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Descriptive Finding

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Abstract

BACKGROUND
With the emergence of obesity as a global health issue, an increasing number of major demographic surveys are collecting measured anthropometric data. Yet little is known about the characteristics and reliability of these data.

OBJECTIVES
We evaluate the accuracy and reliability of anthropometric data collected in the home during Wave IV of the National Longitudinal Study of Adolescent to Adult Health (Add Health), compare our estimates to national standard, clinic-based estimates from the National Health and Nutrition Examination Survey (NHANES) and, using both sources, provide a detailed anthropometric description of young adults in the United States.

METHODS
The reliability of Add Health in-home anthropometric measures was estimated from repeat examinations of a random subsample of study participants. A digit preference

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analysis evaluated the quality of anthropometric data recorded by field interviewers. The adjusted odds of obesity and central obesity in Add Health vs. NHANES were estimated with logistic regression.

RESULTS
Short-term reliabilities of in-home measures of height, weight, waist and arm circumference − as well as derived body mass index (BMI, kg/m^2) − were excellent. Prevalence of obesity (37% vs. 29%) and central obesity (47% vs. 38%) was higher in Add Health than in NHANES, while socio-demographic patterns of obesity and central obesity were comparable in the two studies.

CONCLUSIONS
Properly trained non-medical field interviewers can collect reliable anthropometric data in a nationwide, home visit study. This national cohort of young adults in the United States faces a high risk of early-onset chronic disease and premature mortality.

1. Introduction

With the emergence of obesity as a global health threat (Caballero 2007), the value of accurate and reliable anthropometric data has never been greater. This is particularly true for panel studies, which are invaluable for studying the predictors, trajectories, and consequences of overweight and obesity. However, national panel studies in the United States have traditionally relied on potentially biased self-reported anthropometrics (Lee et al. 2011). Only recently have a number of major longitudinal social surveys initiated the collection of measured anthropometric data (Vaupel, Wachter, and Weinstein 2007). Yet little is known about the characteristics and reliability of these data, particularly when collected in the home and by trained non-medical staff. As the first major social survey in the United States to collect reliability data on measured anthropometrics, the National Longitudinal Study of Adolescent to Adult Health (Add Health) is uniquely positioned to address this gap.

The first purpose of this paper, then, is to provide a comprehensive report on the characteristics and reliability of the expanded anthropometric data in Add Health Wave IV. This information will be valuable to the 10,000+ Add Health researchers and other investigators interested in collecting these measures in research participants' homes. Second, we describe the anthropometric characteristics of this national cohort and compare them to those of young adults in the National Health and Nutrition Examination Survey (NHANES), the primary source of anthropometric data on the U.S. population.

2. Methods

2.1 Add Health sample

Add Health is a nationally representative probability sample of U.S. adolescents in grades 7 through 12 in the 1994−95 school year (Harris 2009). At Wave IV (2008), 15,701 original participants, ranging in age from 24−32 years, were re-interviewed (80% response rate). Further study details (Harris et al. 2009) and user guides are available at the project website: http://www.cpc.unc.edu/projects/addhealth. Add Health procedures and the present study were approved by the Public Health-Nursing Institutional Review Board (IRB) at the University of North Carolina.

2.2 Add Health in-home anthropometric measures

After each participant completed the Wave IV interview, typically in their home, one of 323 trained and certified field interviewers (FIs) collected standing height, weight, waist circumference, and (upper) arm circumference. Height was measured in the Frankfort horizontal plane to the nearest 0.5 cm; weight to the nearest 0.1 kg using a high capacity (200 kg), digital bathroom scale; and waist circumference to the nearest 0.5 cm at the superior border of the iliac crest. Measured height, weight, and waist circumference were further classified according to National Institutes of Health Clinical Guidelines. Specifically, BMI was calculated as weight in kilograms divided by height in meters squared. Overweight was defined as a BMI of 25 to 29.9 kg/m^2, obesity as a BMI $\geq$30.0 kg/m^2; and central obesity as a waist circumference >88 cm in women and >102 cm in men (NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Obesity in Adults 1998). To determine the correct blood pressure cuff size, upper arm circumference was measured and categorized as <13 inches, 13−16 inches, or >16 inches. Cooperation rates for the measurement of height, weight, and waist circumference exceeded 99%. Following 11% of interviews, post-encounter telephone calls were made to participants to verify FI adherence to the anthropometric protocol (RTI International 2010). Further details on the study's anthropometric protocols are published elsewhere (Entzel et al. 2009).

2.3 NHANES external comparison sample

With its national representation and standardized, clinic-based measurement, NHANES provided an excellent comparison sample for external validation of our in-home

measures. NHANES 2007−2008 was a population-based, cross-sectional survey of the civilian, non-institutionalized U.S. population (CDC 2010). The survey included in-home interviews (78% response rate) and health measurements made in mobile examination centers (75% response rate).

NHANES anthropometric data were collected under uniform conditions in the mobile examination clinics by two staff working together. Standing height was measured to the nearest 0.1 cm using a fixed stadiometer and with the head aligned in the Frankfort horizontal plane, weight to the nearest 0.1 kg using a digital scale, and waist circumference to the nearest 0.1 cm (CDC 2007).

2.4 Analysis

2.4.1 Reliability analysis

In a separate quality control study, the short-term test-retest reliability of anthropometric measures was assessed among a race/ethnicity and sex-stratified random sample of 100 Add Health Wave IV participants (mean age 29 years; 50% female; 64% non-Hispanic White; 16% non-Hispanic Black; 12% Hispanic/Latino; 8% other). The participants were examined twice, one to two weeks (mean: 8.6 days) apart. At both examinations, height, weight, and arm circumference were measured following the protocol described above, typically by the same FI (84% of participants) and at approximately the same time of day (mean absolute difference: 52 minutes; range 0−302 minutes).

A nested, random-effects model was first used to partition the variance of the height, weight, waist and arm circumference measures into their between-participant, between-visit, and within-visit components. To facilitate comparison with other studies, reliability was then computed as the ratio of the between-participant to total variance ($\sigma^2_{BP} / \sigma^2_T$), i.e., an intra-class correlation coefficient (ICC) with 95% confidence intervals (95% CI), computed using the delta method under the assumption of normality (Oehlert 1992). The ICC represents the proportion of variance that is not due to measurement variance. It can be interpreted as the correlation between repeated measurements from the same individual. All random effects models were implemented in SAS® 9.1 (SAS Institute Inc., Cary, NC) using PROC MIXED and the restricted maximum likelihood method.

2.4.2 Digit preference analysis

FI-specific digit preference was monitored using a Pearson χ^2 test of the null hypothesis that all possible digits (0, 1, 2, …, 9) were observed with equal frequency. Exact tests were implemented when the number of FI-specific participant observations was less than fifty. Adjustments for multiple comparisons were made using the Bonferroni method. Calculation of a digit preference score (DPS) was also used to reduce Type I error, otherwise inherent in identification of divergence from a uniform distribution of digits at even modest sample sizes. The DPS can range from 0 to 100, with scores of 20 or higher considered problematic (National Heart, Lung, and Blood Institute 1989).

2.4.3 Add Health [home]-NHANES [clinic] comparisons

Cross-survey comparisons were made between adults aged 24−32 years in Add Health and NHANES. BMI analyses used data from 14,026 Add Health and 743 NHANES non-pregnant participants aged 24−32 with non-missing survey weights and measured height and weight. Waist circumference analyses used data from 14,119 Add Health and 716 NHANES non-pregnant participants with non-missing survey weights and measured waist circumference.

Mean BMI and waist circumference for Add Health participants were referenced against NHANES participants before and after weighting for unequal sampling probabilities, clustering, and predicted probabilities of participant selection (i.e., propensities). Propensities were conditional on age, sex, race/ethnicity, nativity, education, and income.

Weighted logistic regression models estimated the probability of selection into Add Health (versus NHANES) conditional on participant characteristics. Add Health and NHANES sampling weights were then adjusted via multiplication by the inverse probabilities of selection. Persons in categories under-represented in Add Health versus NHANES were thereby given higher weight, and vice versa. We then recomputed mean BMI and waist circumference in Add Health and NHANES using these adjusted weights. Finally, logistic regression models were used to estimate the odds of obesity and central obesity in Add Health versus NHANES, using adjusted weights and controlling for the full set of above-mentioned covariates. All summary statistics were estimated using STATA®/SE 10 (StataCorp LP, College Station, TX) and corrected for the complex survey design, unequal probability of selection, and non-response to produce nationally representative estimates. The Stata code for the construction and implementation of the adjusted weights is available as a supplemental file.

3. Results

3.1 Participant characteristics

The socio-demographic characteristics of Add Health and NHANES participants are summarized in Table 1. On average, stratum-specific sample sizes were 17 (range: 5−28 times) times higher and the precision of corresponding estimates much greater in Add Health than in NHANES. In both samples the mean age was 28 and there was an equal representation of females and males. Participants in Add Health were less likely than those in NHANES to be of Mexican origin (6% vs. 13%) and to be foreign-born (5% vs. 19%). Conversely, educational attainment was greater among Add Health participants.

Table 1: Participant characteristics of the Add Health Wave IV (2008) and NHANES 2007-2008 population, ages 24–32 years

	Add Health, Wave IV (Home)		NHANES 2007-2008 (Clinic)	
	n	% (95% CI)[a]	n	% (95% CI)[b]
Age, Mean (SD)	14751	28 (2)	805	28 (2)
Sex				
Males	6899	51 (49, 52)	399	51 (47, 55)
Females	7852	49 (48, 51)	406	49 (45, 53)
Race/Ethnicity				
White, Non-Hispanic	7833	66 (60, 71)	310	62 (50, 72)
Black, Non-Hispanic	2958	15 (11, 19)	175	13 (9, 18)
Asian/Pacific Islander, non-Hispanic	834	3 (2, 5)	—	—
Other Race/Multiracial	908	5 (4, 6)	32	6 (3, 11)
Mexican	981	6 (4, 9)	196	13 (9, 20)
Other Hispanic	1177	5 (3, 8)	92	6 (4, 10)
Nativity				
U.S. Born	13625	95 (93, 96)	595	81 (73, 87)
Foreign-Born	1119	5 (4, 7)	210	19 (13, 27)
Education				
0-11 years	1134	9 (8, 11)	217	19 (15, 24)
H.S. graduate/GED	2377	18 (16, 20)	192	23 (19, 27)
Some college/AA degree	6504	43 (41, 45)	232	31 (25, 37)
4-yr college or greater	4733	30 (27, 33)	164	27 (21, 35)
Household income				
≤ $20,000[c]	1590	13 (11, 14)	162	16 (12, 21)

[a] Percent (95% confidence interval) weighted to be representative of U.S. adolescents in grades 7-12 in the 1994-1995 school year.
[b] Weighted percent (95% confidence interval)
[c] Federal poverty line for a family of four in 2008 = $21,200

3.2 Reliability

The short-term test-retest reliabilities of Add Health Wave IV measured height, weight, waist circumference, and arm circumference − as well as derived BMI − were uniformly excellent. Consistent with other studies (Crespi et al. 2012; El-Moalem et al. 1997; Mueller et al. 1996), ICCs for these measures ranged from 0.92 to 1.00 (Table 2).

Table 2: Variance and reliability of anthropometric measures: Add Health, Wave IV (2008)

	Variance					
Measure[a]	Between-Participant	Between-Visit	Within-Visit	Total	ICC (95% CI)	N
Weight (kg)	588.816	0.0263	0.9948	589.8372	1.00 (1.00-1.00)	100
Height (cm)	103.515	0.8524	1.0017	105.3691	0.98 (0.98-0.99)	100
BMI (kg/m^2)	65.1638	0.0000	0.3248	65.4886	0.99 (0.99-1.00)	100
Waist (cm)	311.944	6.7752	1.0002	319.7194	0.98 (0.97-0.99)	100
Arm Circumference (cm)	3.664	0.0000	0.3356	3.9994	0.92 (0.87-0.97)	42[b]

[a] ICCs were insensitive to log-transformation and did not differ significantly when both observations were recorded by the same vs. different field interviewers.

[b] Upper arm circumference was measured to the nearest quarter inch only among pretest participants in the embedded reliability study.

ICC (95% CI) = intra-class correlation coefficient, 95% confidence interval. BMI = body mass index.

3.3 Digit preference

There was little evidence of substantial digit preference in FI recording of measured weight, height, and waist circumference. There was, however, some evidence of whole- and half-unit rounding by FIs, despite training aimed at eliminating it. Although each measure was associated with a significant overall chi-square test statistic, corresponding digit preference scores (DPS) ranged from 1.4 to 6.7 − well below the threshold of concern (i.e., DPS ≥20) applied in prior studies (National Heart, Lung, and Blood Institute 1989).

3.4 Add Health [home] and NHANES [clinic] BMI/obesity

The mean BMIs in Add Health (29 kg/m^2) and NHANES (28 kg/m^2) were comparable and placed the average U.S. young adult in the overweight category (Table 3). Table 3 also reveals that the overall prevalence of obesity was higher in Add Health (37%; 95% CI: 35, 39) than in NHANES (29%, 95% CI: 23, 34). Survey weights and propensities for differential selection into Add Health versus NHANES failed to account for the

between-study differences in obesity. The adjusted odds of obesity in Add Health versus NHANES were 1.4 (95% CI = 1.1, 1.8; Table 4).

Table 3: Comparison of body mass index and waist circumference (cm) by socio-demographic characteristics, Add Health (2008) and NHANES (2007–2008), ages 24–32 years[a]

	Mean BMI (SD)		% Obese[b] (95% CI)		Mean Waist (SD)		Central Obesity[c] % (95% CI)	
	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic
Overall	29 (8)	28 (5)	37 (35, 39)	29 (23, 34)	98 (17)	94 (13)	47 (46, 49)	38 (32, 44)
Sex								
Males	29 (7)	27 (5)	36 (34, 37)	25 (20, 29)	100 (15)	94 (12)	34 (33, 36)	24 (19, 30)
Females	29 (9)	28 (6)	38 (35, 41)	33 (26, 41)	97 (19)	93 (15)	61 (59, 64)	53 (45, 61)
Race/Ethnicity								
White, Non-Hispanic	29 (7)	27 (4)	34 (32, 36)	27 (21, 35)	98 (15)	94 (11)	46 (44, 48)	38 (31, 47)
Black, Non-Hispanic	31 (10)	30 (9)	45 (42, 47)	39 (34, 45)	101 (22)	96 (19)	52 (49, 55)	44 (40, 48)
Asian/Pacific Islander	27 (8)	__	24 (18, 32)	__	91 (19)	__	31 (23, 40)	__
Other Race/Multiracial	30 (9)	25 (3)	40 (34, 46)	8 (1, 44)[d]	99 (20)	85 (7)	47 (41, 53)	12 (3, 33)[d]
Hispanic/Latino	30 (8)	29 (7)	43 (38, 47)	31 (26, 37)	99 (19)	95 (16)	50 (46, 55)	40 (32, 48)
Mexican	30 (7)	29 (7)	44 (39, 50)	34 (26, 43)	101 (15)	96 (17)	54 (48, 60)	44 (35, 53)
Cuban	29 (11)	__	43 (36, 50)	__	97 (33)	__	44 (37, 51)	__
Puerto Rican	29 (8)	__	40 (30, 50)	__	97 (18)	__	44 (36, 53)	__
Other Hispanic	30 (6)	28 (7)	41 (33, 50)	25 (17, 36)	98 (15)	92 (16)	48 (39, 57)	33 (22, 45)
Nativity								
U.S. Born	29 (7)	28 (5)	37 (35, 39)	30 (25, 35)	98 (17)	94 (13)	48 (46, 49)	40 (34, 46)
Foreign-Born	28 (8)	27 (6)	31 (26, 35)	24 (12, 42)	94 (18)	91 (14)	39 (34, 44)	30 (16, 48)
Education								
0-11 years	29 (7)	29 (6)	39 (35, 42)	35 (27, 43)	100 (16)	96 (15)	49 (45, 53)	46 (38, 54)
H.S. graduate/GED	30 (7)	28 (6)	42 (39, 46)	26 (18, 37)	101 (17)	94 (15)	50 (47, 53)	33 (23, 44)
Some college/AA degree	30 (8)	29 (5)	41 (39, 43)	32 (23, 44)	100 (18)	95 (13)	52 (49, 54)	42 (32, 53)
4-year college or greater	27 (7)	27 (4)	26 (24, 29)	22 (15, 30)	94 (16)	91 (11)	38 (36, 41)	32 (22, 45)
Household income								
≤ $20,000	30 (8)	28 (7)	39 (35, 43)	32 (21, 46)	100 (19)	94 (16)	52 (49, 56)	42 (32, 54)
> $20,000	29 (7)	28 (5)	36 (34, 38)	28 (23, 34)	98 (17)	94 (12)	46 (45, 48)	37 (31, 44)

[a] Estimates exclude pregnant women
[b] Obese if BMI ≥30
[c] Central obesity: Men: > 102 cm; Women > 88 cm
[d] Estimate should be interpreted with caution: relative standard error > 30% (National Center for Health Statistics, Centers for Disease Control and Prevention. Analytic and Reporting Guidelines: The National Health and Nutrition Examination Survey (NHANES). Hyattsville, Maryland, 2006).

Table 4: Effect of weighting and propensity scoring on mean body mass index and prevalence of obesity (panel A) and mean waist circumference and prevalence of central obesity (panel B), ages 24–32 Years

Panel A: BMI and Obesity

	Add Health [Home], Wave IV (2008)			NHANES [Clinic] (2007–2008)			Odds of obesity in Add Health vs. NHANES n=13762	
	n	BMI	BMI ≥ 30 % (95% CI)	n	BMI	BMI ≥ 30 % (95% CI)	Crude OR (95% CI)	Adjusted AOR[b] (95% CI)
Unweighted	13049	29	37 (36, 38)	713	28	31 (28, 35)	1.3 (1.1, 1.5)	1.4 (1.1, 1.6)
Weighted	13049	29	36 (35, 38)	713	28	29 (24, 35)	1.4 (1.1, 1.8)	1.4 (1.1, 1.8)
Propensity-scored[a]	13049	29	36 (34, 38)	713	28	29 (23, 37)	1.4 (1.0, 1.9)	1.4 (1.1, 1.8)

Panel B: Waist Circumference and Central Obesity

	Add Health [Home], Wave IV (2008)			NHANES [Clinic] (2007–2008)			Odds of Central Obesity in Add Health vs. NHANES n=13828	
	n	Waist	Central Obesity % (95% CI)	n	Waist	Central Obesity % (95% CI)	Crude OR (95% CI)	Adjusted AOR[b] (95% CI)
Unweighted	13138	98	48 (47, 49)	690	94	41 (37, 45)	1.3 (1.1, 1.6)	1.4 (1.2, 1.7)
Weighted	13138	98	47 (45, 49)	690	94	38 (32, 44)	1.5 (1.1, 1.9)	1.5 (1.2, 2.0)
Propensity-scored[a]	13138	98	47 (45, 49)	690	94	37 (30, 45)	1.5 (1.1, 2.0)	1.5 (1.2, 1.9)

[a] Adjusted for the predicted probability of being in the Add Health (versus NHANES) population conditional on age, sex, race/ethnicity, nativity, education, and income.

[b] Logistic regression model included all above-listed covariates.

This pattern of similar mean BMI values but higher obesity rates in Add Health generally holds throughout Table 3. Mean BMI values in Add Health were typically between 0−2 kg/m^2 higher than in NHANES. At the same time, a consistently higher prevalence of obesity was found in Add Health for all socio-demographic categories. In both studies the prevalence of obesity was higher among females, Blacks, and U.S. born participants, and lower among college graduates. Pronounced sex differences in obesity within racial/ethnic groups were also found in both studies (Table 5).

3.5 Add Health [home] and NHANES [clinic] waist circumference/central obesity

Waist circumference and central obesity comparisons between Add Health and NHANES participants (Tables 3 and 5) largely mirrored those observed for BMI and obesity. While socio-demographic patterns were similar across the two studies, both mean waist circumference and central obesity prevalence were consistently higher in Add Health. Among Add Health and NHANES women, the weighted mean waist circumferences (97 cm and 93 cm, respectively) exceeded the threshold for central

obesity (88 cm). In both studies, the prevalence of central obesity was higher among females, Mexican-origin Hispanics, and U.S. born participants. Those with four-year college degrees tended to have a relatively lower prevalence of central obesity, although high school and college graduates in NHANES were indistinguishable on this characteristic. Survey weights and propensities for differential selection into Add Health versus NHANES again failed to account for between-study differences in central obesity. The adjusted odds of central obesity in Add Health versus NHANES were 1.5 (95% CI = 1.2, 1.9; Table 4).

Table 5: Comparison of body mass index and waist circumference by race and sex, Add Health (2008) and NHANES (2007-2008), ages 24–32 years[a]

	Mean BMI (SD)		% Obese[b] (95% CI)		Mean Waist (SD)		Central Obesity % (95% CI)[c]	
	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic	Add Health Home	NHANES Clinic
Among Males								
White, non-Hispanic	29 (6)	27 (4)	35 (33, 37)	26 (21, 32)	100 (13)	95 (10)	35 (33, 37)	27 (21, 34)
Black, non-Hispanic	29 (7)	28 (6)	37 (33, 40)	31 (23, 41)	99 (19)	92 (16)	33 (30, 36)	22 (16, 29)
Asian/Pacific Islander	28 (8)	__	30 (21, 40)	__	94 (18)	__	21 (14, 30)	__
Other Race/Multiracial	30 (7)	25 (2)	40 (32, 49)	0	100 (18)	86 (6)	36 (28, 45)	0
Hispanic/Latino	30 (7)	28 (6)	40 (35, 46)	26 (20, 33)	101 (17)	96 (15)	36 (31, 42)	25 (18, 33)
Mexican	30 (7)	29 (6)	40 (33, 48)	31 (21, 43)	103 (15)	97 (16)	40 (32, 48)	30 (22, 39)
Cuban	31 (12)	__	51 (39, 63)	__	103 (37)	__	35 (19, 55)	__
Puerto Rican	30 (7)	__	40 (28, 52)	__	99 (17)	__	30 (21, 41)	__
Other Hispanic	29 (6)	28 (6)	40 (30, 50)	14 (6, 31)[d]	99 (14)	94 (14)	33 (23, 44)	14 (7, 28)[d]
Among Females								
White, non-Hispanic	28 (7)	28 (4)	34 (31, 36)	29 (19, 42)	96 (17)	92 (11)	59 (56, 62)	51 (39, 62)
Black, non-Hispanic	32 (12)	32 (10)	53 (50, 56)	45 (38, 51)	102 (25)	98 (21)	72 (69, 75)	60 (55, 66)
Asian/Pacific Islander	25 (8)	__	18 (11, 27)	__	87 (17)	__	42 (31, 54)	__
Other Race/Multiracial	30 (10)	25 (4)	40 (34, 47)	27 (3, 81)[d]	97 (22)	83 (9)	58 (52, 65)	36 (13, 68)[d]
Hispanic/Latino	30 (9)	29 (8)	46 (38, 53)	38 (30, 47)	97 (20)	93 (17)	66 (60, 71)	59 (49, 69)
Mexican	30 (8)	29 (7)	50 (41, 58)	38 (28, 49)	98 (18)	95 (17)	71 (66, 77)	63 (50, 74)
Cuban	28 (12)	__	37 (29, 45)	__	93 (35)	__	51 (40, 62)	__
Puerto Rican	29 (11)	__	40 (27, 56)	__	94 (23)	__	62 (50, 73)	__
Other Hispanic	30 (8)	28 (8)	42 (29, 57)	38 (26, 52)	97 (19)	90 (17)	62 (50, 73)	53 (37, 69)

[a] Estimates exclude pregnant women

[b] Obese if BMI ≥30

[c] Central obesity: men: > 102 cm; women > 88 cm

[d] Estimate should be interpreted with caution: relative standard error > 30% (National Center for Health Statistics, Centers for Disease Control and Prevention. Analytic and Reporting Guidelines: The National Health and Nutrition Examination Survey (NHANES). Hyattsville, Maryland, 2006).

4. Discussion

The recent increase in the number of major social and demographic surveys collecting measured anthropometric and other biomarkers in field settings (Harris 2010) has heightened demand for details on the quality of these data. To address this need, we evaluated the characteristics and reliability of in-home anthropometrics collected in a national sample of 15,701 young adults. Based on the findings, we conclude that the reliability of Add Health Wave IV anthropometric measures is high. There was no evidence of substantial digit preference and the short-term test-retest reliabilities of measured height, weight, waist, and arm circumference were excellent.

Our descriptive analysis provides new and troubling data on the anthropometric profile of young adults in the United States. In this nationally representative cohort of 24−32 year-olds, the average BMI (29 kg/m^2) was in the overweight category and 37% were obese. Further, apart from Asian/Pacific Islander females, the prevalence of obesity was 30% or greater for every racial/ethnic by sex group examined and 50% or greater for Mexican-origin females (50%), Cuban-origin males (51%), and Black females (53%).

The prevalence of obesity by sex, race/ethnicity, nativity, and education was consistently higher among Add Health versus NHANES young adults. These findings are similar to Add Health-NHANES comparisons made at Waves I and III (Gordon-Larsen et al. 2004). Sample differences likely account, in part, for the discordance. While both samples are nationally representative, Add Health is representative of U.S. adolescents in grades 7−12 during the 1994−95 school year who were followed into adulthood. NHANES, by contrast, is representative of the current U.S. population of young adults. This distinction is important. For example, the percentage of foreign-born young adults − due to recent migration patterns − is significantly higher in NHANES (19%) than in Add Health (5%). Still, the higher prevalence of obesity and central obesity in Add Health versus NHANES persisted even after weighting for unequal sampling probabilities, clustering, and predicted probabilities of participant selection.

4.1 Study strengths and limitations

Strengths of this study include the careful investigation of several potential sources of anthropometric measurement error in a nationally representative in-home study. To our knowledge, Add Health is the first major U.S. social survey to report on the reliability of home-based anthropometric measures. Add Health also extends NHANES data by contributing the first national anthropometric data for Puerto Rican and Cuban American young adults. The substantially larger sample of young adults in Add Health

(vs. NHANES) also yields more precise estimates of obesity and central obesity by key socio-demographic characteristics.

The main limitations of this study pertain to the practical challenges associated with collecting anthropometric data in the home within the context of a large, nationwide sample involving 323 field interviewers. Both cost and logistics were important considerations in the design of the measurement protocols. Field interviewers worked alone and often some walking was required to reach participants, making the weight and portability of their interview materials, which included a laptop and blood spot collection kit, key considerations. Thus, while a portable stadiometer may have provided more accurate height measurements, this potential benefit was offset by its added cost, weight, and bulk.

4.2 Conclusions

Obesity is an established risk factor for morbidity and mortality (Bogers et al. 2007; Flegal et al. 2007). Consequently, its high prevalence in these young adults may foreshadow an exceptional burden of chronic disease and premature mortality as they enter middle adulthood (Reither, Olshansky, and Yang 2011). Indeed, a high prevalence of hypertension and diabetes − both of which are strong risk factors for cardiovascular disease − already exists in this cohort (Nguyen et al. 2011, 2014). These troubling indicators highlight the value of collecting, documenting, and disseminating reliable anthropometric data that − when linked to longitudinal socio-demographic and contextual measures − can significantly advance our understanding of this growing threat to population health.

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References

Bogers, R.P., Bemelmans, W.J.E., Hoogenveen, R.T., Boshuizen, H.C. , Woodward, M., Knekt, P., van Dam, R.M., Hu, F.B., Visscher, T.L.S., Menotti, A., Thorpe, R.J., Jamrozik, K., Calling, S., Strand, B.H., and Shipley, M.J. (2007). Association of Overweight With Increased Risk of Coronary Heart Disease Partly Independent of Blood Pressure and Cholesterol Levels. A Meta-analysis of 21 Cohort Studies Including More Than 300 000 Persons. *Archives of Internal Medicine* 167(16): 1720−1728. doi:10.1001/archinte.167.16.1720.

Caballero, B. (2007). The Global Epidemic of Obesity: An Overview. *Epidemiologic Reviews* 29(1): 1−5. doi:10.1093/epirev/mxm012.

CDC [Centers for Disease Control and Prevention] (2007). National Health and Nutrition Examination Survey (NHANES). Anthropometry Procedures Manual [electronic resource]. Atlanta, GA: National Center for Health Statistics. [http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf]

CDC [Centers for Disease Control and Prevention] (2010). NHANES 2007-2008 [electronic resource]. Atlanta, GA: National Center for Health Statistics. [http://wwwn.cdc.gov/nchs/nhanes/search/nhanes07_08.aspx]

Crespi, C.M., Alfonso, V.H., Whaley, S.E., and Wang, M.C. (2012). Validity of child anthropometric measurements in the Special Supplemental Nutrition Program for Women, Infants, and Children. *Pediatric Research* 71(3): 286−292. doi:10.1038/pr.2011.37.

El-Moalem, H.E., Gagnon, J., Province, M., Bouchard, C., Leon, A.S., Skinner, J.S., Wilmore, J.H., and Rao, D.C. (1997). Race differences in reproducibilities: The HERITAGE family study. *American Journal of Human Biology* 9(4): 415−424. doi:10.1002/(SICI)1520-6300(1997)9:4<415::AID-AJHB1>3.0.CO;2-V.

Entzel, P., Whitsel, E.A., Richardson, A., Tabor, J., Hallquist, S., Hussey, J.M., Halpern, C.T., and Harris, K.M. (2009). Add Health Wave IV Documentation. Cardiovascular and Anthropometric Measures [electronic resource]. Chapel Hill, NC: Carolina Population Center. [http://www.cpc.unc.edu/projects/addhealth/data/guides/Wave IV cardiovascular and anthropometric documentation 110209.pdf]

Flegal, K.M., Graubard, B.I., Williamson, D.F., and Gail, M.H. (2007). Cause-Specific Excess Deaths Associated With Underweight, Overweight, and Obesity. *JAMA* 298(17): 2028−2037. doi:10.1001/jama.298.17.2028.

Gordon-Larsen, P., Adair, L.S., Nelson, M.C., and Popkin, B.M. (2004). Five-year obesity incidence in the transition period between adolescence and adulthood: the National Longitudinal Study of Adolescent Health. *American Journal of Clinical Nutrition* 80(3): 569−575.

Harris, K.M. (2009). The National Longitudinal Study of Adolescent to Adult Health (Add Health), Waves I & II, 1994–1996; Wave III, 2001–2002; Wave IV, 2007−2009. (machine-readable data file and documentation). Chapel Hill, NC: Carolina Population Center, University of North Carolina at Chapel Hill.

Harris, K.M. (2010). An integrative approach to health. *Demography* 47(1): 1−22. doi:10.1353/dem.0.0091.

Harris, K.M., Halpern, C.T., Whitsel, E., Hussey, J., Tabor, J., Entzel, P., and Udry, J.R. (2009). The National Longitudinal Study of Adolescent to Adult Health: Research design [electronic resource]. Chapel Hill, NC: Carolina Population Center. [http://www.cpc.unc.edu/projects/addhealth/design]

Lee, H.E., Lee, D., Guo, G., and Harris, K.M. (2011). Trends in Body Mass Index in Adolescence and Young Adulthood in the United States: 1959–2002. *Journal of Adolescent Health* 49(6): 601−608. doi:10.1016/j.jadohealth.2011.04.019.

Mueller W.H., Taylor, W.C., Chan, W., Sangi-Haghpeykar, H., Snider, S.A., and Hsu, H.-A. (1996). Precision of Measuring Body Fat Distribution in Adolescent African American Girls From the 'Healthy Growth Study'. *American Journal of Human Biology* 8: 325−329. doi:10.1002/(SICI)1520-6300(1996)8:3<325::AID-AJHB3>3.0.CO;2-Z.

National Heart, Lung and Blood Institute, Atherosclerosis Risk in Communities Study (1989). Manual 12: Quality assurance and quality control, section 5.2. Monitoring for digit preference [electronic resource]. Chapel Hill, NC: Collaborative Studies Coordinating Center. [http://www.cscc.unc.edu/aric/visit/]

Nguyen, Q.C., Tabor, J.W., Entzel, P.P., Lau, Y., Suchindran, C., Hussey, J.M., Halpern, C.T., Harris, K.M., and Whitsel, E.A. (2011). Discordance in National Estimates of Hypertension Among Young Adults. *Epidemiology* 22(4): 532−541. doi:10.1097/EDE.0b013e31821c79d2.

Nguyen, Q.C., Whitsel, E.A., Tabor, J.W., Cuthbertson, C.C., Wener, M.H., Potter, A.J., Halpern, C.T., Killeya-Jones, L.A., Hussey, J.M., Suchindran, C., and Harris, K.M. (2014). Blood spot–based measures of glucose homeostasis and diabetes prevalence in a nationally representative population of young US adults.

Annals of Epidemiology 24(12): 903−909. doi:10.1016/j.annepidem.2014.09.010.

NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Obesity in Adults (US) (1998). Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report [electronic resource]. Bethesda, MA: National Heart, Lung, and Blood Institute. [http://www.ncbi.nlm.nih.gov/books/NBK2003/]

Oehlert, G.W. (1992). A Note on the Delta Method. *American Statistician* 46(1): 27−29. doi:10.2307/2684406.

Reither, E.N., Olshansky, S.J., and Yang, Y. (2011). New Forecasting Methodology Indicates More Disease And Earlier Mortality Ahead For Today's Younger Americans. *Health Affairs* 30(8): 1562−1568. doi:10.1377/hlthaff.2011.0092.

RTI International (2010). Add Health field interviewer verification script [electronic resource]. Chapel Hill, NC: Carolina Population Center. [http://www.cpc.unc.edu/projects/addhealth/data/guides/FI_verify.pdf]

Vaupel, J.W., Wachter, K.W., and Weinstein, M. (2007). Introduction. In: Weinstein, M., Vaupel, J.W., and Wachter, K.W. (eds.). *Biosocial Surveys.* Washington, D.C.: The National Academies Press: 1−11.

Appendix

Table A: Comparison of anthropometry procedures for Add Health (2008) and NHANES (2007−8)

	Add Health Home	NHANES Mobile Clinic
Height	standing shoes removed level, firm surface (avoid carpet; rugs) four contact points with wall head aligned in Frankfort position carpenter's square steel tape measure measured to nearest 0.5 cm manual data entry	standing shoes removed stadiometer four contact points with backboard head aligned in Frankfort position stadiometer head piece digital measurement device w/ head piece measured to nearest 0.1 cm automated data entry
Weight	standing portable digital weight scale on level, firm surface subjects wear street clothes shoes; wallets; keys; etc. removed from person measured to nearest 0.1 kg manual data entry	standing digital weight scale built into exam room floor subjects wear disposable gown of shirt, pants shoes; wallets; keys; etc. absent from person measured to nearest 0.1 kg automated data entry
Waist Circumference	standing measured at superior border of iliac crest SECA 200 fiberglass circumference tape measure measured to nearest 0.5 cm manual data entry	standing measured at superior border of iliac crest retractable steel measuring tape recorded to nearest 0.1 cm manual data entry
Arm Circumference	upper arm mid-point 16-inch low-stretch, fiberglass tailor's tape recorded categorically as "Adult" (< 13 inches); "Large adult" (13-16 inches); "Large adult exceeding large [blood pressure] cuff size" (> 16) manual data entry	upper arm mid-point retractable steel measuring tape recorded to nearest 0.1 cm manual data entry
	For complete protocol, see Entzel et al. 2009. Add Health Wave IV Documentation: Cardiovascular and Anthropometric Measures. Available at: http://www.cpc.unc.edu/projects/addhealth/data/guides/	For complete protocol, see CDC 2007. National Health and Nutrition Examination Survey (NHANES) Anthropometry Procedures Manual. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf