and weekdays plus weekend days among geographic regions for boy and girls, separately

Gender	Measurement	Region	Steps·day^{-1} (95% CI)^{w}
Boys	Weekdays	Other	606 (−1154, 2366)
		Europe	2389 (1060, 3717)
		Western Pacific[a]	NA
	Weekdays + weekend days	Other	−1209 (−3228, 811)
		Europe	−1210 (−2684, 265)
		Western Pacific	1839 (288, 3390)
Girls	Weekdays	Other	−310 (−3687, 3067)
		Europe	2375 (1351, 3399)
		Western Pacific	3340 (2440, 4240)
	Weekdays + weekend days	Other	38 (−2216, 2291)
		Europe	198 (−1053, 1448)
		Western Pacific	1604 (318, 2889)

Note: WHO regional groupings: Other = China and Saudi Arabia; Europe = Sweden, United Kingdom, Belgium, Czech Republic, France, Greece, Switzerland; Americas = Canada and U.S. (comparison group). Random effects models controlled for the linear and nonlinear effects of age on steps·day^{-1w}

[a]Unable to estimate because only one study for this region was included in the review reporting steps·day^{-1} for this time frame

son to all other countries, apart from two (U.S. boys aged 8 years, United Kingdom boys aged 10 years, and boys from Greece aged 12 years). A similar pattern was observed for girls. The Western Pacific region had, on average, 1839 and 1604 steps·day^{-1w} more, respectively, than boys and girls from the U.S. and Canada (see Table 2).

Average sample-weighted steps·day^{-1w} for those aged 5–18 years across both monitoring time frames suggested similar patterns in activity, with the most steps·day^{-1w} observed for those aged 9–13 years, with a marked decline occurring thereafter. The difference between the two estimates occurs at the youngest ages (<8 years), where for weekdays, steps·day^{-1w} values are lower and gradually increase to a peak around age 9 years (Figure 1). Conversely, for weekdays plus weekend days, steps·day^{-1w} values are greater for those aged 5 years, with lower estimates for those aged 6–12 years, followed by a steeper decline among those aged 12–18 years (Figure 2).

Discussion

Although only one study represented several of the countries, we found clear differences in levels of physical activity as recorded by pedometer among young people from individual countries and regions. These findings are consistent with studies examining the worldwide decline in levels of cardiovascular fitness[9,14,76] and increases in the prevalence of overweight youth.[6–8] Across age, gender, and physical activity–monitoring time frame (i.e., weekdays versus weekday plus weekend days), the Western Pacific region (Australia and New Zealand) demonstrated some of the highest, if not the highest, physical activity levels. Swedish youth are also some of the most physically active. Furthermore, the differences among countries indicate that a single global steps/day recommendation for a given age or gender may be unrealistic.

The reasons that young people in the Western Pacific region and several European countries were most physically active are unclear and cannot be directly inferred from the original studies. These findings do, however, focus attention on these countries and what might be learned from them. From a socioecologic perspective,[77,78] these differences imply individual, environmental (both social and physical), policy, and geopolitical variations that have created overall environments and societies that beneficially promote physical activity. Higher levels of physical activity may be a result of less auto-centered lifestyles, and environments where walking and biking are more common. The least-active countries, such as the U.S., rely more heavily on cars for short trips.[79] The differences may also be a result of varying opportunities to be physically active, either within school (e.g., in daily physical education classes) or outside of school, such as participation in community sports leagues.

Many countries consistently exhibited low levels of physical activity, notably the U.S.[80] Countries seeking to adopt a lifestyle more similar to that in the U.S. should, therefore, be cautious in making environmental and/or policy-level changes toward this end, such as more motorized transportation. Doing so may potentially remove opportunities for young people to be physically active.[81]

A major barrier in evaluating global patterns of physical activity is a lack of standardized measures. This has led to the development of self-report instruments (e.g., IPAQ, www.ipaq.ki.se/ipaq.htm) and multinational projects[82] designed to obtain comparable estimates of physical activity across nations. Self-reported physical activity, although informative, generally provides an overestimate of activity levels when compared to objectively measured physical activity,[83,84] and it therefore serves as a coarse proxy only. Although there is no one "right" measure of physical activity,[85] it is accepted that objective measures (e.g., accelerometers, pedometers) provide a more precise estimate of physical activity.

One of the arguments against objective monitoring of physical activity at the population level is the cost-prohibitive nature of collecting such data. However, as demonstrated by the more recent NHANES[85,86] and Canadian Fitness and Lifestyle Research Institute[23] surveillance study, objective monitoring can be done at a population level, and pedometers may be an inexpensive method. The main critique against pedometers has been their inability to provide estimates of moderate to vigorous physical activity (MVPA). However, with the advancement of technology, new features have been introduced[87] to pedometers that allow for an estimate of MVPA based on steps·minute^{-1}. In addition, unlike accelerometers,[20,21] pedometers have a uniform unit of measure (i.e., steps·day^{-1}) that allows for direct comparisons across studies. Thus, pedometers serve as one of the few objective measures that can be readily used to identify global patterns of physical activity.

This study has several limitations. For a majority of the countries, only a few studies, representing a limited age range, were available for review, and many of the studies were not designed to collect data on a nationally representative sample. In addition, there were too few countries represented to further divide regions into smaller parcels (e.g., Mediterranean, Eastern European),[8] limiting inferences about patterns of activity by region. Variations in data collection procedures may also account for the differences in observed steps·day^{-1}, and because younger youth are more physically active than their older peers,[28,88] the aggregation of ages in 3-year age spans may downwardly bias steps·day^{-1} estimates for younger youth. Finally, a number of studies were excluded because they reported data on youth across a large age span (e.g., those aged 5–12 years), on divisions of healthy- and unhealthy-weight young people, or were from select populations (e.g., indigenous people). These factors limit the inferences that can be drawn from the analyses.

Conclusion

Global monitoring of population levels of youth physical activity can inform policymakers and public health advocates regarding the health and well-being of children and adolescents. The information presented in this study serves as preliminary data for such efforts. This study demonstrates that the use of a widely available, inexpensive tool such as a pedometer might be a feasible way to develop cross-national comparisons of physical activity among young people.

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Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2009.09.045.