A Catalog of Rules, Variables, and Definitions Applied to Accelerometer Data in the National Health and Nutrition Examination Survey, 2003–2006

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Abstract

Introduction
The National Health and Nutrition Examination Survey (NHANES) included accelerometry in the 2003–2006 data collection cycles. Researchers have used these data since their release in 2007, but the data have not been consistently treated, examined, or reported. The objective of this study was to aggregate data from studies using NHANES accelerometry data and to catalogue study decision rules, derived variables, and cut point definitions to facilitate a more uniform approach to these data.

Methods
We conducted a PubMed search of English-language articles published (or indicated as forthcoming) from January 2007 through December 2011. Our initial search yielded 74 articles, plus 1 article that was not indexed in PubMed. After excluding 21 articles, we extracted and tabulated details on 54 studies to permit comparison among studies.

Results
The 54 articles represented various descriptive, methodological, and inferential analyses. Although some decision rules for treating data (eg, criteria for minimal wear-time) were consistently applied, cut point definitions used for accelerometer-derived variables (eg, time spent in various intensities of physical activity) were especially diverse.

Conclusion
Unique research questions may require equally unique analytical approaches; some inconsistency in approaches must be tolerated if scientific discovery is to be encouraged. This catalog provides a starting point for researchers to consider relevant and/or comparable accelerometer decision rules, derived variables, and cut point definitions for their own research questions.

Introduction
The National Health and Nutrition Examination Survey (NHANES) is a publicly available data resource that provides information from self- or proxy reports of health conditions and behaviors and biomedical data for a sample representing the US civilian noninstitutionalized population (www.cdc.gov/nchs/nhanes.htm). NHANES is administered in 2-year data collection cycles; the Physical Activity Monitor (PAM) component was introduced in the 2003–2004 and 2005–2006 cycles to collect accelerometer-based measures of physical activity among participants aged 6 years or older. During these 2 cycles, an ActiGraph model 7164 accelerometer (ActiGraph, LLC, Pensacola, Florida) was provided to ambulatory participants, representing the first time that a surveillance study collected accelerometer measures on a US representative sample.

The uniaxial accelerometer measured and recorded vertical acceleration as “activity counts.” The device also recorded “steps” by using a proprietary signal-filtering algorithm. These 2 related quantities measure physical activity movement associated primarily with locomotion. A 1-minute time interval, or “epoch,” was used in NHANES. Data for activity counts and steps were recorded during each epoch for up to 1 week. Both activity count and step data were
The release of PAM data in 2007 provided researchers a unique opportunity to study objectively measured physical activity on a large and representative US sample and relate it to a range of other health-related variables. Numerous studies using the data have been published, but these studies have treated, analyzed, and reported the data by using myriad accelerometer decision rules, derived variables, and cut point definitions. A catalog of these rules, variables, and definitions is needed so that researchers can begin to work toward more standardized and comparable data. The objective of this study was to catalogue the accelerometer decision rules, derived variables, and cut point definitions used in studies on PAM data published since 2007.

Methods

Data sources
We conducted an advanced English-only literature search of original research articles in PubMed by using the key terms “activity monitor” or “ActiGraph” or the wildcard term “acceleromet*” in addition to “NHANES” or “National Health and Nutrition Examination Survey.” We searched articles published from January 1, 2007, through December 31, 2011. We used the following search strategy: (“activity monitor” OR ActiGraph OR acceleromet*) AND (NHANES OR “National Health and Nutrition Examination Survey”) AND English[Language] AND (“2007/01/01”[Date of publication]: “2011/12/31”[Date of publication]). We included forthcoming and “epub ahead of print” articles and updated the search on February 10, 2012. We found 74 articles that met our search criteria. One author (R.P.T.) identified 1 other published study, prepared for a special conference, not indexed in PubMed (1) bringing the initial search total to 75 articles.

Study selection
Twenty-one articles (28%) did not directly analyze PAM data, and they were eliminated; the remaining 54 articles (72%) were included in this review.

Data extraction
The first author read and abstracted the following details from each identified article: 1) citation; 2) purpose of study; 3) PAM data collection cycle(s) analyzed (ie, 2003–2004 and/or 2005–2006); 4) study sample size and age of participants in sample; 5) whether investigators reported using the NCI-supplied SAS syntax; 6) rules for defining nonwear time (ie, time that the accelerometer was not likely worn), a valid day (ie, the minimum number of wear-hours required to be considered representative of a day’s behavior), and the minimum number of valid days required for a participant to be included in the analysis; 7) accelerometer-derived variables (eg, activity counts/day, time spent in moderate-intensity activity, steps in vigorous-intensity activity); and 8) cut point definitions used for each accelerometer-derived variable (ie, values used to categorize continuous data). The second author verified the details independently. Discrepancies were discussed and consensus achieved. The results were tabulated to facilitate comparison among studies. We made no attempt to contact the articles’ authors to obtain unreported information or clarify writing; data extraction was made on face value.

Results
The purpose of the 54 articles varied (Table 1); they represented, for example, descriptive analyses (2-5), methodological analyses (1,6,7), and inferential analyses (8-10). Eighteen studies used the NHANES 2003–2004 cycle, 15 used the 2005–2006 cycle, and 21 combined data from both cycles. Sample sizes ranged from 103, representing prostate cancer survivors (11), to 6,329, representing participants with 1 or more days of wear in the 2003–2004 cycle (2,3). Fourteen studies focused primarily on children and/or adolescents (through age 19 y), 33 on adults (including 1 study on all participants aged ≥16 y), 2 on older adults, and 3 on all ages (ie, ≥6 y). Two reported only the mean age of cancer survivors.

Twenty-four studies reported using the NCI-supplied SAS syntax (1,2,4,5,7,9,10,12-28). Eight studies (11,29-35) cited previous work, notably the first published study (2), that used the SAS syntax. The remaining 22 studies did not attribute their decision rules to another source (3,6,8,36-54). Most studies (42 of 54) defined nonwear time as 60 minutes or more of consecutive zeros, with or without allowance for interruptions, variously defined (Table 2). One study defined 10 minutes or more of identical consecutive nonzero counts as missing data (38). Seven studies that
focused on children or adolescents or both defined nonwear time as 20 minutes or more of consecutive zeros (8,39,42,45,47,48). Four studies did not define a valid day; however, 2 of these studies may have implemented decision rules embedded in the NCI-supplied SAS syntax, which they reported using. Regardless, 49 of 54 studies defined a valid day as 10 hours or more of wear. The minimum number of valid days required for a participant to be included in the analysis varied; 17 studies required a minimum of 1 day; 23 studies required a minimum of 4 days; and 10 required a minimum of 4 days, including 1 weekend day.

Studies on adults typically presented multiple accelerometer-derived variables (Table 3). Definitions differed for some similarly named variables. For example, some studies defined time in sedentary behavior as less than 100 activity counts per minute; others defined it as less than 260 activity counts per minute. Time in light intensity was defined as 100 to 759 activity counts per minute, 100 to 573 activity counts per minute, 100 to 1,951 activity counts per minute, 100 to 2,019 activity counts per minute, 260 to 1,951 activity counts per minute, and 500 to 2,019 activity counts per minute. Time in moderate- to vigorous-intensity physical activity (MVPA) was defined as 500 or more activity counts per minute, 574 or more activity counts per minute, 760 or more activity counts per minute, 1,000 or more activity counts per minute, 1,500 or more activity counts per minute, 1,952 or more activity counts per minute, 2,000 or more activity counts per minute, or 2,020 or more activity counts per minute. Time in MVPA was sometimes considered as any minute above the cut point and at other times only as minutes within a bout of 10 minutes or more (which may or may not have allowed for an interruption of 1 or 2 minutes below the cut point). Step data were reported in 2 ways: 1) in a raw or uncensored format (ie, not adjusted in any way) and 2) following a process of censoring steps from any minute with less than 500 activity counts per minute. (The latter process was designed to interpret the higher values of accelerometer-based step data against lower pedometer-based scales.) Physical activity levels were categorized according to a step-defined graduated index. Additional accelerometer-derived variables included time in incremental cadence (steps per minute) bands and peak cadence indicators (defined as the highest level of physical activity, or natural best effort, measured during a given day).

The 2 primary cut point definitions of time spent in MVPA for studies on children or adolescents or both were age-specific values, building on previous research (55), and 3,000 or more activity counts per minute (Table 4). Bouts were defined as any minute, 1 to 4 minutes, 5 to 9 minutes, and 10 or more minutes above threshold, again at times allowing for minimal interruptions below the cut point. Uncensored and censored steps per day were reported. Data were also presented according to a child-specific step-defined graduated index.

**Discussion**

An obvious advantage of NHANES accelerometer data is that they reflect objectively measured behaviors that can be examined, compared, and related to other NHANES data. NCI-supplied SAS syntax has facilitated analysis of these data. When studies in our review did not explicitly report some decision rules, they frequently reported use of SAS syntax or they cited previous methods that had used this tool, suggesting that SAS syntax was likely applied. Clearly, researchers have treated, analyzed, and reported PAM data in nonstandardized ways, which compromises the ability to make comparisons among studies. This lack of uniformity is perhaps most apparent in the multiple cut point definitions of time spent in MVPA. Inconsistent approaches will impede the ability to track behaviors over time in the United States and compare US behaviors with behaviors in other countries.

The intent of this review was neither to judge researchers’ decisions about examining PAM data nor to make pronouncements on the most appropriate strategies. Unique research questions may require equally unique analytical approaches; some degree of inconsistency must be tolerated if scientific discovery is to be encouraged. That being said, consumers (including the research community) of these data must be informed about inconsistencies, especially when different cut point definitions are used for similarly named variables.

One of the primary challenges to implementing a measure of accelerometer-based physical activity in a study is ensuring compliance with monitoring protocols. The 2003–2004 and 2005–2006 NHANES protocols asked participants to remove the accelerometer only during sleep and water-based activities (eg, swimming, showering, bathing). Conclusions about accelerometer-based behavior are affected by definitions of nonwear time and a valid day (56). Most studies included in our review defined nonwear time as 60 minutes or more of consecutive zeros. Differences between allowances for interruptions may simply represent reporting discrepancies, especially because many of the studies catalogued in Table 2 also reported using SAS syntax (or cited methods of previous work that did). The NCI decision to use 60 minutes of consecutive zeros to identify nonwear time was based on research by Mâsse et al (57). These researchers demonstrated that sample sizes were optimized when nonwear time was defined as 60 minutes, rather than 20 minutes, of continuous zeros. A recent study indicated that 90 minutes of continuous zeros may provide more accurate estimates of time in sedentary and active behaviors (58).

Researchers were also almost perfectly consistent in defining a valid day as 10 or more hours of wear time, which is also the definition provided by SAS syntax. (In 2 of the 4 studies that did not report nonwear criteria, we assumed that they used this definition because they reported using SAS syntax.) Mâsse et al (57) compared results of studies that
used different definitions of a valid day, and although they did not recommend a specific number of hours of wear time
to define a valid day, they noted that the strictest requirement (≥12 h/d) negatively affected sample size. They also
speculated that stricter requirements might unduly limit inclusion of inactive people, thereby affecting overall data
distribution. The popularity of using 10 or more hours of wear time to define a valid day is likely due to numerous
factors: 1) it was a component of one of the decision-rule algorithms evaluated by Mâsse et al (57); 2) it was used in the
seminal NHANES PAM data publication (2); and 3) it was built into the NCI-provided SAS syntax to accompany the
NHANES accelerometer data. Using 2005–2006 NHANES data, Tudor-Locke et al (7) showed that, as population
estimates of nonwear increase, all other time in intensity (eg, MVPA) and volume (ie, activity counts/d, steps/d)
indicators decrease to some degree, but the negative effect is most pronounced on estimates of time spent in sedentary
behavior. Nonwear time is more likely to reflect time spent in sedentary behaviors than in active behaviors. Mâsse et al
(57) reached a similar conclusion: varying minimal wear-time requirements primarily affected minutes of inactivity
(their preferred term). Others concluded the same (22). The effect of reduced wear time on estimates of sedentary
behavior should not differ by age. Although there is apparent consensus that 10 or more hours of wear time is adequate
to define a valid day, a 24-hour wear-time protocol would remove much ambiguity from analysis (59).

Regardless of how scientists have analyzed NHANES accelerometer data, however, it remains clear that the US
citizenry is not very active. Troiano et al (2) reported that less than 5% of adults achieve public health guidelines,
although this low estimate may be an artifact of the minimal bout criterion and a cut point definition that was based
primarily on locomotor activities. Matthews et al (3) reported that more than 50% of monitored time is spent in
sedentary behaviors. Tudor-Locke et al (12) reported that NHANES adults took an average of approximately 6,500
steps/day (considered “low active” on a pedometer-based scale). Using identical accelerometer models and analytic
methods to directly compare Swedish data with NHANES data, Hagströmer et al (43) showed that the amount of time
spent in MVPA was not uniformly greater in Sweden than in the United States, even though Sweden has a population
that is generally considered to be quite active.

Although we limited our online search to English-language articles indexed in PubMed, we are confident that this
search engine was the best one for identifying articles on NHANES accelerometer data. This free resource is
maintained by the National Center for Biotechnology Information at the US National Library of Medicine, which is
located at the National Institutes of Health. We included only 1 article that was not indexed in PubMed. Our search
spanned 2007 (the year that these data were released) through 2011; however, we acknowledge there may be
additional forthcoming articles that we did not identify. This review necessarily represents a limited time frame.

NHANES accelerometer data represent an important public use resource for researchers and practitioners engaged in
designing and directing health programs and services and developing public health policy. This review was undertaken
to summarize existing research that has used these data. The studies we identified bear evidence of the multiple and
diverse uses of these data, and we can anticipate that they will continue to be used in epidemiologic and health sciences
research. We hope that the resulting catalog of accelerometer decision rules, derived variables, and cut point
definitions used to analyze these NHANES data serves as a useful starting point for future researchers to consider as
they plan and report their own analyses.

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References
1. Troiano RP, Dodd KW. Differences between objective and self-report measures of physical activity. What do they
mean? The Korean Journal of Measurement and Evaluation in Physical Education and Sport Science 2008;10
(2):31-42.
2. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States
measured by accelerometer. Med Sci Sports Exerc 2008;40(1):181-8. PubMed
3. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, et al. Amount of time spent in
sedentary behaviors in the United States, 2003-2004. Am J Epidemiol 2008;167(7):875-81. CrossRef PubMed
4. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps/day in U.S. children and youth. Med Sci Sports Exerc 2010;42(12):2244-50. CrossRef PubMed

5. Tudor-Locke C, Brashear MM, Katzmarzyk PT, Johnson WD. Peak stepping cadence in free-living adults: 2005-2006 NHANES. J Phys Act Health. Forthcoming. PubMed

6. Fan AZ, Ham SA, Muppidi SR, Mokdad AH. Validation of reported physical activity for cholesterol control using two different physical activity instruments. Vase Health Risk Manag 2009;5:649-61. CrossRef PubMed

7. Tudor-Locke C, Johnson WD, Katzmarzyk PT. US population profile of time-stamped accelerometer outputs: impact of wear time. J Phys Act Health 2011;8(5):693-8. PubMed

8. Mark AE, Janssen I. Dose-response relation between physical activity and blood pressure in youth. Med Sci Sports Exerc 2008;40(6):1007-12. CrossRef PubMed

9. Sisson SB, Camhi SM, Church TS, Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps/day and metabolic syndrome. Am J Prev Med 2010;38(6):575-82. CrossRef PubMed

10. Lynch BM, Dunstan DW, Healy GN, Winkler E, Eakin E, Owen N. Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: findings from NHANES (2003-2006). Cancer Causes Control 2010;21(2):283-8. CrossRef PubMed

11. Lynch BM, Dunstan DW, Winkler E, Healy GN, Eakin E, Owen N. Objectively assessed physical activity, sedentary time and waist circumference among prostate cancer survivors: findings from the National Health and Nutrition Examination Survey (2003-2006). Eur J Cancer Care (Engl) 2011;20(4):514-9. CrossRef PubMed

12. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps per day in US adults. Med Sci Sports Exerc 2009;41(7):1384-91. CrossRef PubMed

13. Tudor-Locke C, Brashear MM, Johnson WD, Katzmarzyk PT. Accelerometer profiles of physical activity and inactivity in normal weight, overweight, and obese U.S. men and women. Int J Behav Nutr Phys Act 2010;7(1):60. CrossRef PubMed

14. Clark BK, Healy GN, Winkler EA, Gardiner PA, Sugiyama T, Dunstan DW, et al. Relationship of television time with accelerometer-derived sedentary time: NHANES. Med Sci Sports Exerc 2011;43(5):822-8. CrossRef PubMed

15. Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. Eur Heart J 2011;32(5):590-7. CrossRef PubMed

16. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S.: adults compliance with the physical activity guidelines for Americans. Am J Prev Med 2011;40(4):454-61. CrossRef PubMed

17. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Relationship between accelerometer-determined steps/day and other accelerometer outputs in US adults. J Phys Act Health 2011;8(3):410-9. PubMed

18. Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined lifestyle activities in US adults. J Phys Act Health 2011;8(3):382-9. PubMed

19. Lynch BM, Friedenreich CM, Winkler EA, Healy GN, Vallance JK, Eakin EG, et al. Associations of objectively assessed physical activity and sedentary time with biomarkers of breast cancer risk in postmenopausal women: findings from NHANES (2003-2006). Breast Cancer Res Treat 2011;130(1):183-94. CrossRef PubMed

20. Tudor-Locke C, Camhi SM, Leonardi C, Johnson WD, Katzmarzyk PT, Earnest CP, et al. Patterns of adults stepping cadence in the 2005-2006 NHANES. Prev Med 2011;53(3):178-81. CrossRef PubMed

21. Evenson KR, Buchner D, Morland KB. Objective measurement of physical activity and sedentary behavior among United States adults 60 years and older. Prev Chronic Dis 2012;9:E26. PubMed

22. Winkler EA, Gardiner PA, Clark BK, Matthews CE, Owen N, Healy GN. Identifying sedentary time using automated estimates of accelerometer wear time. Br J Sports Med 2012;46(6):436-42. PubMed

23. Vallance JK, Winkler EA, Gardiner PA, Healy GN, Lynch BM, Owen N. Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005-2006). Prev Med 2011;53(4-5):284-8. CrossRef PubMed

24. Peart T, Velasco Mondragon HE, Rohm-Young D, Bronner Y, Hossain MB. Weight status in US youth: the role of activity, diet, and sedentary behaviors. Am J Health Behav 2011;35(6):756-64. CrossRef PubMed

25. Lee H, Cardinal B, Loprinzi PD. Effects of socioeconomic status and acculturation on accelerometer-measured moderate to vigorous physical activity among Mexican American adolescents: findings from NHANES 2003-2004. J Phys Act Health 2011. PubMed

26. Gortmaker SL, Lee R, Cradock AL, Sobol AM, Duncan DT, Wang YC. Disparities in youth physical activity in the United States: 2003-2006. Med Sci Sports Exere 2012. CrossRef PubMed
27. Smith WA, Nolan VG, Robison LL, Hudson MM, Ness KK. Physical activity among cancer survivors and those with no history of cancer — a report from the National Health and Nutrition Examination Survey 2003-2006. Am J Transl Res 2011;3(4):342-50. PubMed

28. Yang K, Lee YS, Chasnus ER. Outcomes of health care providers’ recommendations for healthy lifestyle among U.S. adults with prediabetes. Metab Syndr Relat Disord 2011;9(3):231-7. CrossRef PubMed

29. Bankowski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. Diabetes Care 2011;34(2):497-503. CrossRef PubMed

30. Belcher BR, Berrigan D, Dodd KW, Emken BA, Chou CP, Spruijt-Metz D. Physical activity in US youth: effect of race/ethnicity, age, gender, and weight status. Med Sci Sports Exerc 2010;42(12):2211-21. CrossRef PubMed

31. Mendoza JA, Watson K, Nguyen N, Cerin E, Baranowski T, Nicklas TA. Active commuting to school and physical activity among youth. J Phys Act Health 2011;8(4):488-95. PubMed

32. Luke A, Dugas LR, Durazo-Arvizu RA, Cao G, Cooper RS. Assessing physical activity and its relationship to cardiovascular risk factors: NHANES 2003-2006. BMC Public Health 2011;11(1):387. CrossRef PubMed

33. Van Domelen DR, Koster A, Caserotti P, Brychta RJ, Chen KY, McClain JJ, et al. Employment and physical activity in the U.S. Am J Prev Med 2011;41(2):136-45. CrossRef PubMed

34. Holman RM, Carson V, Janssen I. Does the fractionalization of daily physical activity (sporadic vs. bouts) impact cardiometabolic risk factors in children and youth? PLoS ONE 2011;6(10):e25733. CrossRef PubMed

35. Loprinzi P, Cardinal B, Crespo C, Brodowicz G, Andersen R, Sullivan E, et al. Objectively measured physical activity and C-reactive protein: National Health and Nutrition Examination Survey 2003-2004. Scand J Med Sci Sports 2011. CrossRef PubMed

36. Strath SJ, Holleman RG, Ronis DL, Swartz AM, Richardson CR. Objective physical activity accumulation in bouts and nonbouts and relation to markers of obesity in US adults. Prev Chronic Dis 2008;5(4):A191. PubMed

37. Janney CA, Richardson CR, Holleman RG, Glasheen C, Strath SJ, Conroy MB, et al. Gender, mental health service use and objectively measured physical activity: Data from the National Health and Nutrition Examination Survey (NHANES 2003-2004). Ment Health Phys Act 2008;1(1):9-16. CrossRef PubMed

38. Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Patterns of objectively measured physical activity in the United States. Med Sci Sports Exerc 2008;40(4):630-8. CrossRef PubMed

39. Mark AE, Janssen I. Influence of bouts of physical activity on overweight in youth. Am J Prev Med 2009;36 (5):416-21. CrossRef PubMed

40. Hawkins MS, Storti KL, Richardson CR, King WC, Strath SJ, Holleman RG, et al. Objectively measured physical activity of USA adults by sex, age, and racial/ethnic groups: a cross-sectional study. Int J Behav Nutr Phys Act 2009;6:31. CrossRef PubMed

41. Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Associations between patterns of objectively measured physical activity and risk factors for the metabolic syndrome. Am J Health Promot 2010;24(3):161-9. CrossRef PubMed

42. LeBlanc AG, Janssen I. Dose-response relationship between physical activity and dyslipidemia in youth. Can J Cardiol 2010;26(6):201-5. CrossRef PubMed

43. Hagströmer M, Troiano RP, Sjöström M, Berrigan D. Levels and patterns of objectively assessed physical activity — a comparison between Sweden and the United States. Am J Epidemiol 2010;171(10):1055-64. CrossRef PubMed

44. Ham SA, Ainsworth BE. Disparities in data on Healthy People 2010 physical activity objectives collected by accelerometer and self-report. Am J Public Health 2010;100 Suppl 1:S263-8. CrossRef PubMed

45. 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. PubMed

46. Atienza AA, Moser RP, Perna F, Dodd K, Ballard-Barbash R, Troiano RP, et al. Self-reported and objectively-measured activity related to biomarkers using NHANES. Med Sci Sports Exerc 2011. CrossRef PubMed

47. Carson V, Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC Public Health 2011;11:274. CrossRef PubMed

48. Mark AE, Janssen I. Influence of movement intensity and physical activity on adiposity in youth. J Phys Act Health 2011;8(2):164-73. PubMed

49. Hawkins MS, Sevick MA, Richardson CR, Fried LF, Arena VC, Kriska AM. Association between physical activity and kidney function: National Health and Nutrition Examination Survey. Med Sci Sports Exerc 2011;43(8):1457-64. CrossRef PubMed
Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined moderate intensity lifestyle activity and cardiometabolic health. Prev Med 2011;52(5):358-60. CrossRef PubMed

Tudor-Locke C, Leonardi C, Johnson WD, Katzmarzyk PT, Church TS. Accelerometer steps/day translation of moderate-to-vigorous activity. Prev Med 2011;53(1-2):31-3. CrossRef PubMed

Evenson KR, Wen F. Prevalence and correlates of objectively measured physical activity and sedentary behavior among US pregnant women. Prev Med 2011;53(1-2):39-43. CrossRef PubMed

Chasens ER, Yang K. Insomnia and physical activity in adults with prediabetes. Clin Nurs Res. Forthcoming. PubMed

Mendoza JA, Nicklas TA, Liu Y, Stuff J, Baranowski T. General versus central adiposity and relationship to pediatric metabolic risk. Metab Syndr Relat Disord 2012;10(102):128-36. CrossRef PubMed

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. CrossRef PubMed

Sirard JR, Forsyth A, Oakes JM, Schmitz KH. Accelerometer test-retest reliability by data processing algorithms: results from the Twin Cities Walking Study. J Phys Act Health 2011;8(5):668-74. PubMed

Mâsse LC, Fuemmeler BF, Anderson CB, Matthews CE, Trost SG, Catellier DJ, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. Med Sci Sports Exerc 2005;37(11 Suppl):S544-54. CrossRef PubMed

Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. Med Sci Sports Exerc 2011;43(2):357-64. CrossRef PubMed

Matthews CE, Hagströmer M, Pober DM, Bowles HR. Best practices for using physical activity monitors in population-based research. Med Sci Sports Exerc 2012;44(1 Suppl 1):S68-76. CrossRef PubMed

### Tables

**Table 1. Studies Published Since 2007 (or Forthcoming) on Physical Activity Monitor Data, National Health and Nutrition Examination Surveys, 2003–2004 and 2005–2006**

| Reference                  | Purpose                                                                 | Years of Study | Study Sample Size | Age of Study Participants, y |
|----------------------------|-------------------------------------------------------------------------|----------------|-------------------|------------------------------|
| Troiano and Dodd (1)       | Compare self-reported PA to objectively measured PA                     | 2003–2004      | 3,087             | ≥20                          |
| Troiano et al (2)          | Describe objectively measured PA                                        | 2003–2004      | 4,867 with ≥4 d, 6,329 with ≥1 d | ≥6                           |
| Matthews et al (3)         | Describe objectively measured time in sedentary behaviors              | 2003–2004      | 6,329             | 6–85                         |
| Tudor-Locke et al (4)      | Describe objectively measured step-defined PA in children and youth    | 2005–2006      | 2,610             | 6–19                         |
| Tudor-Locke et al (5)      | Describe peak stepping cadence in adults                               | 2005–2006      | 3,522             | ≥20                          |
| Fan et al (6)              | Validate self-reported PA for cholesterol control                      | 2003–2004      | 789               | ≥18                          |
| Tudor-Locke et al (7)      | Examine effects of wear time on accelerometer-derived variables       | 2005–2006      | 3,744             | ≥20                          |
| Mark and Janssen (8)       | Examine dose-response relationship between objectively measured PA and blood pressure in children and adolescents | 2003–2004      | 1,170             | 8–17                         |
| Sisson et al (9)           | Examine associations between steps/d and metabolic syndrome and cardiovascular risk factors | 2005–2006      | 1,446             | ≥20                          |
| Reference                  | Purpose                                                                 | Years of Study       | Study Sample Size | Age of Study Participants, y |
|----------------------------|-------------------------------------------------------------------------|----------------------|-------------------|------------------------------|
| Lynch et al (10)           | Examine relationship of objectively measured PA and sedentary time with adiposity in breast cancer survivors | 2003–2004 and 2005–2006 | 111               | Mean 69.2                    |
| Lynch et al (11)           | Examine the relationship between objectively measured PA, sedentary time, and waist circumference of prostate cancer survivors | 2003–2004 and 2005–2006 | 103               | Mean 75.4                    |
| Tudor-Locke et al (12)     | Describe objectively measured step-defined PA                          | 2005–2006            | 3,744             | 20–85                        |
| Tudor-Locke et al (13)     | Compare objectively measured PA and inactivity profiles in normal-weight, overweight, and obese US men and women | 2005–2006            | 3,522             | ≥20                          |
| Clark et al (14)           | Examine the relationship between self-reported television viewing time and accelerometer-determined total sedentary time | 2003–2004 and 2005–2006 | 5,738             | ≥20                          |
| Healy et al (15)           | Examine the relationship between accelerometer-determined sedentary time and cardiometabolic health | 2003–2004 and 2005–2006 | 4,757             | ≥20                          |
| Tucker et al (16)          | Assess self-reported and objectively measured PA relative to 2008 Physical Activity Guidelines for Americans | 2005–2006            | 3,082             | ≥20                          |
| Tudor-Locke et al (17)     | Examine relationship between steps/d and other accelerometer-derived variables | 2005–2006            | 3,744             | ≥20                          |
| Camhi et al (18)           | Describe accelerometer-determined lifestyle activities and relationship with MVPA | 2005–2006            | 3,744             | ≥20                          |
| Lynch et al (19)           | Examine relationship between objectively measured PA, sedentary time, and biomarkers of breast cancer risk | 2003–2004 and 2005–2006 | 1,024             | ≥20                          |
| Tudor-Locke et al (20)     | Describe patterns of stepping cadence in adults                       | 2005–2006            | 3,744             | ≥20                          |
| Evenson et al (21)         | Describe objectively measured PA and sedentary behavior in adults 60 years or older | 2003–2004 and 2005–2006 | 2,630             | ≥60                          |
| Winkler et al (22)         | Compare methods of identifying sedentary time using automated estimates of accelerometer wear time | 2003–2004            | 4,741             | ≥20                          |
| Vallance et al (23)        | Examine the relationship between objectively measured PA, sedentary time, and depression | 2005–2006            | 2,862             | ≥20                          |
| Peart et al (24)           | Assess association between objectively measured PA, diet, sedentary behaviors, and overweight and obesity in US youth | 2003–2004 and 2005–2006 | 2,638             | 12–19                        |
| Lee et al (25)             | Examine the relationship between socioeconomic status and acculturation on objectively measured MVPA among Mexican American adolescents | 2003–2004            | 322               | 13–19                        |
| Reference                | Purpose                                                                 | Years of Study          | Study Sample Size | Age of Study Participants, y |
|--------------------------|-------------------------------------------------------------------------|-------------------------|-------------------|-----------------------------|
| Gortmaker et al (26)     | Examine changes in child/adolescent PA by race/ethnicity between NHANES cycles | 2003–2004 and 2005–2006 | 3,381             | 6–19                        |
| Smith et al (27)         | Compare objectively measured PA levels among 5-year cancer survivors with those with no history of cancer | 2003–2004 and 2005–2006 | Not reported      | ≥20                         |
| Yang et al (28)          | Examine relationship between receiving health care provider’s recommendation and adherence to healthy lifestyle among adults with prediabetes | 2005–2006              | 2,853             | ≥20                         |
| Bankoski et al (29)      | Examine the relationship between accelerometer-determined sedentary time and metabolic syndrome independent of PA | 2003–2004 and 2005–2006 | 1,367             | ≥60                         |
| Belcher et al (30)       | Describe objectively measured PA by race/ethnicity, age, sex, and weight status in youth | 2003–2004 and 2005–2006 | 3,106             | 6–19                        |
| Mendoza et al (31)       | Examine the relationship between active commuting to school and objectively measured PA and adiposity | 2003–2004              | 789               | 12–19                       |
| Luke et al (32)          | Examine the relationship of objectively measured PA with cardiovascular risk factors | 2003–2004, and 2005–2006 | 3,370             | 20–65                       |
| Van Domelen et al (33)   | Examine the relationship between employment and objectively measured PA | 2003–2004              | 1,826             | 20–60                       |
| Holman et al (34)        | Determine whether sporadic vs bout accumulation of MVPA was more strongly associated with cardiometabolic risk in children and youth | 2003–2004 and 2005–2006 | 2,754             | 6–19                        |
| Loprinzi et al (35)      | Examine association between objectively measured PA and C-reactive protein | 2003–2004              | 4,555             | ≥6                          |
| Strath et al (36)        | Describe objectively measured MVPA accumulation in bouts/nonbouts in relation to obesity | 2003–2004              | 3,272 Waist circumference analysis; 3,250 body mass index analysis | ≥18 |
| Janney et al (37)        | Examine relationship between objectively measured PA levels and use of mental health services | 2003–2004              | 3,809             | 18–85                       |
| Metzger et al (38)       | Describe patterns of objectively measured PA | 2003–2004              | 3,802 ≥1 d, 3,462 ≥3 d | 20–85 |
| Mark and Janssen (39)    | Compare MVPA bouts vs nonbouts in predicting overweight in youth | 2003–2004 and 2005–2006 | 2,498             | 8–17                        |
| Hawkins et al (40)       | Examine objectively measured PA among sex, age, and racial/ethnic groups | 2003–2004              | 2,688             | ≥18                         |
| Metzger et al (41)       | Examine patterns of objectively measured PA associated with metabolic syndrome | 2003–2004              | 1,620             | 20–85                       |
| Reference                      | Purpose                                                                 | Years of Study               | Study Sample Size | Age of Study Participants, y |
|--------------------------------|--------------------------------------------------------------------------|-----------------------------|-------------------|-----------------------------|
| LeBlanc and Janssen (42)       | Determine dose-response relationship between objectively measured PA and dyslipdemia in youth | 2003–2004, and 2005–2006    | 1,235             | 12–19                      |
| Hagströmer et al (43)          | Compare objectively measured PA between Sweden and United States         | 2003–2004                   | 2,925             | 18–75                      |
| Ham and Ainsworth (44)         | Describe disparities in objectively measured PA                          | 2003–2004                   | 3,043             | ≥18                        |
| LeBlanc and Janssen (45)       | Examine differences between objective and self-reported MVPA in youth   | 2003–2004 and 2005–2006     | 2,761             | 12–19                      |
| Atienza et al (46)             | Examine the independent associations of self-reported and objectively measured MVPA with physiologic and anthropometric biomarkers | 2003–2004 and 2005–2006     | 5,797             | ≥20                        |
| Carson and Janssen (47)        | Examine the relationship between sedentary behavior and cardiometabolic health in children and adolescents | 2003–2004 and 2005–2006     | 2,527             | 6–19                       |
| Mark et al (48)                | Explore effects of objectively measured PA intensity and incidental movement on body fat in children and youth | 2003–2004                   | 1,165             | 8–17                       |
| Hawkins et al (49)             | Examine the relationship between objectively measured PA intensity and kidney function | 2003–2004 and 2005–2006     | 2,117             | ≥18                        |
| Camhi et al (50)               | Examine the relationship between accelerometer-determined lifestyle activities and cardiometabolic health | 2005–2006                   | 1,371             | ≥18                        |
| Tudor-Locke et al (51)         | Compute a steps/d translation of time in MVPA                           | 2005–2006                   | 1,197             | ≥20                        |
| Evenson et al (52)             | Describe objectively measured PA and sedentary behavior in pregnant women | 2003–2004 and 2005–2006     | 359               | ≥16                        |
| Chasens and Yang (53)          | Examine the relationship between insomnia and objectively measured PA in adults with prediabetes | 2005–2006                   | 958               | ≥20                        |
| Mendoza et al (54)             | Examine the relationship of objectively measured MVPA and pediatric metabolic risk | 2003–2004, 2005–2006        | 2,155             | 6–19                       |

Abbreviations: PA, physical activity; MVPA, moderate- to vigorous-intensity PA; NHANES, National Health and Nutrition Examination Survey.
Table 2. Rules for Data in Studies Published Since 2007 (or Forthcoming) on Accelerometer Data, National Health and Nutrition Examination Surveys, 2003–2004 and 2005–2006

| Rule                                                                 | No. of Studies | References                                      |
|----------------------------------------------------------------------|----------------|-------------------------------------------------|
| **Nonwear (time that the accelerometer was not likely worn) or missing**                                                                                   |
| ≥60 min of consecutive zeros                                          | 11             | (5,20,22,24,27,36-38,40,41,49)                   |
| ≥60 min of consecutive zeros with allowance for up to 2 min up to 100 activity counts/min                                                               | 25             | (1-4,6,7,9,12,13-15,18,21,22,26,29-33,43,44,46,52) |
| ≥60 consecutive zeros with allowance for up to 2 min <50 activity counts/min                                                                              | 5              | (10,11,14,19,22)                                |
| ≥60 consecutive zeros with allowance for interruptions               | 1              | (23)                                            |
| ≥10 min identical consecutive nonzero counts                         | 1              | (38)                                            |
| ≥20 min of consecutive zeros                                         | 1              | (8,34,39,42,45,47,48)                           |
| Not reported<sup>a</sup>                                               | 7              | (25,28,35,50,51,53,54)                          |
| **Valid day (minimum no. of wear-hours required to be considered representative of a day’s behavior)**                                                      |
| 10 h                                                                  | 49             | (1-20,22-26,28-37,39,40,42-51,53,54)             |
| Length of time that 70% of sample wore the accelerometer, multiplied by 70%                                                                  | 1              | (52)                                            |
| Not reported<sup>a</sup>                                               | 4              | (21,27,38,41)                                   |
| **Minimum no. of valid days required for a participant to be included in the analysis**                                                              |                |                                                 |
| All (missing data imputed)                                           | 1              | (41)                                            |
| 1                                                                     | 17             | (2-7,9,12,13,17,18,20,22,38,50,51,54)           |
| 2                                                                     | 1              | (53)                                            |
| 3                                                                     | 1              | (21,38)                                         |
| 4                                                                     | 23             | (1,2,14,16,22-26,29-33,35-37,40,43,46,49,52,54) |
| 4, including 1 weekend day                                           | 10             | (8,15,19,34,39,42,44,45,47,48)                  |
| Not reported<sup>a</sup>                                               | 5              | (10,11,27,28)                                   |

<sup>a</sup> Decision rules embedded in the National Cancer Institute–supplied SAS syntax may have been used.

Table 3. Accelerometer-Derived Variables and Cut Point Definitions Used in Studies Published Since 2007 (or Forthcoming) on Accelerometer Data for Adults, National Health and Nutrition Examination Surveys, 2003–2004 and 2005–2006<sup>a</sup>

| Accelerometer-derived variable | Cut point definition                          | Reference |
|--------------------------------|-----------------------------------------------|-----------|
| Activity counts/d             | Sum of daily activity counts                  | (13)      |
| Mean activity counts/min      | Sum of daily activity counts/number of min worn | (2,6,13,21,30,32,33,35,43,52) |
| Mean counts/min of most intense 10 min/wk | ≥2,020 Activity counts/min                   | (6)       |
| Accelerometer-derived variable                      | Cut point definition                                      | Reference |
|-----------------------------------------------------|-----------------------------------------------------------|-----------|
| Time in sedentary behaviors (any min)               | <100 Activity counts/min                                  | (3,7,10,11,13-15,17,19,21-23,29,30,33,43,49,52) |
| Steps in sedentary behaviors (any min)              | Steps detected <100 activity counts/min                   | (12)      |
| Time in sedentary behaviors (>5-min bouts)          | <100 Activity counts/min                                  | (29)      |
| Time in sedentary behaviors (any min)               | <260 Activity counts/min                                  | (37,40)  |
| Proportion of sedentary time                        | Proportion of valid wear time at <100 activity counts/min | (29,33)  |
| Stillness                                           | Average intensity during time <100 activity counts/min    | (29)      |
| Time in inactive intensity (any min)                | 100–499 Activity counts/min                              | (12)      |
| Steps in inactive intensity (any min)               | Steps detected 100–499 activity counts/min               | (12)      |
| Time in low intensity (any min)                     | 100–499 Activity counts/min                              | (7,13,17) |
| Time in low intensity (any min)                     | 100–759 Activity counts/min                              | (43)      |
| Time in lifestyle intensity (any min)               | 760–2,019 Activity counts/min                            | (18,33,43,50) |
| Proportion of time in lifestyle intensity           | Proportion of valid wear time at 760–2,019 activity counts/min | (18,33)  |
| Steps in lifestyle intensity (any min)              | Steps detected 760–2,019 activity counts/min              | (18,50)  |
| Proportion of steps/d in lifestyle activity         | Proportion of steps/d at 760–2,019 activity counts/min   | (18)      |
| Time in light intensity (any min)                   | 100–573 Activity counts/min                              | (52)      |
| Time in light intensity (any min)                   | 100–759 Activity counts/min                              | (33)      |
| Time in light intensity (any min)                   | 100–1,951 Activity counts/min                            | (10,11,15,23,49) |
| Time in light intensity (any min)                   | 260–1,951 Activity counts/min                            | (37,40)  |
| Time in light intensity (any min)                   | 100–2,019 activity counts/min                            | (52)      |
| Time in light intensity (any min)                   | 500–2,019 Activity counts/min                            | (12,13,17) |
| Proportion of time in light intensity               | Proportion of valid wear time at 100–759 activity counts/min | (33)      |
| Steps in light intensity (any min)                  | Steps detected in 500–2,019 activity counts/min           | (12)      |
| Time in moderate-intensity activity (any min)       | 574–4,944 Activity counts/min                            | (52)      |
| Time in moderate-intensity activity (any min)       | 2,020–5,998 Activity counts/min                          | (2,6,16,17,27,30,35,38,52) |
| Accelerometer-derived variable | Cut point definition | Reference |
|--------------------------------|---------------------|-----------|
| Steps in moderate-intensity activity (any min) | Steps detected in 2,020–5,998 activity counts/min | (12) |
| Time in moderate intensity (modified 10-min bouts) | ≥500 Activity counts/min | (21) |
| Time in moderate intensity (modified 10-min bouts) | 760–5,999 Activity counts/min | (44) |
| Time in moderate intensity (modified 10-min bouts) | ≥1,000 Activity counts/min | (21) |
| Time in moderate intensity (modified 10-min bouts) | ≥1,500 Activity counts/min | (21) |
| Time in moderate intensity (modified 10-min bouts) | ≥2,000 Activity counts/min | (21) |
| Time in moderate intensity (≥10-min bouts) | ≥2,020 Activity counts/min | (53) |
| Time in moderate intensity (modified 10-min bouts) | 2,020–5,998 Activity counts/min | (2,13,28) |
| Time in vigorous-intensity activity (any min) | ≥4,945 Activity counts/min | (52) |
| Time in vigorous-intensity activity (any min) | ≥5,999 Activity counts/min | (2,7,12,13,16,17,27,30,32,35,38,52) |
| Time in vigorous (any min) | Not reported | (6) |
| Steps in vigorous-intensity activity (any min) | Steps detected ≥5,999 activity counts/min | (12) |
| Time in vigorous intensity (modified 10-min bouts) | ≥5,999 Activity counts/min | (2,28,32,44) |
| Time in MVPA (any min) | ≥500 Activity counts/min | (21) |
| Time in MVPA (any min) | ≥574 Activity counts/min | (52) |
| Time in MVPA (any min) | ≥760 Activity counts/min | (37) |
| Time in MVPA (any min) | ≥1,000 Activity counts/min | (21) |
| Time in MVPA (any min) | ≥1,500 Activity counts/min | (21) |
| Time in MVPA (any min) | ≥1,952 Activity counts/min | (10,11,19,22,23,37,40) |
| Time in MVPA (any min) | ≥2,000 Activity counts/min | (21) |
| Time in MVPA (any min) | ≥2,020 Activity counts/min | (2,7,18,33,41,43,50-52) |
| Proportion of time in MVPA | Proportion of valid wear time ≥2,020 activity counts/min | (18,33) |
| Time in MVPA (any min outside a ≥10-min bout) | ≥760 Activity counts/min | (36) |
| Time in MVPA (modified 10-min bouts) | ≥2,020 Activity counts/min | (1,6,18,28,38,46) |
| Time in MVPA (in bouts ≥10 min) | ≥760 Activity counts/min | (36) |
| Time in MVPA (in bouts ≥10 min) | ≥2,020 Activity counts/min | (35) |
| Time active | >100 Activity counts/min | (29) |
| Time in total PA | ≥260 Activity counts/min | (40) |
| Day/wk ≥MVPA | ≥2,020 Activity counts/min | (6) |
| Accelerometer-derived variable                                  | Cut point definition                                                                                                                                                                                                 | Reference |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Adherence to PA recommendations (modified 10-min bout)          | 30 Min of moderate or greater intensity activity on 5 of 7 d                                                                                                                                                            | (2,13)    |
| Uncensored (raw) steps/d                                       | Reporting steps as detected                                                                                                                                                                                          | (9,12,13,20,28,51,53) |
| Censored steps/d                                               | Disqualify steps taken at less than 500 activity counts/min                                                                                                                                                           | (9,12,13) |
| Uncensored (raw) steps/min                                     | Total raw steps accumulated during 1,440 min (24 h or 1 d), divided by time worn                                                                                                                                      | (13)      |
| Censored steps/min                                             | Total steps accumulated during 1,440 min after censoring out steps at an intensity <500 activity counts/min, divided by time worn                                                                                     | (13)      |
| Transitions/d                                                  | Total occurrences of when activity counts rose from <100 activity/counts in 1 min to ≥100 activity counts in the subsequent min                                                                                  | (13,15,29) |
| Basal physical activity                                         | <2,500 Steps/d                                                                                                                                                                                                       | (5,12,13) |
| Limited physical activity                                       | 2,500–4,999 Steps/d                                                                                                                                                                                                  | (5,12,13) |
| Sedentary                                                      | <5,000 Steps/d                                                                                                                                                                                                       | (9,28)    |
| Low active                                                     | 5,000–7,499 Steps/d                                                                                                                                                                                                  | (5,12,13,28) |
| Low- to somewhat active                                        | 5,000–9,999 Steps/d                                                                                                                                                                                                  | (9)       |
| Somewhat active                                                | 7,500–9,999 Steps/d                                                                                                                                                                                                  | (5,12,13,28) |
| Active to highly active                                         | ≥10,000 Steps/d                                                                                                                                                                                                       | (9)       |
| Active                                                         | 10,000–12,499 Steps/d                                                                                                                                                                                                 | (5,12,13) |
| Highly active                                                  | ≥12,500 Steps/d                                                                                                                                                                                                       | (5,12,13) |
| Time in incremental cadence bands                              | 0 Steps/min (nonmovement)                                                                                                                                                                                                | (20)      |
|                                                                | 1–19 Steps/min (incidental movement)                                                                                                                                                                                      |           |
|                                                                | 20–39 Steps/min (sporadic movement)                                                                                                                                                                                       |           |
|                                                                | 40–59 Steps/min (purposeful steps)                                                                                                                                                                                        |           |
|                                                                | 60–79 Steps/min (slow walking)                                                                                                                                                                                            |           |
|                                                                | 80–99 Steps/min (medium walking)                                                                                                                                                                                           |           |
|                                                                | 100–119 Steps/min (brisk walking)                                                                                                                                                                                          |           |
|                                                                | ≥120 Steps/min (all faster human locomotor movements)                                                                                                                                                                     |           |
| Peak 1-min cadence                                             | Steps/min recorded for the single highest min in a day                                                                                                                                                                  | (5)       |
| Peak 30-min cadence                                            | Average steps/min recorded for the 30 highest, but not necessarily consecutive, min in a day                                                                                                                                 | (5)       |

Abbreviation: MVPA, moderate- to vigorous-intensity physical activity.

Hagströmer et al (43) also reported the number of bouts and accumulated time in each bout in each intensity category (sedentary, low, lifestyle, and moderate or greater). A sedentary bout was defined as more than 5 consecutive minutes within the designated count range, including an allowance for 1 minute above threshold (29). An MVPA bout was defined as 10 or more consecutive minutes within the designated count range, including an allowance for interruption of 1 or 2 minutes below threshold. Metzger et al (38) considered 70% of minutes above threshold in a 10-minute bout; all others considered 80%.
| Accelerometer-derived variable                     | Cut point definition                                                                                                                                                                                                 | Reference |
|--------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Mean activity counts/min                         | Sum of daily activity counts/number of min worn                                                                                                                                                                     | (2,26,35) |
| Time in sedentary behaviors                     | <100 Activity counts/min                                                                                                                                                                                         | (3,30,47) |
| Sedentary behavior bout                          | ≥30 Min with ≥80% of min <100 activity counts/min (no more than 5 consecutive min ≥100 activity counts/min)                                                                                                           | (47)      |
| Break min                                        | Within each sedentary behavior bout (defined above), those mins ≥100 activity counts/min                                                                                                                                 | (47)      |
| Time in incidental movement (any movement)       | <2,000 Activity counts/min                                                                                                                                                                                       | (48)      |
| Time in low intensity (any movement)             | 2,000–2,999 Activity counts/min                                                                                                                                                                                   | (48)      |
| Time in low intensity                            | Between 100 activity counts/min and age-specific cut point definitions                                                                                                                                               | (47)      |
| Time in moderate-intensity activity (any min)    | Age-specific cut point definitions                                                                                                                                                                                   | (2,30,38) |
| Time in moderate-intensity activity (any min)    | 3000–5,199 Activity counts/min                                                                                                                                                                                     | (48)      |
| Time in moderate-intensity activity (modified 10-min bouts) | Age-specific cut point definitions                                                                                                                                                                               | (2)       |
| Time in vigorous-intensity activity (any min)    | Age-specific cut point definitions                                                                                                                                                                                   | (2,30)    |
| Time in vigorous-intensity activity (any min)    | ≥5200 Activity counts/min                                                                                                                                                                                         | (48)      |
| Time in vigorous-intensity activity (modified 10-min bouts) | Age-specific cut point definitions                                                                                                                                                                               | (2)       |
| Time in MVPA (any min)                          | Age-specific cut point definitions                                                                                                                                                                                   | (2,25,26,30,31,34,35,47,54) |
| Time in sporadic MVPA (any min <5 min)          | Age-specific cut point definitions                                                                                                                                                                                   | (34)      |
| Time in sporadic MVPA (any min <10 min)         | Age-specific cut point definitions                                                                                                                                                                                   | (34)      |
| Time in MVPA (any min)                          | ≥1,500 Activity counts/min                                                                                                                                                                                         | (24)      |
| Time in MVPA (any min)                          | ≥3,000 Activity counts/min                                                                                                                                                                                         | (8,39,42) |
| Time in MVPA (1- to 4-min bouts)                 | ≥3000 Activity counts/min                                                                                                                                                                                          | (39,42,45) |
| Time in MVPA (modified 5- to 9-min bouts)        | ≥3000 Activity counts/min                                                                                                                                                                                          | (39,42,45) |
| Time in MVPA (modified 10-min bouts)             | ≥3,000 Activity counts/min                                                                                                                                                                                         | (39,42,45) |
| Time in MVPA (≥5-min bouts)                      | Age-specific cut point definitions                                                                                                                                                                                   | (34)      |
| Time in MVPA (≥10-min bouts)                     | Age-specific cut point definitions                                                                                                                                                                                   | (34)      |
| Time in moderate-intensity activity (modified 10-min bouts) | Age-specific cut point definitions                                                                                                                                                                               | (2)       |
| Time in total PA                                 | ≥2,000 activity counts/min                                                                                                                                                                                          | (8)       |
| Adherence to PA recommendations (children, any min; adolescents, any min and modified 10-min bout) | 30 min of moderate- or greater-intensity activity on 5 of 7 d                                                                                                                                                     | (2)       |
| Accelerometer-derived variable | Cut point definition | Reference |
|-------------------------------|----------------------|-----------|
| Uncensored (raw) steps/d      | Reporting steps as detected | (4)       |
| Censored steps/d              | Disqualify steps taken <500 activity counts/min | (4)       |
| Sedentary                     | <10,000 Steps/d (boys aged 6–11); <7,000 steps/d (girls aged 6–11) | (4)       |
| Low active                    | 10,000–12,499 Steps/d (boys aged 6–11); 7,000–9,499 steps/d (girls aged 6–11) | (4)       |
| Somewhat active               | 12,500–14,999 Steps/d (boys aged 6–11); 9,500–11,999 steps/d (girls aged 6–11) | (4)       |
| Active                        | 15,000–17,499 Steps/d (boys aged 6–11); 12,000–14,499 steps/d (girls aged 6–11) | (4)       |
| Highly active                 | ≥17,500 Steps/d (boys aged 6–11); ≥14,500 steps/d (girls aged 6–11) | (4)       |

Abbreviations: PA, physical activity; MVPA, moderate- to vigorous-intensity PA.