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BMI-referenced standards for recommended pedometer-determined steps/day in children

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Abstract

Background: Recommended levels of youth physical activity (PA) should emerge from data related to important health outcomes. The purpose of the present study was to establish criterion-referenced standards for PA (using pedometer-assessed steps/day) related to healthy body composition. **Methods:** This is a secondary analysis of an existing data set (including pedometer-assessed PA and objectively measured BMI) of 1,954 children (995 girls, 959 boys; ages 6-12 years) from the U.S.A., Australia, and Sweden. The contrasting groups method (Safrit, 1986) for establishing criterion-referenced cut points was used to identify optimal age- and sex-specific standards for steps/day related to international BMI cut points for normal weight and overweight/obesity. **Results:** The selected cut points for steps/day for 6-12 year olds were 12,000 steps/day for girls and 15,000 steps/day for boys. **Conclusions:** The analytical process undertaken in this study illuminated the difference in previously used norm-referenced standards vs. criterion-referenced standards based on BMI categories. The steps/day cut points established herein, using an international sample, are higher than previously suggested normative standards but are not inconsistent with recent advances in our understanding of PA needs in youth. This analysis provides the foundation for cross-validation and evaluation of these BMI-referenced steps/day cut points in independent samples and with longitudinal study designs.

MeSH Keywords: Exercise, anthropometry, obesity, child

Introduction

The worldwide obesity epidemic includes a trend towards increased prevalence of overweight and obesity in youth (1, 2). Although obesity is emerging as a problem in developing countries (3, 4) as well, the very high and increasing prevalence (regardless of specific standards used to define overweight/obesity) reported in developed countries is cause for more immediate concern. For example, in the U.S.A, direct measures of body mass and height obtained through the National Health and Nutrition Examination Survey (NHANES) indicate that ≈15% of 6-19 year olds were classified as overweight (95th percentile of age- and sex-specific body mass index derived from 5 previous NHANES surveys) in 1999-2000, up ≈5% from 1988-1994 (5). Using the 85th percentile (as a cut point for overweight) and the 95th percentile (as a cut point for obesity) derived from international standards (6), 19-23% of Australian children and adolescents were overweight or obese (7). Using the 91st and 98th percentiles of body mass reference curves for the U.K. (8), to respectively define overweight and obesity from self-reported height and weight, ≈11% of Swedish boys and ≈5% of Swedish girls ages 12, 15, and 18 years were overweight; the corresponding values for obesity were ≈8% and ≈4% (9).

A potential contributor to this epidemic is a shift towards ever-diminishing physical activity behaviors (10). For example, only 21-22% of American youth participate in physical education classes (11, 12) and evidence suggests that children are moderately or vigorously active less than 9% of actual class time (13). Transportation surveys in the U.S., indicate an increase in the use of motorized vehicles, including for purposes of chauffeuring children (14) and the number of trips made by children by foot or by bicycle has declined 37% between 1977 and 1995 (15). In fact, ≈50% of 5-15 year old American school children are driven to school in privately-owned motor vehicles compared to only ≈10% who walk (16). Most recently, a report of school transportation modes in a Southern U.S. state indicates that almost 42% of children living ≤ 1 mile from school are usually driven there in a private motor vehicle (17). Finally, 65-67% of 8-16 year old American youth watch television ≥ 2 hours/day (18, 19). Such elevated levels of television viewing have been related to youth overweight and obesity (18-22).

In 1996, the U.S. Surgeon General (23) endorsed public health recommendations (24) that all individuals over the age of 2 years accumulate 30 minutes or more of at least moderate intensity activity, on most, if not all, days of the week. Similar recommendations were made specifically for adolescents (25). Accumulating evidence suggested that a majority of young people meet these recommendations, however, leading to questions about their appropriateness (26). Since that time researchers have suggested that the recommendations be modified to higher levels of duration (26) and/or intensity (27) for optimal functioning. In 1998, a convened symposium in the U.K. recommended that all young people should engage in physical activity of at least moderate intensity for one hour per day (28). Guidelines established by the National Association for Sport and Physical Education (NAPSE) in 1993 (29) agreed that elementary school children should be active for at least 30-60 minutes daily and the most recent revision of that document suggests the accumulation of at least 60 minutes and up to several hours of moderate to vigorous physical activity daily (30). A recent report from the Institute of Medicine reinforces this higher recommendation (i.e., at least one hour daily) for both adults and children (31) if body fat maintenance is the objective.

Setting appropriate benchmarks or cut points for health-related physical activity is hampered by imperfect assessment of this behavior. Most of the data previously collected has been based on self-reported surveys, the limitations of which are well-known (32), especially for younger children (33). In recent years there has been an increased interest in objective monitoring of daily physical activity using simple and inexpensive pedometers (34-36). Pedometers are small, light-weight, unobtrusive instruments that have been accepted by researchers as practical physical activity assessment tools that are particularly sensitive to ambulatory activities (37-39). Accumulated evidence indicates that pedometers are acceptably agreeable compared to accelerometers, direct observation, measures of energy expenditure, and self-report (40). Correct interpretation of steps/day in relation to desired health outcomes demands the development of appropriate and pedometer-specific cut points. Although 10,000 steps/day appears to be readily accepted by the media (41-44) and can be traced to Japanese health promotion efforts (45), emerging data on children indicates that this value is likely too low to elicit substantial health benefits in this population segment. Limited evidence shows that 8-10 year old U.K. children to take 12,000-16,000 steps/day (lower for girls than boys) (46). The 2001-2002 President’s Challenge Physical Activity and Fitness Awards Program (47) also recognized that the popular 10,000 steps/day cut point was likely too low for children by recommending instead that children accumulate 11,000 steps (for girls) to 13,000 steps (for boys) at least 5 days a week for a standard healthy base. These recommendations were based on norm-referenced standards determined from a U.S. sample (48); the validity of even this level of steps/day to prevent or decrease overweight and obesity in youth is unknown.

In an attempt to answer, “How many steps are enough?”, we can turn to experts who advocate the use of appropriate statistical techniques for establishing criterion-referenced performance standards on physical fitness tests (49-52). Criterion-referenced standards are set based on their likelihood to elicit a specific benefit (53), and are therefore preferable to norm-referenced standards. Simply put, recommended levels of steps/day should emerge from data related to important health outcomes (in this case BMI, an accepted indicator of relative obesity). The purpose of the present study was to establish preliminary criterion-referenced standards for physical activity using pedometer-assessed steps/day related to healthy body composition in youth as indicated by international cut points for BMI (6).

Methods

This is a secondary analysis of an existing data set of 1,954 children (995 girls, 959 boys; ages 6-12 years) from the U.S.A., Australia, and Sweden. Recruitment and data collection methods have been described previously in detail (54) and are summarized again here. The previous paper focused on between-country differences in steps/day and BMI. The statistical analysis undertaken herein has not been performed previously and is therefore novel.

Participants

Data were collected during the 2000 school year. Within each country, children (ages 6-12 years) were recruited from a local school district. Specific schools were selected based on their accessibility to local researchers and their willingness to participate. American children (386 girls, 325 boys) came from a moderate size (400,000) urban community in Arizona. Australian children (285 girls, 278 boys) came from a large (1,000,000) urban city in Queensland. Finally, Swedish children (324 girls, 356 boys) came from two smaller (60,000 and 20,000) Southeast coast communities. The greatest ethnic diversity was apparent in the American sample: 53% White, 30% Hispanic, 4% Native American, 3% African American, 2% Pacific Island/Asian, and 8% Other-mixture of ethnicities. In both Sweden and Australia the students were predominantly White. Ethical approval for study in each country was granted by local university Institutional Review Boards. All children involved submitted a written informed consent form signed by their parents.

Body Mass Index

Body mass and height were directly measured without shoes. All data were transformed to metric equivalents (i.e., kilograms and meters) prior to analysis. Body mass index (BMI) was computed as kg/m^2.

Pedometer-determined Physical Activity

Throughout monitoring, pedometers (My Life Stepper, MLS-2000, Yamax, Tokyo, Japan) were sealed (with a cable tie) to prevent behavior modification due to access to recorded feedback. Children were also familiarized with the pedometers during a physical education class prior to the scheduled monitoring frame. On the first day of monitoring (Monday), children were instructed on pedometer attachment (at the waist), its removal (only during showering, bathing, swimming, or sleeping), and re-attachment each morning before going to school. They were also asked not to tamper with the cable ties and to go about their normal activities during the monitoring frame (four consecutive school days). Four days of monitoring is a sufficient length of time to determine habitual activity levels in children (55, 56). At school each morning, research staff collected the pedometers, recorded steps taken, and then re-sealed and returned them to children (within one hour) to begin the next day of monitoring. During this time, 8-12 year old children were asked to complete a brief survey to verify that the pedometers were worn for the entire time on the previous day. The survey was not considered developmentally appropriate for younger children. Survey results were used to identify those participants who reported removing their pedometer for ≥1 hour; their data were subsequently deleted prior to analysis.

Data Treatment and Statistical Analysis

A distribution of average steps/day for each sex and age group was computed and smoothed to 1000 step/day increments. Smaller increments were rejected (after testing) due to lack of clarity. International sex- and age-appropriate BMI cut points (6) were used to discriminate weight status as either normal weight or overweight/obese strata. The analysis sample was comprised of all individuals identified as overweight/obese and a randomly drawn selection of sex- and age-matched normal weight individuals (representativeness of the drawn sample was verified against the source).

The contrasting groups method (57) for establishing criterion-referenced cut points is predicated on the existence of dichotomous groups with respect to the criterion (i.e., BMI cut point discriminating weight status). This assumption was tested by examining differences in steps/day between normal weight and overweight/obese strata using a two-tailed independent samples *t*-test.

Selection of an optimal age- and sex-specific criterion standard for steps/day is based on overall examination and interpretation of several computed statistical indices: 1) probability of correct decisions; 2) misclassification of errors; 3) validity coefficient; and, 4) utility analysis (57, 58). Each is described briefly below; a more complete discussion of the contrasting groups technique and detailed statistical calculations of indices are presented elsewhere (58).

The *probability of correct decisions* is a computed score that indicates the probability of correct classifications of “true normal weight” and “true overweight/obese” versus the probability of incorrect classifications of “false normal weight” and “false overweight/obese”. The cut point corresponding with the highest score is considered optimal.

Misclassification errors are Type I (false overweight/obese) and Type II error (false normal weight) probabilities that estimate the likelihood of incorrectly classifying someone on the basis of body mass index. In this case, a Type I error would occur when an individual is normal weight but does not achieve the steps/day cut point and is incorrectly classified as overweight/obese. A Type II error occurs when an individual is overweight/obese but achieves the steps/day cut point and is incorrectly classified as normal weight. In this case, the cut point corresponding with the lowest score is considered optimal.

The *validity coefficient* is the relationship between the body mass index and weight status (i.e., normal or overweight/obese). This is a measure of the extent to which a predictor classification of individuals (based on a particular cut point) accurately estimates weight status. The cut point corresponding to the highest validity coefficient will yield the highest probability of correct decisions.

Utility analysis is the final step in the contrasting-groups method of establishing criterion references. This process provides an estimate of the expected maximum utility for a given cut point. First, expected disutility and utility are computed. Disutility is the expected loss (misclassification from the “true overweight/obese” status) associated with a given cut point. Again, both Type I and Type II errors can occur here. Expected utility is calculated as the sum of the proportions of both error types after assigning weights to these misclassifications. The weighting reflects the investigators’ judgment that a Type I error is equally as serious as a Type II error. Finally, expected maximum utility represents the sum of expected disutility and utility. This sum is then multiplied by the sample size of the combined groups. The largest resulting value indicates the optimal cut point for classifying weight status by steps/day.

Selection of the final BMI-referenced standard for each sex and age group was based on consideration of all statistical indices simultaneously (i.e., a higher probability of correct classifications, a lower probability incorrectly classifications, a higher validity coefficient, lower expected disutility, and higher expected utility). Finally, the median of all optimal steps/day cut points for 6-12 year olds was computed for each sex.

Results

Mean±SD steps/day are presented in Table 1 for each sex and age group, stratified for weight status as either normal weight or overweight/obese. The *t*-test results were consistently significant for all sex and age strata with only two exceptions (6 and 7 year old girls). In both these cases the number of subjects was small compared to other strata.

A summary of the analytical steps (i.e., probability of correct decisions, misclassification of errors, validity coefficient, utility analysis) undertaken to evaluate and select step/day cut points (indicated by *) for each age group is presented in Table 2 (girls) and Table 3 (boys). Based on optimal criterion-referenced cut points indicated for each sex and age group, the median cut point for steps/day for 6-12 year olds was 12,000 steps/day for girls and 15,000 steps/day for boys.

Discussion

In this secondary analysis of an existing international database, we used accepted analytical procedures to establish BMI-referenced standards for pedometer-determined physical activity. Such cut points are necessary to guide surveillance, intervention, and evaluation. For example, the proportion of youth meeting or falling short of set cut points can be reported, cut points can be used as behavior change goals in the course of intervention, and they can be consulted when evaluating the impact of programs as well as environmental and policy changes. The cut points established herein are preliminary, however, and must be submitted to rigorous cross-validation on an independent sample prior to universal acceptance. Clearly, these are cross-sectional data and conclusions about causality are therefore limited. Longitudinal study designs are warranted to ascertain causal relationships between steps/day and indicators of body composition.

Although the correlation between BMI and steps/day is modest at best (54), it is not likely that a linear relationship best represents the link between physical activity and the fluctuating BMI curve representing growing and developing children (6). Our decision to link steps/day to international sex- and age- specific BMI cut points (6) discriminating normal weight and overweight/obesity is justified based on the overwhelming evidence of an increasing world-wide obesity epidemic (1, 2) and further supported by the statistical differences in steps/day identified herein between sex and age group BMI category pairs (with the exception of young girls). Williams et al.(59) have shown that those who fail to meet body fat standards using skinfolds are more likely to have higher blood lipids and higher blood pressure than non-fat peers. The social, health, and economic costs associated with the prevalence and severity of obesity in youth has dramatically increased over the past 20 years (60). Other youth-appropriate health-related criteria that may be related to steps/day in future investigations include blood pressure (61, 62).

In contrast to the pedometer used herein, the CSA accelerometer utilizes an internal timing mechanism to recording movement parameters over brief units of time (typically one minute). Activity count cut points developed in laboratory studies allow translation of CSA accelerometer-determined physical activity to duration (and bouts) of specific intensity categories (63). Trost and colleagues (64) previously used CSA accelerometers to assess physical activity in obese (defined using age-, race-, and sex-specific 95th percentile for BMI from NHANES-1) and non-obese children (mean age 11.4 years). Obese children accumulated lower total activity counts (consistent with our own findings), and specifically time (and bouts) spent in moderate and vigorous intensity activities. In a second study using CSA accelerometer-determined physical activity (65), reported sex differences reflected those found herein; boys were consistently more active than girls, especially with regards to time spent in vigorous intensity activities. Although accelerometers have become important physical activity assessment tools they are less feasible for field applications including screening, intervention, and evaluation due to their cost (as much as $450 per unit) and requisite hardware, software, and technical expertise (35). Although less-expensive pedometers are not sensitive to activity intensity and are not capable of recording bouts of activity, the simple, raw output of steps taken is sufficient for a number of practical purposes and therefore establishing associated criterion-referenced standards for recommended steps/day is justified. Both types of motion sensors do not detect non-weight bearing activities (such as cycling), cannot be worn during water sports, and likely miss more complex and upper body movement patterns exhibited by youth.

We determined that the median optimal cut point for steps/day for 6-12 year old children was 12,000 steps/day for girls and 15,000 steps/day for boys. That is, girls taking <12,000 steps/day and boys taking <15,000 steps/day were more likely to be classified as overweight/obese. This translates to approximately 120 minutes/day of activity for girls and 150 minutes/day for boys (66-69). The relatively large sex difference in steps/day cut points demands explanation. Although some may argue that it is socially irresponsible to advocate separate recommendations based on sex, sex-related differences in objectively monitored physical activity have been consistently reported (46, 48, 65) and therefore cannot be ignored. A weakness of making this recommendation is that PA is not the only contributor to weight status. Factors such as genetic heritage and quality and quantity of energy intake are not accounted for by this study. It is plausible that boys must take additional steps/day to accommodate sex-related differences in energy intake (21). Regardless, our findings are consistent with Epstein et al. (70) who speculated that youth (regardless of gender, though) likely need 120 to 150 minutes/day of total physical activity (based on a review of 26 studies of heart-rate measured activity in youth) and the new NASPE guidelines that suggest children need at least 60 minutes and up to several hours of physical activity daily (30).

The analytical process undertaken herein illuminated the difference in norm-referenced vs. criterion-referenced standards. Since we only have aggregate data from isolated adult samples approximating adult norm-references (or “expected values”) (34), a similar process needs to be undertaken using international adult samples. Preliminary cut points have been proposed for adults (71). In that study cut points were set based on the mean steps/day associated with BMI-defined normal weight and obese categories. Adults who took more than ≈9,000 steps/day were more frequently classified as normal weight (BMI<25kg/m^2). In contrast, adults who took less than ≈5,000 steps/day were more frequently classified as obese (BMI ≥30kg/m^2). This present study extends these cut points to younger populations and suggests that a higher level of activity is typical of youth compared to adults; even those children classified as obese take more steps/day than the 10,000 steps/day that has been recommended for adults (45). Setting lower standards (e.g., 11,000-13,000) may undermine attempts to address the obesity epidemic since most youth currently achieve this. The cut points that we propose are criterion-referenced and, although somewhat lofty compared to the status quo, are likely attainable in this young population.

In summary, the BMI-referenced steps-day cut points established herein using an international sample are higher than previously suggested (47) but not inconsistent with recent advances in our understanding of physical activity needs in youth (26-28, 31, 70). This analysis provides the foundation for cross-validation and evaluation of these BMI-referenced recommended steps/day cut points in independent samples and with longitudinal study designs.

References

1. Troiano RP, Flegal KM, Kuczmarski RS. Overweight prevalence and trends for children and adolescents. Archives of Pediatrics and Adolescent Medicine 1995;149:1085-91.

2. Wang Y, Monteiro C, Popkin BM. Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia. Am J Clin Nutr 2002;75(6):971-7.

3. Popkin BM. The nutrition transition and obesity in the developing world. J Nutr 2001;131(3):871S-3S.

4. Caballero B. Introduction. Symposium: Obesity in developing countries: biological and ecological factors. J Nutr 2001;131(3):866S-70S.

5. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. JAMA 2002;288(14):1728-32.

6. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320(7244):1240-3.

7. Booth M. Assessment of physical activity: An international perspective. Res Q Exerc Sport 2000;71(2):114-20.

8. Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. Arch Dis Child 1995;73(1):25-9.

9. Berg IM, Simonsson B, Brantefor B, Ringqvist I. Prevalence of overweight and obesity in children and adolescents in a county in Sweden. Acta Paediatr 2001;90(6):671-6.

10. Walker ARP, Walker BF. Rises in schoolchildren's anthropometry: what do they signify in developed and developing populations? J Roy Soc Health 1998;118(3):159-66.

11. Gordon-Larsen P, McMurray RG, Popkin B. Determinants of adolescent physical activity and inactivity patterns. Pediatrics 2000;105(6):e83.

12. Lowry R, Wechsler H, Kann L, Collins JL. Recent trends in participation in physical education among US high school students. J Sch Health 2001;71(4):145-52.

13. Simons-Morton BG, Taylor WC, Snider SA, Huang IW. The physical activity of fifth-grade students during physical education classes. Am J Public Health 1993;83(2):262-4.

14. US Department of Transportation. Proceedings from the Nationwide Personal Transporation Survey Symposium, October 29-31, 1997. In: Nationwide Personal Transporation Survey Symposium; 1999; Bethesda, Md.: Federal Highway Administration; 1999.

15. McCann B, DeLille B. Mean streets 2000: Pedestrian safety, health and federal transportation spending. Columbia, SC: Centers for Disease Control and Prevention; 2000.

16. Federal Highway Administration. Our Nation's Travel: 1995 NPTS Early Results Report. Washington, DC: U.S. Department of Transporation; 1997.

17. CDC. School transportation modes--Georgia, 2000. MMWR Morb Mortal Wkly Rep 2002;51(32):704-5.

18. Anderson RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: Results from the Third National Health and Nutrition Examination Survey. JAMA 1998;279(12):938-42.

19. Eisenmann JC, Bartee RT, Wang MQ. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey. Obes Res 2002;10(5):379-85.

20. Dowda M, Ainsworth BE, Addy CL, Saunders R, Riner W. Environmental influences, physical activity, and weight status in 8- to 16-year-olds. Arch Pediatr Adolesc Med 2001;155(6):711-7.

21. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. Arch Pediatr Adolesc Med 2001;155(3):360-5.

22. Hernandez B, Gortmaker SL, Colditz GA, Peterson KE, Laird NM, Parra-Cabrera S. Association of obesity with physical activity, television programs and other forms of video viewing among children in Mexico city. Int J Obes Relat Metab Disord 1999;23(8):845-54.

23. US Surgeon General. Surgeon General's report on physical activity and health. From the Centers for Disease Control and Prevention. JAMA 1996;276(7):522.

24. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995;273(5):402-7.

25. Sallis JF, Patrick K. Physical activity guidelines for adolescents: Consensus statement. Pediatric Exercise Science 1994;6:302-14.

26. Pate R, Trost S, Williams C. Critique of existing guidelines for physical activity in young people. In: Biddle S, Sallis J, Cavill N, editors. Young People and Physical Activity: HEA Consensus Meeting. London: Health Education Authority; 1998.

27. Corbin CB, Pangrazi RP, Welk GJ. Toward understanding of appropriate physical activity levels for youth. President's Council of Physical Activity and Sport. Physical Activity and Fitness Research Digest 1994;1(8):1-8.

28. Biddle S, Cavill N, Sallis J. Policy framework for young people and health-enhancing physical activity. In: Biddle S, Cavill N, Sallis J, editors. Young and Active. London, UK: Health Education Authority; 1998.

29. National Association of Physical Education and Sports. Physical Activity for Children: A Statement of Guidelines. Reston, VA: National Association of Physical Education and Sports,; 1993.

30. National Association of Physical Education and Sports. Guidelines for Appropriate Physical Activity for Elementary School Children: Update 2003. Reston, VA: National Association of Physical Education and Sports,; 2003.

31. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Protein and Amino Acids (Macronutrients). Washington, DC: National Academy of Sciences; 2002 September 05.

32. Sallis JF, Saelens BE. Assessment of physical activity by self-report: Status, limitations, and future directions. Res Q Exerc Sport 2000;71(2):1-14.

33. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. Sports Med 2001;31(6):439-54.

34. Tudor-Locke C, Myers AM. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. Res Q Exerc Sport 2001;72(1):1-12.

35. Tudor-Locke C, Myers AM. Challenges and opportunities for measuring physical activity in sedentary adults. Sports Med 2001;31(2):91-100.

36. Rowlands AV, Eston RG, Ingledew EK. Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. Sports Med 1997;24(4):258-72.

37. Bassett Jr. DR. Validity and reliability issues in objective monitoring of physical activity. Res Q Exerc Sport 2000;71(2):30-6.

38. Freedson PS, Miller K. Objective monitoring of physical activity using motion sensors and heart rate. Res Q Exerc Sport 2000;71(2):21-9.

39. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. Res Q Exerc Sport 2000;71(Suppl. 2):59-73.

40. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: convergent validity. Sports Med 2002;32(12):795-808.

41. Krucoff C. Popular, low-cost pedometers: 10,000 steps to a better health. The Seattle Times 1999 Sunday, December 5.

42. Spilner M, Robertson S. Take 10,000 a day! Prevention 2000:90.

43. DeSa P. Easy steps to shape up and slim down. Prevention 2001:150-7.

44. Kosta E. Make every step count. Walking 2001:54-61, 100-1.

45. Hatano Y. Use of the pedometer for promoting daily walking exercise. ICHPER 1993;29:4-8.

46. Rowlands AV, Eston RG, Ingledew DK. Relationship between activity levels, aerobic fitness, and body fat in 8- to 10-yr-old children. J App Physiol 1999;86(4):1428-35.

47. President's Council on Physical Fitness and Sports. The President's Challenge Physical Activity and Fitness Awards Program. Bloomington, IN: President's Council on Physical Fitness and Sports, U.S. Department of Health and Human Services; 2001.

48. Vincent SD, Pangrazi RP. An examination of the activity patterns of elementary school children. Pediatric Exercise Science 2002;14(4):432-41.

49. Rutherford WJ, Corbin CB. Validation of criterion-referenced standards for tests of arm and shoulder girdle strength and endurance. Res Q Exerc Sport 1994;65(2):110-9.

50. Chun DM, Corbin CB, Pangrazi RP. Validation of criterion-referenced standards for the mile run and progressive aerobic cardiovascular endurance tests. Res Q Exerc Sport 2000;71(2):125-34.

51. Rikli RE, Petray C, Baumgartner TA. The reliability of distance run tests for children in grades K-4. Res Q Exerc Sport 1992;63(3):270-6.

52. Cureton KJ, Warren GL. Criterion-referenced standards for youth health-related fitness tests: a tutorial. Res Q Exerc Sport 1990;61(1):7-19.

53. Corbin CB, Pangrazi RP. Are American children and youth fit? Res Q Exerc Sport 1992;63(2):96-106.

54. Vincent SD, Pangrazi RP, Raustorp A, Tomson LM, Cuddihy TF. Activity levels and BMI of children in the United States, Sweden, and Australia. Med Sci Sports Exerc in review.

55. Vincent SD, Pangrazi RP. Does reactivity exist in children when measuring activity levels with pedometers? Pediatric Exercise Science 2002;14:56-63.

56. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: How many days of monitoring are needed? Med Sci Sports Exerc 2000;32(2):426-31.

57. Safrit MJ. Introduction to Measurement in Physical Eduation and Exercise Science. St. Louis, MO: Mosby College Publishing; 1986.

58. Berk RA. Determination of optimal cutting scores in criterion-referenced measurement. Journal of Experimental Education 1976;45(4-9).

59. Williams DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS, et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. Am J Public Health 1992;82(3):358-63.

60. Wang G, Dietz WH. Economic burden of obesity in youths aged 6 to 17 years: 1979-1999. Pediatrics 2002;109(5):E81-1.

61. Sorof JM. Prevalence and consequence of systolic hypertension in children. Am J Hypertens 2002;15(2 Pt 2):57S-60S.

62. Sorof J, Daniels S. Obesity hypertension in children: a problem of epidemic proportions. Hypertension 2002;40(4):441-7.

63. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science Applications, Inc. accelerometer. Med Sci Sports Exerc 1998;30(5):777-81.

64. Trost SG, Kerr LM, Ward DS, Pate RR. Physical activity and determinants of physical activity in obese and non-obese children. Int J Obes 2001;25:822-9.

65. Trost SG, Pate RR, Sallis JF, Freedson PS, Taylor WC, Dowda M, et al. Age and gender differences in objectively measured physical activity in youth. Med Sci Sports Exerc 2002;34(2):350-5.

66. Bassett Jr. DR, Ainsworth BE, Leggett SR, Mathien CA, Main JA, Hunter DC, et al. Accuracy of five electronic pedometers for measuring distance walked. Med Sci Sports Exerc 1996;28(8):1071-7.

67. Welk GJ, Differding JA, Thompson RW, Blair SN, Dziura J, Hart P. The utility of the Digi-walker step counter to assess daily physical activity patterns. Med Sci Sports Exerc 2000;32(9):S481-S8.

68. Tudor-Locke C, Jones GR, Myers AM, Paterson DH, Ecclestone NA. Contribution of structured exercise class participation and informal walking for exercise to daily physical activity in community-dwelling older adults. Res Q Exerc Sport 2002;73(3):350-6.

69. Tudor-Locke C, Myers AM, Bell RC, Harris S, Rodger NW. Preliminary outcome evaluation of The First Step Program: a daily physical activity intervention for individuals with Type 2 diabetes. Patient Educ Couns 2002;47(1):23-8.

70. Epstein LH, Paluch RA, Kalakanis LE, Goldfield GS, Cerny FJ, Roemmich JN. How much activity do youth get? A quantitative review of heart-rate measured activity. Pediatrics 2001;108(3):E44.

71. Tudor-Locke C, Ainsworth BE, Whitt MC, Thompson R, Addy CL, Jones DA. The relationship between pedometer-determined ambulatory activity and body composition variables. Int J Obes 2001;25:1571-8.

Table 1. Mean±SD steps/day for girls stratified by weight status

Age	**Normal weight Steps/day (n)**	**Overweight/obese Steps/day (n)**	***t***	**P**
Girls				
6	13246 ± 3122 (8)	10388 ± 3016 (8)	-1.86	0.08
7	13421 ± 3843 (16)	11530 ± 2317 (16)	-1.69	0.10
8	12210 ± 2357 (40)	10795 ± 2993 (40)	-2.35	0.02
9	13445 ± 2869 (39)	11136 ± 3491 (39)	-3.19	0.002
10	12290 ± 3105 (60)	11217 ± 2678 (60)	-2.00	0.048
11	13625 ± 2899 (48)	10539 ± 3140 (48)	-5.00	0.00
12	13405 ± 2104 (23)	10612 ± 2117 (23)	-4.38	0.00
Boys				
6	17548 ± 1580 (8)	12886 ± 2610 (8)	-4.32	0.001
7	16878 ± 2469 (31)	13796 ± 3731 (31)	-3.84	0.00
8	16939 ± 2138 (26)	14290 ± 3067 (26)	-3.61	0.001
9	16520 ± 3184 (29)	14172 ± 4067 (29)	-2.45	0.018
10	15118 ± 4203 (29)	12552 ± 3318 (29)	-2.58	0.012
11	16707 ± 4179 (43)	13296 ± 2807 (43)	-4.43	0.00
12	17074 ± 2904 (15)	12342 ± 3440 (15)	-4.07	0.00

Table 2. A summary of the analytical process undertaken to evaluate step/day cut points in girls aged 6-12 years

Steps/day	**Probability of Correct Decisions**	**Misclassification Error Type I/ Type II (false overweight/obese / false normal weight)**	**Validity Coefficient**	**Utility Analysis**		
				Expected Utility	**Expected Disutility**	**Expected Maximum Utility**
Girls age 6						
10,000	0.69	.06/.25	0.4	0.69	-0.56	0.01
11,000	0.69	.06/.25	0.4	0.69	-0.56	0.01
12,000*	**0.75**	**.19/.06**	**0.52**	**0.75**	**-0.31**	**0.03**
13,000	0.69	.25/.06	0.4	0.69	-0.38	0.02
Girls age 7						
10,000	0.53	.09/.38	0.08	0.53	-0.84	-0.01
11,000	0.63	.13/.25	0.26	0.63	-0.63	0
12,000*	**0.66**	**.19/.16**	**0.31**	**0.66**	**-0.5**	**0.01**
13,000	0.59	.28/.13	0.2	0.59	-0.53	0.01
Girls age 8						
10,000*	**0.66**	**.10/.26**	**0.29**	**0.64**	**-0.63**	**0.01**
11,000	0.61	.13/.24	0.28	0.64	-0.6	0.01
12,000	0.46	.24/.2	0.13	0.56	-0.64	-0.01

Table 2. A summary of the analytical process undertaken to evaluate step/day cut points in in girls aged 6-12 years (cont'd)

Girls age 9						
10,000	0.76	.06/.32	0.27	0.62	-0.71	-0.01
11,000	0.68	.10/.28	0.25	0.62	-0.67	-0.01
12,000	0.6	.17/.27	0.13	0.56	-0.71	-0.01
13,000*	**0.45**	**.19/.14**	**0.34**	**0.67**	**-0.47**	**0.01**
14,000	0.31	.27/.08	0.33	0.65	-0.42	0.01
Girls age 10						
10,000	0.76	.06/.32	0.27	0.62	-0.71	-0.01
11,000	0.68	.10/.28	0.25	0.62	-0.67	-0.01
12,000	0.6	.17/.27	0.13	0.56	-0.71	-0.01
13,000*	**0.45**	**.19/.14**	**0.34**	**0.67**	**-0.47**	**0.01**
14,000	0.31	.27/.08	0.33	0.65	-0.42	0.01
Girls age 11						
10,000	0.72	.07/.29	0.3	0.64	-0.66	-0.01
11,000*	**0.61**	**.09/.21**	**0.41**	**0.7**	**-0.46**	**0.01**
12,000	0.51	.15/.16	0.4	0.7	-0.46	0.01
13,000	0.36	.23/.09	0.37	0.68	-0.42	0.01
Girls age 12						
10,000	0.72	.07/.29	0.3	0.64	-0.66	-0.01
11,000*	**0.61**	**.09/.21**	**0.41**	**0.7**	**-0.46**	**0.01**
12,000	0.51	.15/.16	0.4	0.7	-0.46	0.01
13,000	0.36	.23/.09	0.37	0.68	-0.42	0.01

*** indicates optimal cut point**

Table 3. A summary of the analytical process undertaken to evaluate step/day cut points in boys aged 6-12 years

Steps/day	**Probability of Correct Decisions**	**Misclassification Error Type I/ Type II (false overweight/obese / false normal weight)**	**Validity Coefficient**	**Utility Analysis**		
				Expected Utility	**Expected Disutility**	**Expected Maximum Utility**
Boys age 6						
14,000	0.69	0/.19	0.67	0.81	-0.38	0.03
15,000*	**0.63**	**0/.13**	**0.77**	**0.88**	**-0.25**	**0.04**
16,000	0.5	.06/.06	0.75	0.88	-0.19	0.04
17,000	0.25	.25/0	0.58	0.75	-0.25	0.03
Boys age 7						
13,000	0.79	.02/.31	0.44	0.68	-0.63	0.01
14,000	0.69	.05/.24	0.45	0.71	-0.53	0.01
15,000	0.53	.15/.18	0.36	0.68	-0.5	0.01
16,000*	**0.45**	**.16/.11**	**0.45**	**0.73**	**-0.39**	**0.01**
17,000	0.35	.24/.10	0.34	0.66	-0.44	0.01
Boys age 8						
15,000	0.69	.10/.29	0.25	0.62	-0.67	0.01
16,000	0.46	.19/.15	0.31	0.65	-0.5	0.01
17,000*	**0.35**	**.23/.08**	**0.4**	**0.69**	**-0.38**	**0.01**
18,000	0.21	.33/.04	0.33	0.63	-0.4	0.01

Table 3. A summary of the analytical process undertaken to evaluate step/day cut points in boys aged 6-12 years (cont'd)

Boys age 9						
14,000	0.31	.12/.28	0.22	0.6	-0.67	-0.01
15,000*	**0.62**	**.17/.21**	**0.24**	**0.62**	**-0.59**	**0.01**
16,000	0.41	.28/.19	0.07	0.53	-0.66	-0.01
17,000	0.29	.31/.10	0.19	0.59	-0.52	0.01
Boys age 10						
13,000	0.5	.21/.21	0.17	0.59	-0.62	-0.01
14,000*	**0.45**	**.21/.16**	**0.28**	**0.64**	**-0.52**	**0.01**
15,000	0.25	.26/.12	0.25	0.62	-0.5	0.01
16,000	0.27	.40/.06	0.21	0.54	-0.52	0.01
Boys age 11						
14,000	0.56	.15/.21	0.28	0.64	-0.57	0.01
15,000	0.46	.19/.15	0.33	0.66	-0.49	0.01
16,000*	**0.36**	**.22/.08**	**0.41**	**0.7**	**-0.38**	**0.01**
17,000	0.23	.33/.06	0.28	0.62	-0.44	0.01
Boys age 12						
13,000	0.69	0/.19	0.67	0.81	-0.38	0.03
14,000*	**0.56**	**.06/.13**	**0.63**	**0.81**	**-0.31**	**0.03**
15,000	0.5	.13/.13	0.5	0.75	-0.38	0.02
16,000	0.5	.13/.13	0.5	0.75	-0.38	0.02

*** indicates optimal cut point**