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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,

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Contributor's Statement

Dana Wolff-Hughes conceptualized and designed the study, conducted statistical analyses, oversaw data analysis, drafted the initial manuscript, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Richard Troiano and James McClain conceptualized and designed the study, assisted with the interpretation of the data, critically reviewed and revised the manuscript, and approved the final manuscript as submitted.

Eugene Fitzhugh and William Boyer participated in the conceptualization and design of the study, assisted with the statistical analysis and interpretation of the data, critically reviewed and revised the manuscript, and approved the final manuscript as submitted.

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.

Keywords

Actigraphy; Epidemiologic Measurements; Health Promotion; Motor Activity; New York City

Physical inactivity is a leading contributor to the development of many chronic diseases including obesity, diabetes, and cancer.[1,2] Given the extensive effects on health, the promotion of physical activity (PA) has become a prominent focus of public health efforts.[3,4] 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.[5]

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.[6,7] 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.[5] Thus, many health surveys have begun to supplement self-report PA with objective measures obtained from accelerometers.[8,9] 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.[10]

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.[9,11] 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 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, cholesterol, etc.) than traditional accelerometer-derived minutes spent in MVPA bouts of ≥ 10 minutes.[12] These cross-sectional results suggest that aggregated TAC may be a more robust and predictive measure of PA than intensity-specific analytic approaches.[12]

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.[13,14] 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.

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 2,500 non-institutionalized NYC adult (≥18 years) residents that was designed to provide estimates of PA at the city, borough, and subgroup levels.[15] 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 d 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.

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 second epochs.[15]

The PAT accelerometer data were processed using the 2003 – 2006 National Health and Nutrition Examination Survey (NHANES) accelerometer protocol.[16] Non-wear time was defined as ≥ 60 consecutive minutes with zero accelerometer counts, allowing up to two minutes with < 100 counts/min[17] A valid day was defined as a day with 10 or more hours of monitor wear. The total activity counts per day (TAC/d) variable was defined as the mean daily activity counts accumulated on valid monitoring days.

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 non-response.[15] 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.[18] 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.[13,14] 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.[19,20] The LMS parameters are skewness (L), median (M), and coefficient of variation (S).[20] In order to derive percentiles representative of the US population, all LMS model fitting adjusted for NHANES sample weights.

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 was comprised of 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≤0.0001).

Figure 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≤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= 3,390). 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.

Results of the chi-square analysis indicated a significant difference in the proportion of males in each US population-referenced TAC/d quartile by borough ($\chi^2(12)=2.63$, p=0.002) (Figure 2). Males in Manhattan were most likely to be in the highest US population-reference TAC/d quartiles for activity, with close to 60% in the fourth quartile (i.e., ≥ 75th percentile) and 0% in the first quartile (i.e., ≤ 25th percentile). The lowest levels of activity were seen in the Bronx, with approximately 31% of males in the first quartile (i.e., below the 25th percentile) for US population-referenced TAC/d.

For females, there was no significant difference in US population-reference TAC/d quartile by borough ($\chi^2(12)=1.09$, p=0.36). While not significant, it is important to note that over 50% of females in Brooklyn were in the highest TAC/d quartile. In contrast, females in

Staten Island had the lowest levels of activity, with 38% in the 1st quartile (i.e., <25th percentile) for US population-referenced TAC/d.

DISCUSSION

This study is the first to use population-referenced percentiles for TAC/d to assess community levels of activity. Our findings 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.

Results of this study indicate that the total volume of PA accumulated by NYC adults is significantly greater than the US population. Specifically, the TAC/d of NYC adults was 17% higher than national estimates. This finding is consistent with previous research by Evenson and colleagues which found that older adults (> 60 years) in NYC accumulated significantly more volume (approximately 17 more activity counts/minute) compared to national estimates for older adults.[21] When comparing the TAC/d of each borough to US estimates, however, significant variability was found. In particular, only males in Brooklyn, Manhattan, and Staten Island and NYC females in Brooklyn and Queens were found to have significantly greater TAC/d compared to the US population. Similar results are reported by the *County Health Rankings and Roadmap* which found residents of Manhattan have lower levels of physical inactivity compared to similar US counties, while the Bronx has higher levels of inactivity.[22]

The classification of PA levels using population-referenced TAC/d quartiles also revealed differences in the volume of PA accumulated by NYC residents across boroughs and gender. A significant difference between boroughs was only observed for males, with men in Manhattan and the Bronx in the highest and lowest US population-referenced TAC/d quartiles, respectively. Most notably, there were no males in Manhattan who fell in the 1st quartile (i.e., <25th percentile) for US population-referenced TAC/d. One explanation for this finding is the small sample size (n = 35) of Manhattan men used in this study. Although this result must be interpreted with caution, this finding is supported by previous research indicating the activity levels of Manhattan residents is higher than other NYC boroughs.[23-25] These studies suggest that the built environment may explain the greater levels of PA in Manhattan relative to other boroughs. Specifically, geographic data from the 2011 NYC Physical Activity Transit (PAT) survey found that amongst NYC boroughs, Manhattan had the highest average walkability,[25] with only 9% of Manhattan participants driving to work.[24] Similarly, data from the 2007 NYC Community Health Survey found that compared to other boroughs Manhattan adults were more likely to walk or bicycle more than 10 blocks to destinations (77% vs. 66%).[23]

The TAC/d metric has several advantages. First, TAC/d is a direct expression of what the accelerometer is recording. Second, TAC/d is a continuous measure that weights each minute according to the frequency and intensity of the movement. This allows TAC/d to serve as a proxy for the total volume of PA while preserving the intensity-related variability of the accelerometer-based measure within a sample. In addition, TAC/d provides an alternative to traditional (i.e., cut-point based intensity classification) approaches to

accelerometer data reduction as it avoids the pitfalls of misclassification error associated with these techniques.

Population-referenced TAC/d percentiles have utility in several areas of health promotion. In terms of monitoring and surveillance, TAC/d percentiles provide a nationally standardized objective measure of the total volume of PA. This enables researchers and practitioners to easily draw comparisons across populations and subgroups and identify groups with disparate levels or distributions of PA. Related to the implementation and evaluation of health promotion programs, the identification of population groups with disparate levels of PA can be used to guide the development of targeted programs and policies for PA promotion. Percentile-based TAC/d thresholds can also be used as a part of participant recruitment where individuals falling in a certain percentile range (i.e., individuals below the 50^{th} percentile) are eligible for participation in an intervention. In addition, TAC/d percentiles may be useful for researchers and public health practitioners to identify individual level changes in PA and evaluate the relative impact of a PA program or policy-based changes.

Given the broad implications for health promotion, future research should further examine the utility of population-referenced TAC/d percentiles to classify the PA of population groups. This includes the construction of country-specific and aggregated global percentiles in order to facilitate international comparison of PA levels. In addition, future research should explore the development of criterion-based standards of PA using TAC/d in order to determine dose-response relationships with health outcomes.

Strengths of this study include the sampling design of the NYC Physical Activity Transit Survey, which produces a large, representative sample of New York City residents. The second is that the use of accelerometers, an objective measure of PA, improves the precision with which ambulatory activity is measured.[9,10] It is important to note however, that accelerometers are limited by their inability to capture non-ambulatory activities such as cycling, weight training, and swimming. In addition, the applicability of the NHANES TAC/d percentiles in other populations is limited to samples of adults with waist-worn, ActiGraph accelerometer data.[26] However, the ActiGraph is the most commonly used accelerometer in research.[9,27] Furthermore, while these percentiles are specific to the waist wear location used in the NHANES 2003-06 physical activity monitor (PAM) protocol, population-referenced TAC/d percentiles could be developed and applied to wrist-worn data in the future based on the NHANES 2011-2014 PAM protocol.[9,26]

Conclusion

This paper describes the application of US population-referenced TAC/d percentiles to characterize PA levels of demographic and geographic population subgroups. This method provides public health practitioners a standardized measure of total activity volume that enables comparisons across communities, population subgroups, and to national estimates. The identification of populations and geographic areas with disparate levels or distributions of PA can be used to aid in the development and implementation of targeted policies and programs to increase physical activity and improve health.

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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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Highlights

1. A representative sample of New York City adults was evaluated.
2. Population-referenced total activity counts percentiles used to assess activity.
3. Activity volume of New York City adults varied by gender and borough.
4. Results demonstrate utility of total activity count percentiles in health promotion.

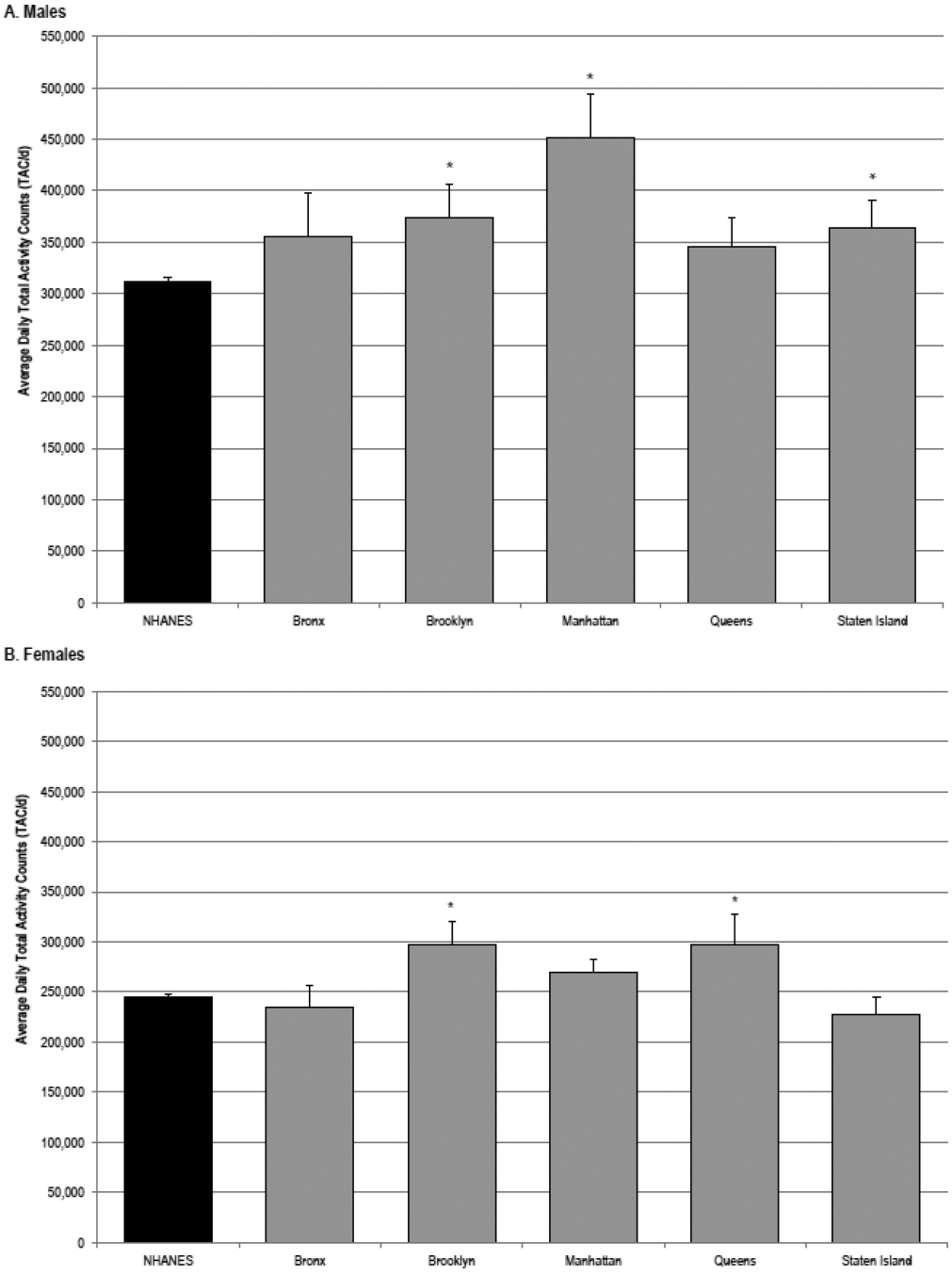

Figure 1.

Average Total Activity Counts per Day in NYC (A) males and (B) females borough: Comparisons to US Estimates. *p<0.05.

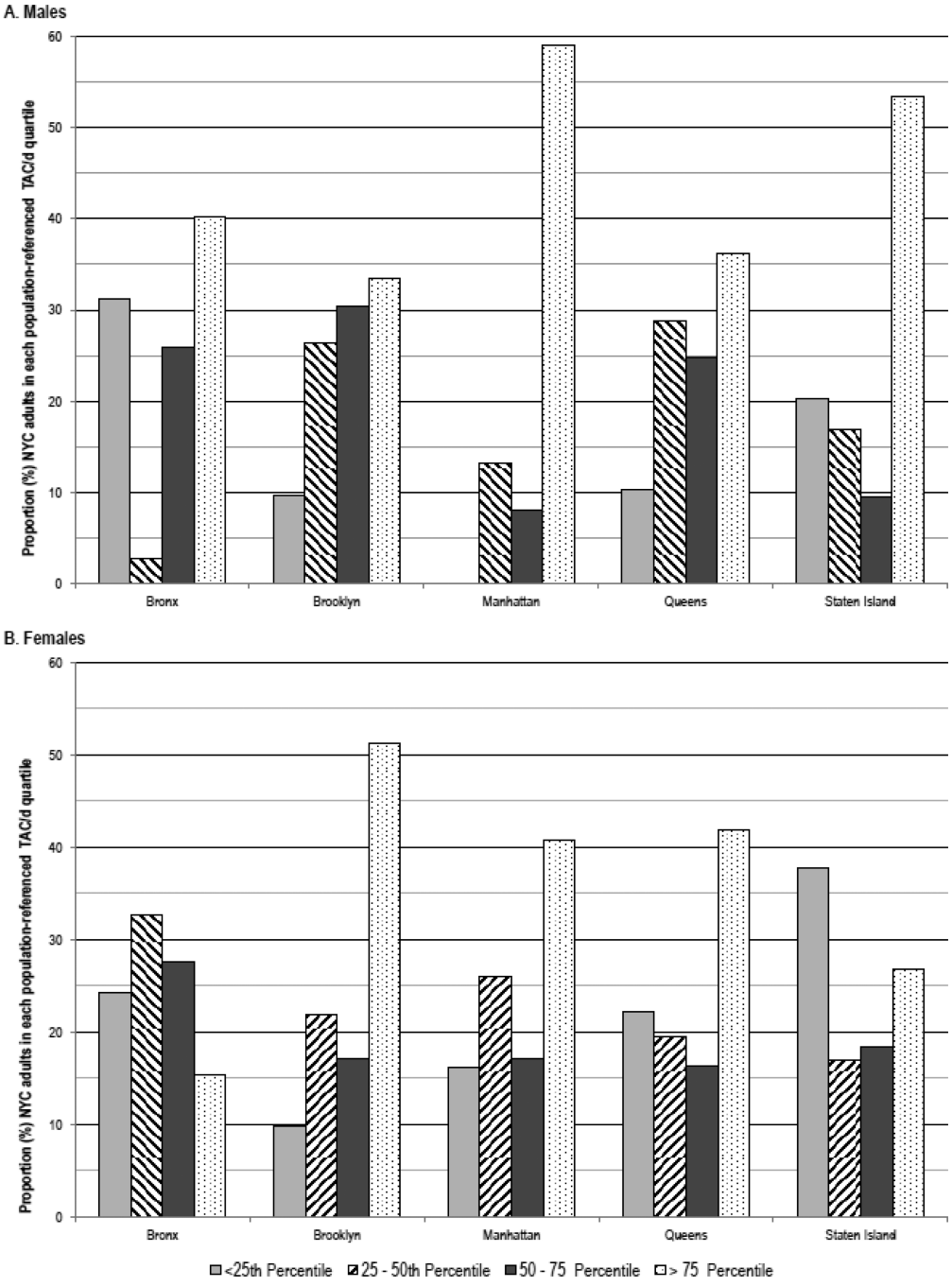

Figure 2.

Differences in the Distribution of NYC (A) males and (B) females in Each US Population-Reference TAC/d Quartile by Borough. *p<0.05.

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.