# Normative Steps/Day and Peak Cadence Values for United States Children and Adolescents: National Health and Nutrition Examination Survey 2005-2006

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**Objective** To provide sex-and-age specific normative values for children and adolescents' accelerometer-determined steps/day, and peak 60-minute cadence adjusted to a pedometer-based scale.

**Study design** The analysis sample was 2610 children and adolescents (1329 girls) from the 2005-2006 National Health and Nutrition Examination Survey. Accelerometer data were adjusted by eliminating steps counted when activity counts/min <500. Peak 60-minute cadence represented the 60 highest minutes of accumulated steps, averaged over monitored days. Normative data included quintile-defined categories of adjusted steps/day and peak 60-minute cadence for 7 age groups (6-7, 8-9, 10-11, 12-13, 14-15, 16-17, and 18-19 years). LMSChartmakerPro produced 10 age-group-specific smoothed curves (5 for each sex) showing the 5th, 25th, 50th, 75th, and 95th percentiles, respectively, for steps/day and peak 60-minute cadence.

**Results** Steps/day was inversely associated with age in both boys and girls. The age-associated reduction was apparent in only small decrements for boys; the girl's reduction was steeper. Boys appeared to maintain or increase their peak 60-minute cadence with increased age between 8 and 15 years of age, with a reduction apparent over the last 2 age groups investigated. The peak 60-minute cadence was more variable for girls; a similar sharp reduction (3-6 steps/min) in tandem with the steps/day was apparent between 10- to 11-year-old girls and 12- to 13-year-old girls.

**Conclusions** We provided detailed information and normative data pertaining to steps/d and peak 60-minute cadence in US children and adolescents. Like well-known body mass index growth curves, these data may be useful for scientists and clinical practitioners. *(J Pediatr 2015;166:139-43)*.

Objectively monitored step-defined physical activity has been increasingly used to describe children's and adolescents' daily ambulatory activity.[1-3] Mean expected values have been assembled,[4] compiled from aggregated studies originally conducted with primarily small and specific samples. Together, these studies indicate that among children, boys average 12 000-16 000 steps/day, and girls average 10 000-13 000 steps/day.[4] Adolescents present decrementally lower steps/day with each year of age until approximately 8000-9000 steps/day are observed in 18-year-olds.[4] Recently, a detailed distribution of normative steps/day data has been reported for Canadian children and adolescents,[1] however, no other similarly detailed data are available for other populations, including US children and adolescents.

A nationally representative normative steps/day value from the US that reflects the complete data distribution beyond a simple indicator of centrality is needed. We have provided this type of information for older adults[5] and demonstrated that, with a few exceptions, steps/day tended to be lower within each quintile-defined category as age increased. Moving beyond this index of ambulatory volume, there is also emerging interest in capturing and presenting young peoples' "best natural daily effort" as peak 60-minute cadence (the mean steps/minute accumulated during the highest, not necessarily consecutive, 60 minutes in a day).[6] Peak 60-minute cadence was also shown to be associated with cardiovascular disease risk factors in children and adolescents.[7]

The 2005-2006 National Health and Nutrition Examination Survey (NHANES) remains the single best source of objectively monitored and step-defined ambulatory activity in the US. Although mean values for accelerometer-determined steps/day[2] and peak 60-minute cadence[6] have been presented for specifically defined age groups, representations of the complete spectrum of steps/day and peak 60-minute cadence in terms of key percentiles by sex-age year have not been published. These types of data can be especially useful to clinicians as they can be used to track physical activity during childhood and adolescence. The purpose of this analysis of the 2005-2006 NHANES is to provide sex-and-age specific

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| LMS | $\lambda$, median, coefficient of variation |
| NHANES | National Health and Nutrition Examination Survey |

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normative values for US children's and adolescents' accelerometer-determined step-related data, including steps/day and peak 60-minute cadence.

## Methods

The NHANES protocols for physical activity measurement have been previously described[2,6] and relevant information is available at http://www.cdc.gov/nchs/tutorials/physicalactivity. Steps were measured using the ActiGraph model 7164 accelerometer (formerly the CSA/MTI AM-7164, manufactured by ActiGraph LLC, Pensacola, Florida). The National Center for Health Statistics ethics review board approved all protocols, and all participants provided informed consent. Parental/guardian consent was obtained for minors. This analysis sample was restricted to participants aged 6-19 years with at least 1 day of valid accelerometer data (more detail below) to keep consistent with previous analyses.[2,5,6]

The SAS code supplied by the National Cancer Institute (http://riskfactor.cancer.gov/tools/nhanes_pam/) was used to determine non-wear time and to identify those days with at least 10 hours of wear time (the threshold used to consider a day's data sufficient and therefore valid).[8] Using previously described methods[2,9] for the steps/day analysis, the values obtained by this particular accelerometer were "censored" or adjusted to better match steps/day obtained by pedometers. This adjustment was applied to every minute that the activity count value was <500 the corresponding step count was set to 0, decreasing the overall steps/day value. Steps/day and peak 60-minute values were averaged across all valid days. Consistent with previous studies,[6,7] peak 60-minute cadence was calculated by rank ordering each minute of wear time based upon steps/minute values, and subsequently calculating the mean for the highest, but not necessarily consecutive, 60 minutes per day. The daily value was then averaged across valid days.[6,10] Although not as easy to obtain from pedometers as steps/day, researchers have reported peak cadence[11] in children's research using devices like the StepWatch accelerometer (Orthocare Innovations, LLC, Mountlake Terrace, Washington),[12-14] which provides an output of peak 1-minute cadence and can facilitate calculation of other peak cadence values.

The analytic sample comprised 2610 children and adolescents (1281 boys and 1329 girls). This same sample has been previously used to present mean values for steps/day[2] and describe cadence patterns and peak 60-minute cadence.[6] Average wear time for the analytic sample was 820 ± 4.5 minute/day, with boys wearing the accelerometer for 828 ± 4.6 minute/day and girls 812 ± 5.9 minute/day.[6]

Descriptive analyses were conducted using SAS (v 9.3; SAS Institute, Inc, Cary, North Carolina). Steps/day and peak 60-minute cadence were computed for quintile-defined categories as previously labeled, in ascending order, as lowest, below average, average, above average, and highest.[1,5] The quintile-defined categories were stratified by age groups (each encompassing 2 years) for a total of 7 groups. In addition, steps/day and peak 60-minute cadence values were computed for the entire sample and separately for each sex.

In order to manage the naturally erratic data string underlying the distribution of both steps/day and peak 60-minute cadence, smoothed percentile curves were created using the LMS (LMSChartMakerPro v 2.54; The Institute of Child Health, London, United Kingdom) curve fitting procedure. This is the same procedure used to present the Centers for Disease Control and Prevention body mass index growth charts.[15] Similarly to the process used in the development of the World Health Organization growth references, data from 6- to 24-year-old participants were used to generate the curves.[16] The LMS method utilizes a Box-Cox power transformation to normalize the data,[17] and this was applied to each age year. Splines were fitted by maximum penalized likelihood[18] to create 3 age-specific, smoothed curves termed L ($\lambda$), M (median), and S (coefficient of variation). Equivalent degrees of freedom for L, M, and S measure the complexity of each fitted curve, and Q statistics test for normality in the location, scale and skewness of the z-scores calculated using the accelerometer measurement and the values of L, M, and S. Centile curves were created using the LMS values at each age along with the normal equivalent deviate. The Q statistic was used in the diagnosis of the best fitting curve as it tests for nonrandom between-group variation in the estimated moments of the z-scores. The LMS software then plots their standardized residuals against the equivalent degrees of freedom.[18] Based on suggestions by Pan and Cole,[18] smoothing constants were chosen to be as small as was possible to center the Q tests around 0 (targeting values between −2 and 2, but values up to 4 were considered acceptable), therefore, creating a parsimonious model. In order to avoid artificially creating differences through modeling procedures, the model was initially fitted for the entire sample, and the L, M, and S values chosen for the entire sample were then applied separately to sex-specific data.

## Results

Sample frequencies stratified by sex, age group, and race/ethnicity are presented in **Table I** (available at www.jpeds.com). **Table II** presents the ranges for steps/day across quintile-defined categories for the entire sample, and stratified by sex and age group. Steps/day was lower within each quintile-defined category with each ascending age group for both boys and girls. For boys, this reduction was apparent in relatively small increments (≈800 steps/day) that were almost negligible between adjacent age groups. The reduction within quintiles ranged between 3000 and 4500 steps/day from 6-7 to 18-19 years of age. For girls the reduction with increasing age grouping was more apparent with a more dramatic drop of approximately 2000 steps/day between 10- to 11-year-old girls and 12- to 13-year-old girls.

**Table III** displays peak 60-minute cadence ranges across the quintile-defined categories for the entire sample, and stratified by sex and the different age groups. In contrast with apparent