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# Use of population-referenced total activity counts percentiles to assess and classify physical activity of population groups

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ABSTRACT

*Objectives.* Population-referenced total activity counts per day (TAC/d) percentiles provide public health practitioners a standardized measure of physical activity (PA) volume obtained from an accelerometer that can be compared across populations. The purpose of this study was to describe the application of TAC/d population-referenced percentiles to characterize the PA levels of population groups relative to US estimates.

*Methods.* A total of 679 adults participating in the 2011 NYC Physical Activity Transit survey wore an ActiGraph accelerometer on their hip for seven consecutive days. Accelerometer-derived TAC/d was classified into age- and gender-specific quartiles of US population-referenced TAC/d to compare differences in the distributions by borough ($N = 5$).

*Results.* Males in Brooklyn, Manhattan, and Staten Island had significantly greater TAC/d than US males. Females in Brooklyn and Queens had significantly greater levels of TAC/d compared to US females. The proportion of males in each population-referenced TAC/d quartile varied significantly by borough ($\chi^2(12) = 2.63$, $p = 0.002$), with disproportionately more men in Manhattan and the Bronx found to be in the highest and lowest US population-referenced TAC/d quartiles, respectively. For females, there was no significant difference in US population-reference TAC/d quartile by borough ($\chi^2(12) = 1.09$, $p = 0.36$).

*Conclusions.* These results demonstrate the utility of population-referenced TAC/d percentiles in public health monitoring and surveillance. These findings also provide insights into the PA levels of NYC residents relative to the broader US population, which can be used to guide health promotion efforts.





## 1. Introduction

Physical inactivity is a leading contributor to the development of many chronic diseases including obesity, diabetes, and cancer (Lee et al., 2012; World Health Organization). Given the extensive effects on health, the promotion of physical activity (PA) has become a prominent focus of public health efforts (Kohl et al., 2012; Centers for Disease Control and Prevention, 2010). Obtaining accurate and reliable estimates of population-level PA is crucial to this effort, as it forms the basis to guide all aspects of PA promotion, from monitoring and surveillance to measuring the effectiveness of programs and interventions designed to increase PA (Bauman et al., 2006).

At the population level, surveillance systems have historically relied on self-report questionnaires to obtain estimates of PA, which are subject to substantial recall bias (Shephard, 2003; Lim et al., 2015). In addition, across national health surveys a variety of self-report measures are used resulting in inconsistent estimates of PA that cannot be directly compared (Bauman et al., 2006). Thus, many health surveys have begun to supplement self-report PA with objective measures obtained from accelerometers (Pedisic and Bauman, 2015; Bassett et al., 2015). Accelerometers have increased in popularity due to their ability to provide reliable estimates of total PA as well as capture the amount and intensity of activity (Bassett, 2012).

The most common analytic technique for accelerometer data is the use of threshold-based cut-points to categorize activity count outputs from the device into time spent in sedentary, light, moderate, or vigorous intensity PA. However, there is concern that the intensity-specific cut-points do not provide accurate estimates of time spent in different intensity levels, leading many to urge the discontinuation of their use (Bassett et al., 2015; Freedson et al., 2012). An alternative approach to intensity-specific cut-point estimates is to use accelerometer-derived total activity counts per day (TAC/d). The total activity counts metric is a proxy for the total volume of PA as it incorporates all intensity categories and weights each minute according to the frequency and intensity of movement. The importance of a global measure of PA based on the aggregation of accelerometer detected movement such

*Abbreviations:* NHANES, National Health and Nutrition Examination Survey; NYC, New York City; PAT, Physical Activity Transit Survey; PA, physical activity; TAC/d, total activity counts per day.

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as TAC/d was demonstrated by Wolff-Hughes and colleagues, who found TAC/d had stronger associations with cardiometabolic biomarkers (i.e., blood pressure, body mass index, and cholesterol) than traditional accelerometer-derived minutes spent in MVPA bouts of ≥10 min (Wolff-Hughes et al., 2015a). These cross-sectional results suggest that aggregated TAC may be a more robust and predictive measure of PA than intensity-specific analytic approaches (Wolff-Hughes et al., 2015a).

Accelerometer-derived TAC/d could also provide a standardized measure of PA that can be compared across studies. In addition, population-referenced TAC/d percentiles provide public health practitioners with a measure of PA volume that can be expressed relative to other populations (Wolff-Hughes et al., 2014; Wolff-Hughes et al., 2015b). However, there has been no research implementing population-referenced TAC/d percentiles to assess the PA of population groups (e.g., state, county, geographic region) relative to a reference population. Thus, the purpose of this study was to demonstrate the utility of the TAC/d population-referenced percentiles for assessing and comparing the PA of population groups relative to US estimates.

## 2. Methods

This study used data from the 2011 New York City Physical Activity Transit (PAT) Survey. The PAT survey was a random digit-dial telephone survey of approximately 2500 non-institutionalized NYC adult (≥18 years) residents that was designed to provide estimates of PA at the city, borough, and subgroup levels (Immerwahr et al., 2012). In addition to PA and transit behaviors, the interview collected demographic, socioeconomic, and health-related information. As part of the 2011 PAT survey, ambulatory individuals were asked to participate in the device follow-up study which aimed to objectively measure PA using accelerometers.

For this study, the sample was limited to ambulatory adults with accelerometer data ($n = 803$). Participants who did not have ≥4 days with ≥10 h of accelerometer wear time were excluded from the analysis, resulting in a final sample of 679 individuals. The original survey protocols were approved by the NYC Health Department institutional review board, and informed consent was obtained from all PAT survey participants.

### 2.1. Accelerometer data collection and analysis

All ambulatory adults participating in the 2011 PAT survey were eligible participants for the accelerometer component. Participants agreeing to complete the device follow-up study were asked to wear an ActiGraph GT3X accelerometer (ActiGraph, Shalimar, FL, USA) on their hip during waking hours for seven days, and to remove it when in water. Accelerometer data were recorded in 10 s epochs (Immerwahr et al., 2012).

The PAT accelerometer data were processed using the 2003–2006 National Health and Nutrition Examination Survey (NHANES) accelerometer protocol (National Cancer Institute). Non-wear time was defined as ≥60 consecutive minutes with zero accelerometer counts, allowing up to two minutes with <100 cpm (Troiano et al., 2008) A valid day was defined as a day with 10 or more hours of monitor wear. The TAC/d variable was defined as the mean daily activity counts accumulated on valid monitoring days.

### 2.2. Statistical analysis

In order to obtain estimates representative of the NYC population, sampling weights specific to the PAT device follow-up survey were used to account for the complex survey design and survey nonresponse (Immerwahr et al., 2012). Data were analyzed using SAS 9.3 (SAS Institute, Inc., Cary, NC) and SUDAAN 11.0 (Research Triangle Park, NC).

Due to gender differences in activity levels, all analyses were stratified by gender. Independent samples t-tests were used to compare US national estimates, based on NHANES 2003–2006 data for TAC/d, to the total NYC population and to each borough. To adjust for the multiple comparisons of each t-test, the false discovery rate was used (Benjamini and Hochberg, 1995). The false discovery rate adjustment threshold for significance was set at $p \leq 0.05$.

Accelerometer-derived TAC/d was classified into age- and gender-specific quartiles of US population-referenced TAC/d and a chi-square was used to compare differences in the distributions by NYC borough (N = 5). The development of age- and gender-specific US population-referenced TAC/d percentiles has been previously described (Wolff-Hughes et al., 2014; Wolff-Hughes et al., 2015b). In brief, the LMS method was applied to 2003–2006 NHANES accelerometer data to create smoothed, sex- and age-specific percentile curves. The LMS method is a statistical approach that normalizes a measure across age using a Box–Cox power transformation and has been used to develop the Centers for Disease Control and Prevention growth charts (Kuczmarski et al., 2000; Cole and Green, 1992). The LMS parameters are skewness (L), median (M), and coefficient of variation (S) (Cole and Green, 1992). In order to derive percentiles representative of the US population, all LMS model fitting is adjusted for NHANES sample weights. Q4

## 3. Results

Demographic characteristics of the 679 adults included in this study are presented in Table 1. The average age of the sample was 44.6 (SE = 1.1) years and comprised 53.4% females, 36.8% Non-Hispanic Whites, and 80.2% having attained a high school education or greater. The average volume of activity accumulated by NYC residents was 17% higher than the US population (324,856 vs. 277,559 TAC/d, $p \leq 0.0001$).

Fig. 1 presents the results of independent samples t-tests examining differences in TAC/d between NHANES and each NYC borough in males and females. New York City males residing in Brooklyn ($M = 355{,}762$; $SE = 41{,}715$; $p = 0.02$), Manhattan ($M = 451{,}776$; $SE = 42{,}292$; $p \leq 0.0001$), or Staten Island ($M = 364{,}493$; $SE = 26{,}803$; $p = 0.03$) accumulated significantly greater TAC/d compared to US males ($M = 312{,}445$; $SE = 3390$). Females residing in Brooklyn ($M = 296597$; $SE = 24{,}175$; $p = 0.005$) or Queens ($M = 296{,}751$; $SE = 30{,}541$; $p = 0.003$) had significantly greater levels of TAC/d compared to US females ($M = 245{,}254$; $SE = 2{,}820$). While not significant, females in the Bronx ($M = 235{,}087$; $SE = 21{,}279$) and Staten Island ($M = 227{,}941$; $SE = 17{,}169$) accumulated lower levels of TAC/d compared to US national estimates.

**Table 1**
Characteristics of participants, 2011 Physical Activity Transit Device Follow-up Survey.

| Variable | % (SE) |
|---|---|
| Age in years [Mean(SE)] | 44.6 (1.1) |
| Gender | |
| Female | 53.4 (3.7) |
| Male | 46.6 (3.7) |
| Race/ethnicity | |
| Non-Hispanic White | 36.8 (3.1) |
| Non-Hispanic Black | 21.5 (2.6) |
| Hispanic | 26.3 (3.2) |
| Asian/Pacific Islander | 12.3 (2.8) |
| Other | 3.09 (1.4) |
| Education Level | |
| <HS | 19.8 (3.2) |
| HS degree | 24.8 (3.1) |
| Some college | 23.1 (2.8) |
| ≥College degree | 32.3 (3.2) |
| TAC/d [Mean(SE)] | 324,856 (10,971) |

Note: Prevalence estimates are age-adjusted.