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Summary of grip strength measurements obtained in the 2011-2012 and 2013-2014 National Health and Nutrition Examination Surveys

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ABSTRACT

Study Design: Cross-sectional and descriptive study.
Introduction: Supported by the Centers for Disease Control and Prevention, the National Health and Nutrition Examination Survey (NHANES) began collecting grip strength data from nationally representative samples in 2011.
Purpose of the Study: To examine the stability of the grip strength values across 2 data release cycles and provide updated US population-based grip strength values for 6 to 80 year olds.
Methods: Handgrip data from 13,676 participants aged 6-80 years were extracted from the NHANES 2011-2014 database. The muscle strength/grip test component measured the isometric grip strength using a Takei digital handgrip dynamometer (Takei Scientific Instruments, Shinagawa-Ku, Tokyo). Grip strength values (best of 3 trials for each hand) were summarized by gender, dominant side, and age group. Grip data from 2 data release cycles (2011-2012 vs 2013-2014) were compared.
Results: Differences between 2 data release cycles were negligible. Hence, we summarize grip strength values across the entire 2011-2014 period. The mean grip strength ranged from 50.3 kg for the dominant hand of 30- to 34-year-old men to 10.0 kg for the nondominant hand of 6-year-old girls.
Discussion: The summary data we present provide relatively current reference values to which tested individuals can be compared. However, clinicians and/or researchers should be aware that the instrumentation and procedures may influence the values.
Conclusions: Results supported the stability of the NHANES grip strength values across data release cycles.

Introduction

Grip strength is easy to administer and has been recommended as an indicator of overall muscle strength[1] and as a biomarker of general health status.[2] Grip strength demonstrates good test-retest reliability,[1,3] validity,[4,5] and responsiveness.[6] Consequently, grip strength is often included among the measures used in population-based studies of health, such as the Health, Aging and Body Composition study,[7] Established Population for the Epidemiological Study of the Elderly,[8] Framingham Offspring Cohort,[9] Canadian Health Measures Survey,[10] Prospective Urban Rural Epidemiology study,[11] National Institutes of Health (NIH) Toolbox,[12] and National Health and Nutrition Examination Survey (NHANES).[13] These studies, along with others that consolidate data from various

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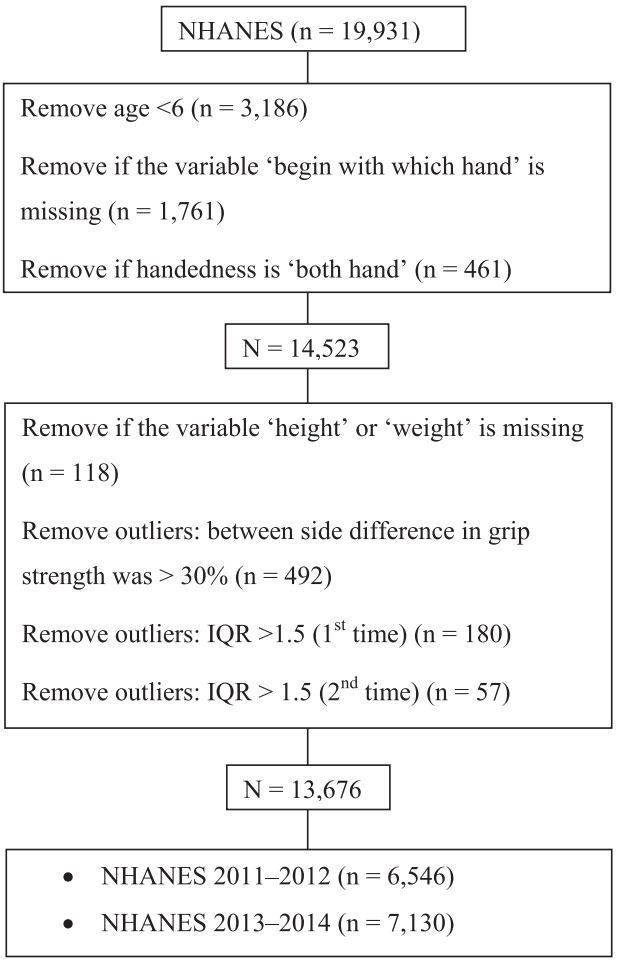

Fig. 1. Data cleaning flowchart. NHANES = National Health and Nutrition Examination Survey; IQR = interquartile range.

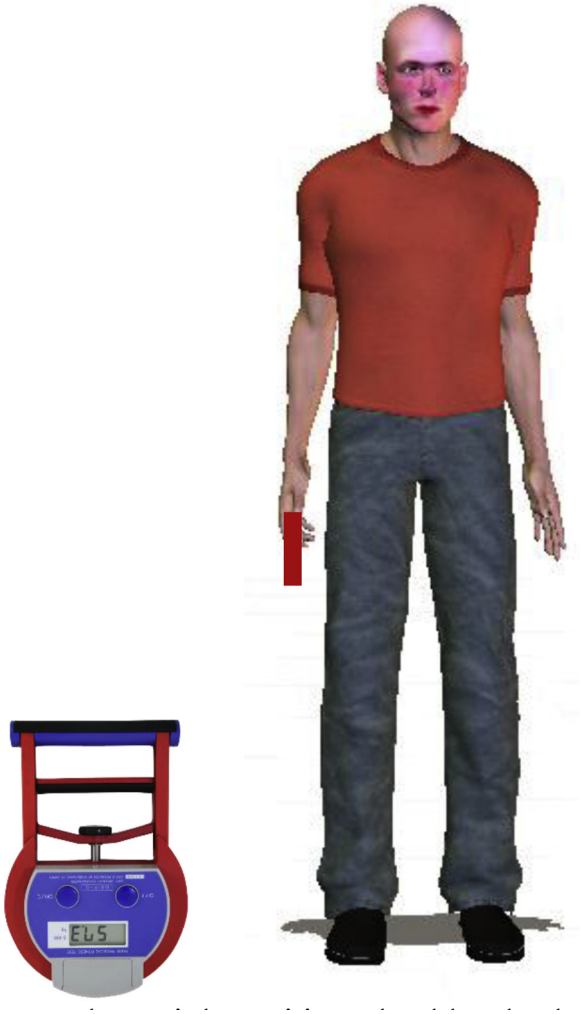

Fig. 2. Testing position and the Takei dynamometer. Torso at the upright position, shoulders back, chest up, shoulder abducted ~10°, arm straight down side, elbow fully extended, wrist in neutral position, knee at comfortable stance, and feet at hip width apart.

sources,[4,14,15] have been used to produce normative reference values for handgrip strength.

The availability of normative reference values and testing protocols notwithstanding,[16-18] we are not aware of any validation of norms based on study replication.[19] Two successive cohorts of the NHANES study (2011-2012 and 2013-2014) provide data by which such a validation is possible. Our purpose, therefore, was to compare normative grip strength data obtained from an original and an intergroup replicative cohort of the NHANES. Our expectation was that normative reference values stratified by age and gender would not differ between the 2 cohorts. If this was found to be the case, we intended to generate normative reference values derived from the consolidation of data from the 2 cohorts.

Method

The NHANES providing data for our study was approved by the National Center for Health Statistics Research Ethics Review Board. Further approval was not sought for our study as the data used were free of personal identifiers.

Participants

The NHANES data we used were from the years 2011-2014. The data were acquired from a stratified multistage probability sample of civilian noninstitutionalized residents of the United States. The NHANES study recruited participants aged 6 years and older. Participants were excluded if they were unable to hold the dynamometer with both hands (eg, missing both arms, both hands, thumbs on both hands, or paralyzed in both hands). Participants who were able to grip the dynamometer with 1 hand still performed the component. Participants who had surgery on either hand or wrist in the last 3 months were not tested on that particular hand.

Of the initial 19,931 data records, 3186 participants were removed because they were younger than 6 years (no handgrip data), and 2340 participants were removed because of missing values (eg, which hand began the test, handedness, height, or weight). In addition, 729 participants were excluded as outliers because their grip strength values were greater than 1.5 interquartile range of the same sex and age group or because their between-side difference in grip strength was ≥30%. Thus, data from 13,676 remaining participants (aged between 6 and 80 years) were included in the final analysis with a comparable representation of males (49.6%) and females (50.4%). By self-report, 91.4% of the sample was right hand dominant. Most of the sample was white (35.7%), whereas other races were represented as black (24.2%),

Table 1
Results of multifactorial analysis of variance

Variable	Sum of squares	df	Mean square	*F*	Significance
Between-subjects effects					
Intercept	19,789,877.6	1	19,789,877.6	296,607.5	.000
Cohort	594.2	1	594.2	8.9	.003
Gender	636,589.6	1	636,589.6	9541.1	.000
Age group	2,018,781.2	26	77,645.4	1163.7	.000
Cohort × gender	2.3	1	2.3	0.0	.852
Cohort × age group	1649.4	26	63.4	1.0	.535
Gender × age group	261,496.0	26	10,057.5	150.7	.000
Cohort × gender × age group	1247.6	26	48.0	0.7	.849
Error	905,267.2	13,568	66.7		
Within-subjects contrasts					
Dominance	15,831.9	1	15,831.9	3112.5	.000
Dominance × cohort	20.0	1	20.0	3.9	.048
Dominance × gender	33.8	1	33.8	6.7	.010
Dominance × age group	2185.7	26	84.1	16.5	.000
Dominance × cohort × gender	0.4	1	0.4	0.1	.775
Dominance × cohort × age group	100.6	26	3.9	0.8	.802
Dominance × gender × age group	212.0	26	8.2	1.6	.027
Dominance × cohort × gender × age group	68.2	26	2.6	0.5	.980
Error (dominance)	69,013.6	13,568	5.1		

df = degrees of freedom.

Mexican American (14.7%), Asian (11.9%), other Hispanic (9.6%), and others including multiracial (3.9%). Figure 1 presents the flowchart of data managing process.

There were 6546 (47.9%) participants from 2011 to 2012 and 7130 (52.1%) participants from 2013 to 2014 cycle. Between the 2 data sets, there were no statistical differences in age ($F = 0.65$; $P = .420$), gender (chi-square = 0.29; $P = .146$), or handedness (chi-square = 0.78; $P = .399$). The 2013-2014 data set had more Mexican American and white participants but fewer black participants (chi-square = 129.3; $P < .001$) comparing with the 2011-2012 data set.

Takei digital dynamometer

The Takei digital dynamometer, model T.K.K.5401, was used to record the maximum reading (kilograms) of the grip strength force (Fig. 2). Dimensions of the device are approximately 154 (weight) × 235 (diameter) × 62 (height) mm. The weight is approximately 0.63 kg. With a liquid crystal display, it has the measuring range of 5.0-100 kg. Calibration checks were performed before data collection as part of the quality control procedures.

Procedures

A detailed description of testing procedures can be found in the NHANES Muscle Strength Procedures Manual.[16] Briefly, before the test, a test administrator adjusted the grip size of a calibrated Takei digital dynamometer until the second joint of the participant's index finger was at a 90° angle on the handle. Participants were instructed to maintain in a proper stance, standing with their feet hip width apart and even, toes pointing forward, knees comfortable but not bent, shoulders back and chest up, eyes straight ahead, shoulder abducted ~10°, arm straight down side, elbow fully extended, and wrist in neutral position.

Participants were randomly assigned to start the test with their dominant hand or nondominant hand. A practice trial was performed with the hand opposite the hand tested first, unless the participant had only 1 hand eligible for the test. Suggested script for the practice trial was "*When I say "squeeze," squeeze as hard as you can until you can't squeeze any harder. Remember to blow out when you squeeze. Ready, take a breath in, let it out, squeeze! Squeeze as hard as you can until you can't squeeze any harder.*"

For the formal trial, participants were asked to squeeze the dynamometer as hard as they could with each hand while in a standing position (unless the participant was physically limited) with the elbow fully extended at the side. Suggested script was "*Ready, take a breath in, let it out, squeeze! Squeeze as hard as you can until you can't squeeze any harder.*"

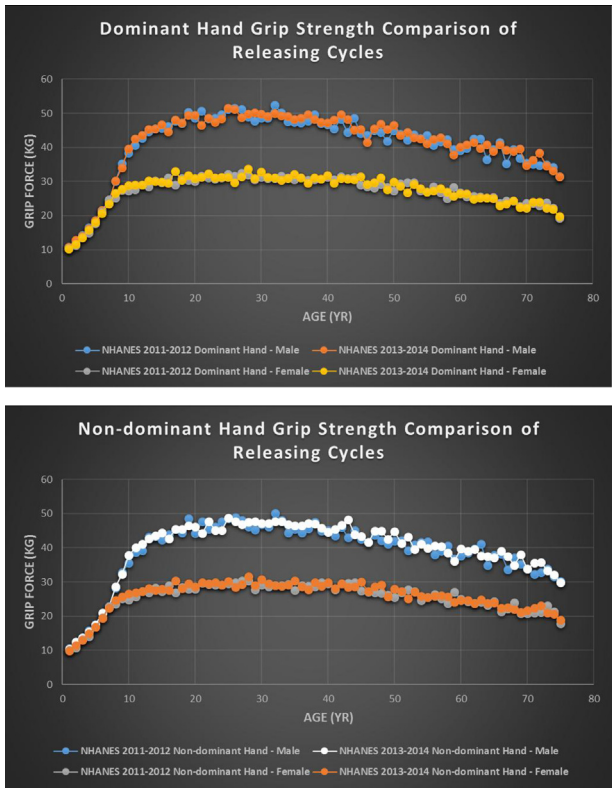

Fig. 3. Comparisons of grip strength values by data release cycles. NHANES = National Health and Nutrition Examination Survey.

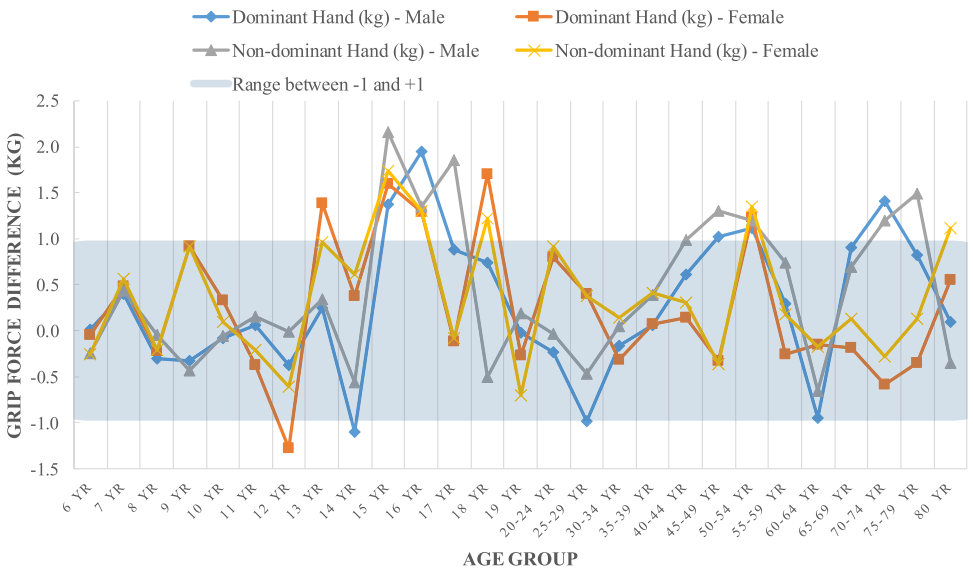

Fig. 4. Differences in grip strength values by data release cycles. Note. Grip force difference (kilograms) = (average grip strength values obtained from the NHANES 2013-2014 data release cycle) minus (average grip strength values obtained from the NHANES 2011-2012 data release cycle) by each age group. The light gray band serves as reference area from −1.0 to +1.0 kg. NHANES = National Health and Nutrition Examination Survey.

Each hand was tested 3 times with 60 seconds of break for the next trial. Best values, expressed in kilograms, were recorded for each hand.

Statistical analysis

To test the stability of grip strength values between 2 data release cycles (2011-2012 vs 2013-2014) and to establish whether grip strength data should be stratified according to gender, side, and age group, a 2 (cohort: 2011-2012 vs 2013-2014) × 2 (gender: male vs female) × 2 (side: dominant vs nondominant) × 27 (age group) multifactorial analysis of variance was performed with grip strength as the dependent variable.

For independent variables found to have a significant main or interactive effect on grip strength, pairwise post hoc comparisons were conducted. Separate comparisons were completed for the dominant and nondominant sides. Descriptive statistics were tabulated. Based on the numerous hypothesis tests conducted and a desire to reduce the risk of type 1 error, a significant level of $P < .001$ was adopted as an indicator of statistical significance.

Results

The analysis of variance (Table 1) revealed that the differences between 2 data release cycles (ie, cohort) were statistically insignificant, and grip strength data should be stratified according to gender, side, and age group (all $P < .001$).

Figure 3 illustrates the comparisons of grip strength values by data release cycles. Figure 4 shows the grip strength differences (in kilograms) between 2 data release cycles (y-axis) by each age group (x-axis). The differences between 2 data release cycles were relatively small, ranging from 0.01 to 2.16 kg with the largest fluctuation zone around participants aged 15-18 years.

Because the differences between 2 data release cycles were negligible, data from 2011 to 2014 were merged to provide grip strength values across the life span. Tables 2 and 3 provide summary grip strength statistics (mean, standard deviation, and percentile) for dominant and nondominant hands stratified by gender and age group.

Discussion

The study was conducted to examine the replicability of the grip strength values across 2 data release cycles and provide updated US population-based grip strength values for 6-80 year olds. Based on the authors' review of the literature, this is the first validation study of grip strength norms based on study replication. Moreover, this study was based on data from a population-based study (larger sample size) with rigorous sampling plans, data collection procedures, and quality control practices. National Center for Health Statistics staff and field supervisors regularly monitored test examiners. Retraining sessions are conducted periodically to reinforce the proper protocols and techniques. In addition, data are reviewed regularly for logical or operational inconsistencies and examiner errors.

Our finding that gender, side, and age group affect grip strength confirms the results of previous studies.[5,13,20] The confirmation was necessary to justify our stratification of grip strength values.

Comparing with 2011-2012 NHANES grip data published by Perna et al,[13] we did not present the grip strength for combined hands but rather for dominant and nondominant hands. Regardless of different data management procedures, the mean grip strength values stratified by gender and age group were very similar. For children aged 6-19 years, the differences in mean grip strength between the study by Perna et al and this study were within 2.3 kg (ie, 5 lbs) for male and female participants. For adults aged 20-70 years, the differences in mean grip strength values ranged from 0.2 to 5.6 kg (ie, 0.4-12.4 lbs) for male participants and 0.1-6.2 kg (0.2-13.7 lbs) for female participants. The small differences between 2 studies further supported the stability of the NHANES grip data across different data release cycles.

However, we note that, unlike NIH Toolbox study, the NHANES study did not use a protocol recommended by the American Society of Hand Therapists (ASHT).[21,22] The standardized positioning recommended by the ASHT is as follows: subject seated in a chair

Table 2
Summary handgrip strength measurements (kilograms) obtained from the dominant hand of male and female participants

Gender	Age (y)	*N*	Mean	SD	95% CI	Percentiles						
						5	10	25	50	75	90	95
Male	6	216	10.8	2.4	10.0-11.6	6.8	7.9	9.0	10.7	12.6	14.2	14.9
	7	215	12.7	2.7	11.9-13.5	8.5	9.5	10.8	12.3	14.9	16.0	17.9
	8	202	14.2	3.0	13.4-15.0	9.3	10.3	11.8	14.4	16.5	18.1	18.7
	9	196	16.4	3.0	15.6-17.3	11.1	12.2	14.5	16.4	18.7	20.4	21.2
	10	190	18.6	3.5	17.8-19.5	13.0	13.9	16.4	18.4	20.7	23.0	25.9
	11	179	21.6	4.9	20.7-22.5	14.2	15.5	17.9	21.0	25.4	28.4	31.2
	12	151	24.0	5.1	23.1-25.0	16.5	17.6	20.4	23.5	27.7	30.4	34.4
	13	160	30.1	6.8	29.2-31.1	20.4	22.2	24.6	29.1	34.8	40.1	42.8
	14	154	34.6	6.9	33.7-35.6	24.0	25.9	30.1	34.2	39.2	43.4	47.8
	15	139	39.0	6.7	38.0-40.0	28.8	30.0	34.7	38.7	43.6	48.4	50.1
	16	166	41.7	7.3	40.7-42.6	30.3	32.7	36.4	41.3	46.8	51.3	55.4
	17	133	43.2	7.3	42.1-44.2	31.8	33.5	37.4	42.8	48.0	53.0	56.1
	18	142	45.0	6.2	44.0-46.0	35.1	37.6	40.7	44.3	49.4	53.3	55.8
	19	131	45.5	7.7	44.5-46.5	32.2	36.0	40.4	44.7	50.4	55.5	58.2
	20-24	471	47.3	8.9	46.8-47.9	33.2	35.4	41.0	47.2	53.2	59.0	62.9
	25-29	380	48.6	8.7	48.0-49.2	35.7	37.9	42.1	47.5	53.9	60.8	64.1
	30-34	418	50.3	8.2	49.7-50.9	35.9	39.7	45.2	50.3	56.0	60.9	63.8
	35-39	363	49.4	8.3	48.8-50.0	35.8	37.9	43.9	49.8	54.7	59.8	63.2
	40-44	387	48.1	7.6	47.5-48.7	36.0	38.9	42.5	47.7	53.2	58.3	61.9
	45-49	357	47.4	7.3	46.7-48.0	35.0	37.5	42.8	47.4	52.2	57.4	60.3
	50-54	365	44.4	7.7	43.7-45.0	31.7	34.8	39.5	44.5	49.7	54.7	57.1
	55-59	347	43.8	7.2	43.2-44.5	31.6	34.0	39.0	43.6	48.7	53.6	56.0
	60-64	407	41.3	8.2	40.7-41.9	27.2	31.1	35.7	41.5	46.8	52.1	54.9
	65-69	280	40.1	8.1	39.4-40.8	26.5	29.3	34.7	40.2	45.4	51.3	53.3
	70-74	226	38.8	7.4	38.0-39.5	26.4	28.4	33.3	38.8	44.2	48.5	51.3
	75-79	161	35.3	7.2	34.4-36.3	23.2	25.9	29.8	35.4	40.6	44.8	47.0
	80	243	31.4	6.9	30.7-32.2	19.4	22.0	26.4	31.6	36.6	40.4	43.0
Female	6	195	10.4	2.2	9.5-11.2	7.2	7.8	8.7	10.1	11.8	13.4	14.3
	7	185	11.5	2.2	10.6-12.4	8.0	8.8	9.8	11.3	13.1	14.6	15.7
	8	177	13.7	2.9	12.8-14.6	9.4	10.2	11.4	13.4	15.7	18.0	19.1
	9	186	15.3	2.9	14.4-16.2	10.8	11.8	13.0	15.1	17.2	19.5	20.5
	10	170	18.0	3.4	17.1-18.9	12.3	13.8	15.6	18.2	20.3	22.5	23.4
	11	222	20.9	4.5	20.1-21.7	13.4	15.1	17.7	20.4	24.0	27.5	28.9
	12	155	24.0	5.0	23.1-25.0	15.9	17.6	20.4	23.8	27.5	29.7	32.5
	13	150	25.8	5.3	24.8-26.7	18.3	19.0	21.9	25.0	29.3	34.0	35.4
	14	155	27.6	4.9	26.6-28.5	19.5	21.7	24.2	26.8	30.9	34.8	36.5
	15	139	28.2	4.1	27.2-29.2	21.3	22.9	25.4	27.8	30.7	34.3	35.7
	16	166	28.4	4.1	27.5-29.3	20.8	23.3	25.8	28.6	30.8	33.9	35.2
	17	121	29.0	5.0	27.9-30.1	20.1	22.3	25.3	29.3	32.6	35.8	37.5
	18	139	29.5	5.2	28.5-30.5	21.7	22.8	25.4	29.1	32.9	36.9	39.7
	19	138	30.2	4.9	29.1-31.2	21.7	23.5	27.0	30.0	33.2	36.6	39.1
	20-24	443	30.5	4.9	30.0-31.1	22.6	24.4	27.3	30.1	33.5	37.3	39.4
	25-29	382	31.1	5.4	30.5-31.7	23.0	24.3	27.1	30.9	34.6	38.2	40.3
	30-34	413	31.6	5.3	31.0-32.1	23.1	24.5	28.0	31.5	35.1	38.5	41.3
	35-39	396	31.2	5.3	30.6-31.8	22.7	24.5	27.6	30.9	34.6	38.3	40.4
	40-44	421	30.8	5.3	30.2-31.4	22.0	23.9	27.0	30.7	34.4	38.1	39.7
	45-49	385	30.9	5.0	30.3-31.5	22.7	24.3	27.7	30.7	34.3	38.0	39.4
	50-54	416	29.2	5.3	28.6-29.8	20.7	22.3	25.5	29.3	32.6	36.4	38.3
	55-59	352	28.6	5.4	27.9-29.2	20.0	22.1	25.0	28.2	32.6	35.4	38.0
	60-64	413	27.1	4.6	26.5-27.7	19.6	20.9	24.0	27.1	30.1	33.1	34.6
	65-69	295	25.7	4.4	25.0-26.4	18.8	20.1	22.5	25.7	29.3	31.3	33.3
	70-74	282	24.0	4.7	23.3-24.7	15.9	17.3	20.9	24.3	27.4	29.8	31.6
	75-79	153	23.1	4.6	22.1-24.0	15.4	17.6	20.0	22.7	26.0	29.8	31.1
	80	248	19.5	4.5	18.8-20.3	12.3	13.4	16.6	19.1	22.8	25.9	27.5

N = number of participants; SD = standard deviation; 95% CI = 95% confidence interval.

without arm rests, shoulders adducted and neutrally rotated, elbow flexed at 90°, and forearm in neutral and wrist between 15° and 30° of dorsiflexion and 0°-15° of ulnar deviation. The ASHT protocol recommends the Jamar dynamometer in the second position and uses the mean of 3 trials of grip strength in each hand. These controls notwithstanding, there are important differences in how grip strength was measured between the NHANES and the NIH Toolbox studies. These include, but are not limited to, number of trials (eg, 1 maximum trial in NIH vs best of 3 trials in NHANES), differences in the hand dynamometer used (eg, Jamar vs Takei), dynamometer handle position (second vs index finger was at a 90° angle on the handle), upper limb position (eg, elbow flexed at 90° vs fully extended), and posture (eg, sitting vs standing). All these factors have the potential to influence grip strength measures. Investigators have reported that the grip strength measured with the elbow in the fully extended position was significantly higher than when the elbow was flexed at 90° regardless of shoulder position (ie, 0°, 90°, and 180° of flexion)[23] or dominant side.[24] Nonetheless, the opposite results were reported by Desrosiers et al.[25] Balogun et al[3] who compared grip strength in 4 positions and showed that grip strength measured in standing with the elbow in full extension (average grip strength = 31.1 kg) was higher than participants in the sitting position with the elbow flexed in 90° flexion (average grip strength = 29.5 kg). There is considerable variation in current methods and devices of assessing grip strength, which makes comparison between studies difficult.[18] In a head-to-head

Table 3
Summary handgrip strength measurements (kilograms) obtained from the nondominant hand of male and female participants

Gender	Age (y)	*N*	Mean	SD	95% CI	Percentiles						
						5	10	25	50	75	90	95
Male	6	216	10.5	0.4	9.7-11.3	6.9	7.6	8.8	10.4	12.0	13.7	14.3
	7	215	12.3	0.4	11.5-13.0	8.2	9.0	10.3	12.0	14.1	15.9	17.2
	8	202	13.8	0.4	12.9-14.6	9.1	9.5	11.1	13.8	16.1	17.7	19.3
	9	196	15.6	0.4	14.8-16.5	10.7	11.6	13.5	15.6	17.7	19.4	20.4
	10	190	17.5	0.4	16.7-18.4	12.1	13.2	15.3	17.4	19.7	22.1	24.4
	11	179	20.9	0.4	20.0-21.8	14.3	15.1	18.0	20.4	23.8	27.5	28.3
	12	151	22.8	0.5	21.8-23.7	14.9	16.6	19.1	22.5	25.7	29.5	32.9
	13	160	28.4	0.5	27.5-29.4	18.3	20.3	23.7	28.4	33.0	36.5	40.0
	14	154	32.6	0.5	31.6-33.5	20.6	23.5	28.3	32.7	36.3	42.0	45.6
	15	139	36.7	0.5	35.8-37.7	26.3	29.1	32.3	37.1	41.8	45.7	47.6
	16	166	39.4	0.5	38.5-40.3	27.6	30.6	34.3	39.4	44.6	48.2	51.9
	17	133	40.2	0.5	39.2-41.2	30.4	32.1	35.4	39.9	44.6	49.5	52.5
	18	142	42.9	0.5	41.9-43.8	31.9	35.6	38.4	42.3	47.1	51.0	54.0
	19	131	43.4	0.5	42.4-44.4	29.6	33.4	38.1	43.4	49.6	53.8	56.9
	20-24	471	44.9	0.3	44.4-45.4	30.5	32.8	38.1	45.0	51.0	56.3	61.3
	25-29	380	45.9	0.3	45.3-46.5	32.4	35.3	39.9	45.2	51.5	57.5	60.3
	30-34	418	47.7	0.3	47.1-48.2	34.2	37.6	42.3	47.6	52.9	57.5	60.8
	35-39	363	47.2	0.3	46.6-47.8	33.2	36.2	41.4	47.8	52.5	57.5	61.3
	40-44	387	46.0	0.3	45.5-46.6	34.4	36.6	40.7	45.9	51.6	56.6	58.9
	45-49	357	45.3	0.3	44.745.9	33.8	36.6	39.9	44.9	50.3	54.6	58.1
	50-54	365	42.8	0.3	42.2-43.4	30.2	32.9	38.5	43.2	47.9	51.6	54.5
	55-59	347	41.7	0.3	41.0-42.3	28.9	32.4	36.9	41.8	46.5	50.8	54.1
	60-64	407	39.2	0.3	38.6-39.8	27.1	29.0	33.5	39.1	44.6	49.7	52.6
	65-69	280	38.4	0.4	37.7-39.1	25.1	28.1	32.3	39.0	44.1	48.8	50.6
	70-74	226	36.7	0.4	35.9-37.5	25.3	26.7	31.5	37.1	41.4	45.5	49.6
	75-79	161	33.7	0.5	32.8-34.6	22.6	24.8	28.3	33.6	38.7	42.6	44.8
	80	243	30.1	0.4	29.3-30.8	18.9	20.8	25.6	30.0	35.1	39.5	40.4
Female	6	195	10.0	0.4	9.2-10.8	6.8	7.1	8.5	9.9	11.5	12.9	14.4
	7	185	11.1	0.4	10.3-12.0	7.8	8.5	9.6	10.9	12.6	14.0	14.8
	8	177	13.1	0.4	12.2-13.9	8.5	9.7	11.2	12.9	15.0	17.2	18.0
	9	186	14.5	0.4	13.6-15.3	10.3	10.9	12.5	14.3	16.5	18.4	19.7
	10	170	16.8	0.5	15.9-17.7	11.5	12.6	14.8	16.5	19.0	20.9	22.3
	11	222	19.5	0.4	18.7-20.3	13.0	14.3	16.7	19.1	22.2	25.6	26.7
	12	155	22.6	0.5	21.7-23.5	15.3	16.2	18.8	22.4	26.0	28.8	30.8
	13	150	24.0	0.5	23.1-25.0	16.4	17.5	20.3	23.7	27.8	31.4	33.1
	14	155	25.5	0.5	24.5-26.4	18.0	19.1	22.0	25.1	29.0	32.2	34.4
	15	139	25.8	0.5	24.8-26.8	19.3	20.9	22.6	25.6	28.2	31.7	33.2
	16	166	26.4	0.5	25.5-27.3	20.5	21.5	23.5	26.3	29.1	30.8	33.2
	17	121	27.2	0.5	26.2-28.3	19.7	21.1	24.1	27.3	30.2	33.3	34.9
	18	139	27.7	0.5	26.7-28.7	20.2	21.4	23.3	26.9	31.2	34.4	36.3
	19	138	27.8	0.5	26.9-28.8	20.4	22.3	24.5	27.4	30.9	34.0	37.6
	20-24	443	28.3	0.3	27.7-28.8	20.4	22.3	24.7	28.2	31.5	34.6	36.7
	25-29	382	29.2	0.3	28.6-29.8	21.4	23.0	25.6	29.0	32.4	36.4	38.1
	30-34	413	29.7	0.3	29.1-30.2	21.9	22.9	25.9	29.4	32.7	36.3	38.9
	35-39	396	29.1	0.3	28.6-29.7	20.7	22.9	25.7	28.8	32.7	36.3	38.1
	40-44	421	28.9	0.3	28.3-29.4	21.0	22.5	25.4	28.9	32.2	35.1	36.7
	45-49	385	29.1	0.3	28.5-29.7	21.6	22.8	25.6	29.0	32.2	35.5	37.5
	50-54	416	27.5	0.3	26.9-28.1	19.3	21.0	24.2	27.4	30.6	33.9	36.1
	55-59	352	26.5	0.3	25.9-27.1	18.4	19.9	23.3	26.5	30.0	33.1	34.5
	60-64	413	25.6	0.3	25.0-26.1	18.4	19.9	22.6	25.4	28.7	31.3	32.5
	65-69	295	24.3	0.3	23.6-24.9	17.4	18.7	21.1	24.1	27.2	30.3	31.5
	70-74	282	22.6	0.4	21.9-23.3	14.4	16.9	19.7	22.8	25.8	28.5	30.3
	75-79	153	21.7	0.5	20.7-22.6	14.8	16.1	18.4	21.6	25.0	27.2	29.1
	80	248	18.3	0.4	17.6-19.1	10.5	12.1	15.0	18.2	21.4	24.4	26.3

N = number of participants; SD = standard deviation; 95% CI = 95% confidence interval.

comparison, Amaral et al[2] found statistical significance comparing the grip strength obtained from the Jamar and the Takei dynamometers. However, their sample size was relatively small with 18 young healthy volunteers. Nonetheless, a direct comparison of the grip strength measurements between the NHANES and the NIH Toolbox studies suggested that values obtained from the NIH Toolbox (1 maximum trial) differed from NHANES best values (of 3 trials) but not NHANES mean values (of 3 trials).[6]

There were several limitations of the study. Because this study included secondary data sources, the researchers were not in control of the recruiting and data collection procedures. The handgrip values were collected as part of larger set of survey questions or performance measures, so fatigue may have had an unknown effect. Some variables such as handedness relied on self-report. Missing data were inevitable in large-scale studies.

Conclusion

The value of handgrip strength as an indicator of overall strength and as a predictor of important outcomes notwithstanding,[3] updated values are needed if the grip strength of individuals and groups of individuals are to be interpreted and compared. Results supported the stability of the NHANES grip strength values across data release cycles. Here, we present the updated grip strength values from the NHANES database. Clinicians

and researchers should be aware of the NHANES testing protocol and use the reference values under similar testing protocol.

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1. Grips were determined from the
   a. average of 5 trials
   b. best of 5 trials
   c. best of 3 trials
   d. mean of 3 trials
2. Grip scores were reported in
   a. kgs
   b. lbs
   c. torque values
   d. foot pounds
3. Scores were organized by
   a. age groups
   b. dominate side
   c. gender
   d. all of the above
4. Grip strengths were
   a. dynamic
   b. eccentric
   c. isometric
   d. concentric
5. The findings support the stability of the NHANES values for grip scores
   a. false
   b. true

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