

Strength and Body Weight in US Children and Adolescents



WHAT'S KNOWN ON THIS SUBJECT: Among US youth 6 to 15 years of age there are differences in strength by gender and age. Little is known about differences in strength by weight status in the US pediatric population.



WHAT THIS STUDY ADDS: This study provides current US nationally representative reference values for 4 measures of strength in youth 6 to 15 years old. Body weight was associated with strength, but the association varied depending upon the measure.

abstract



BACKGROUND AND OBJECTIVES: Regular aerobic and muscle-strengthening physical activity in youth has been positively associated with health and may help prevent obesity. The purpose of this study is to provide reference values on 4 core, upper, and lower body measures of muscle strength among US children and adolescents and to investigate the association between these measures of strength and weight status.

METHODS: We assessed muscular strength using 4 different tests (plank, modified pull-up, knee extension, and grip strength) in 1224 youth aged 6 to 15 years collected during the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey. Mean and median estimates are provided by gender, age, and weight status. Weight status was defined based on standard categories of obesity, overweight, normal weight, and underweight using the gender-specific BMI-for-age Centers for Disease Control and Prevention growth charts.

RESULTS: There were significant positive trends with age for each of the strength tests ($P < .001$) except the modified pull-up among girls. The length of time the plank was held decreased as weight status increased for both girls and boys ($P < .001$). As weight status increased the number of modified pull-ups decreased ($P < .001$ boys and girls). Scores on the knee extension increased as weight status increased ($P < .01$). Grip strength increased as weight status increased ($P < .01$).

CONCLUSIONS: Increasing weight status had a negative association with measures of strength that involved lifting the body, but was associated with improved performances on tests that did not involve lifting the body. *Pediatrics* 2014;134:e782–e789

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KEY WORDS

strength, youth, physical activity, NHANES, NNYFS

ABBREVIATIONS

CDC—Centers for Disease Control and Prevention
NHANES—National Health and Nutrition Examination Survey
NNYFS—NHANES National Youth Fitness Survey

Dr Ervin conceptualized and designed the study, carried out analyses, and drafted the initial manuscript; Ms Fryar, Dr Wang, and Ms Miller reviewed and revised the manuscript; Dr Ogden conceptualized and designed the study and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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The Physical Activity Guidelines for Americans¹ recommend that children and adolescents get ≥ 60 minutes of physical activity daily. Most should be moderate or vigorous intensity aerobic activity. Muscle-strengthening and bone-strengthening physical activity should be included ≥ 3 times per week. A recent report² showing the first nationally representative estimates of core, upper body, and lower body muscle strength among US youth 6 to 15 years of age indicates differences in strength by gender and age but does not investigate differences by weight status. One out of every 3 children in the United States is now overweight or obese, increasing their risk of developing diabetes, heart disease, and cancer over the course of their lives. In addition, low levels of cardiorespiratory fitness and physical activity have been associated with an increase in cardiovascular disease risk factors and metabolic syndrome in children.³ Conversely, increasing cardiorespiratory fitness and physical activity may reduce these risk factors.^{3,4} Regular aerobic and muscle-strengthening physical activity in youth promotes health and fitness and may help to prevent obesity.⁵

The objective of this study is to use the 2012 NHANES, National Youth Fitness Survey (NNYFS) data to provide the first nationally representative reference values on 4 different core, upper body and lower body measures of muscle strength among US youth 6 to 15 years old by gender and age group and to investigate the association between these measures of muscle strength and weight status.

METHODS

The NNYFS 2012 was conducted by the Centers for Disease Control and Prevention's National Center for Health Statistics, to obtain data on physical activity and fitness levels of US youth aged 3 to 15 years. This survey was conducted in conjunction with the 2012

NHANES and the survey design was based on the design for NHANES. NHANES is a series of surveys that use a complex, stratified, multistage probability cluster design representative of the US noninstitutionalized, civilian population.⁶ NNYFS was a single survey conducted in 2012 along with NHANES with the sample selected from an independent sample of dwelling units within the segments selected for NHANES. Similar to NHANES, NNYFS consisted of a home interview followed by a physical examination which included fitness assessments and body measurements in a specially equipped mobile examination center. Trained interviewers conducted the interviews. Trained examiners administered the physical fitness tests and the body measurements. The overall NNYFS examination response rate was 76.3%. For 6- to 15-year-olds, the age group included in this analysis, the examination response rate was 1224/1612, or 75.9%.⁷ Additional details about this survey are available.⁷

In the NNYFS there were 4 different measures of muscular strength: the plank, the modified pull-up, the knee extension test, and the grip strength test.⁷ The plank, an isometric test, assessed core muscular strength. While lying face down on a mat participants lifted their body off the mat keeping their toes and forearms resting on the mat and their back straight, holding this position without movement for as long as possible. Scores were based on the number of seconds participants held the proper position (Supplemental Fig 5).⁸ The modified pull-up (isotonic) test assessed upper body muscular strength. While lying on their backs with outstretched arms under a horizontal bar, participants grasped the bar with an overhand grip and maintained a straight body with their heels on the floor. Scores were based on the number of times the participant could raise and lower their body so that their chest

touched a band hanging 8 inches below the bar (Supplemental Fig 6).⁹ The isotonic knee extension test assessed quadriceps (lower body) strength while participants were seated in a chair with their hips, thighs, and trunk restrained with web belts. A belt-stabilized handheld dynamometer (HHD, microFet2, Hogan Health Industries) was placed perpendicular to the shin near the ankle bones¹⁰ and the participant pressed his or her leg forward into the HHD as hard as possible 3 times (Supplemental Fig 7).¹¹ Scores are presented in pounds and kilograms of force and were based on the maximum force recorded during the right knee extension. The right knee extension was chosen for analysis since there were no significant differences between the mean forces exerted by each leg and no consistent approach has been used by other researchers.^{12–15} The isometric grip test assessed upper body muscle strength using a hand-grip dynamometer (Takei Digital Grip Strength Dynamometer, Creative Health Products). While in a standing position the participant squeezed the handle of the dynamometer as hard as possible 3 times with each hand (Supplemental Fig 8).¹⁶ Scores were in pounds and kilograms and were based on the sum of the maximum readings from each hand.¹⁷

Muscular strength and muscular endurance distinguish between the force a muscle produces with a single contraction and the capacity to hold or repeat that contraction over an extended period of time.¹⁸ Different tests measure strength or endurance. Throughout this paper the outcome strength tests are referred to as muscular strength tests even though some tests measure muscular strength while others measure muscular endurance.¹⁸

Height and weight were measured using a portable stadiometer and a portable digital weight scale. BMI was calculated as weight in kilograms divided by height

TABLE 1 Characteristics of US Youth Aged 6 to 15 y by Gender, Age Group, and BMI, 2012

| Characteristics | Total | Girls | Boys | <i>P</i> |
|---------------------------|-----------------------|-------------|-------------|----------|
| | <i>n</i> (Weighted %) | | | |
| Age group | | | | |
| Total | 1224 (100.0) | 617 (100.0) | 607 (100.0) | .82 |
| 6–9 y | 493 (40.2) | 248 (39.0) | 245 (41.4) | |
| 10–12 y | 370 (30.7) | 191 (31.4) | 179 (30.0) | |
| 13–15 y | 361 (29.0) | 178 (29.5) | 183 (28.6) | |
| BMI ^a category | | | | |
| Normal or underweight | 760 (62.7) | 394 (64.7) | 366 (60.8) | .07 |
| Overweight | 214 (18.2) | 118 (20.2) | 96 (16.3) | |
| Obese | 250 (19.0) | 105 (15.1) | 145 (22.8) | |

Source: CDC/NCHS, NHANES National Youth Fitness Survey.

^a BMI is calculated as wt in kilograms divided by height in meters squared (kg/m²). *P* is χ^2 test of independence.

in meters squared. Obesity was an age- and gender-specific BMI at or above the 95th percentile of the 2000 Centers for Disease Control and Prevention (CDC) gender- and age-specific growth charts, overweight was a BMI between the 85th and 95th percentiles, normal weight was a BMI less than the 85th percentile but at or above the 5th percentile, and underweight was a BMI less than the 5th percentile.¹⁹ For this article, the underweight and normal weight groups were combined.

Data Analyses

Analyses were conducted on youth 6 to 15 years of age. In NNYFS the knee extension and grip strength tests were conducted only on children aged 6 to 15, and the modified pull-up was conducted only on children aged 5 to 15 years. Although the plank test was conducted on youth 3 to 15 years of age, only 67% of children 3 to 5 years of age (and 44% of 3-year-olds) were able to complete this test.

Changes in strength between genders have been shown to occur at puberty and may be related to differences in height and weight.¹² Because these changes tend to appear between 10 and 12 years of age,^{12,13,20} we present mean and median values by single year of age. When needed for sufficient sample size for analysis by weight status, and for some analyses of the number of modified pull-ups, we

used 3 age groups: 6 to 9 years, 10 to 12 years, and 13 to 15 years.

Nearly 28% of girls and 15% of boys were not able to perform any modified pull-ups. Because the distribution was not normal, results for the modified pull-up are reported as means, medians, and the percentage performing a range of pull-ups. Categories were informed by the *Fitnessgram* Modified Pull-Up: Standards for Healthy Fitness Zone for girls and boys 6 to 15 years old.²¹ The *Fitnessgram* uses criterion-referenced standards to evaluate fitness performance. The criterion is based on the presence or absence of a disease, a disease risk factor, or some other health measure.²² The categories created for reporting our results are 0 pull-ups, 1 to 4 pull-ups, 5 to 8 pull-ups, and >8 pull-ups. The top 2 categories were collapsed when the number of pull-ups was analyzed by weight status because of small sample sizes.

Mean, standard errors, and medians are reported for all fitness tests by gender and single year of age. Means and standard errors by BMI status stratified by gender and age are reported for the plank, knee extension, and grip strength tests. Percentages are reported for the modified pull-up because of the non-normal distribution of the results.

Sample weights, which account for the differential probabilities of selection, nonresponse, and noncoverage, were incorporated into the estimation pro-

cess.⁷ The standard errors of the means and percentages were estimated using Taylor series linearization, a method that incorporates the sample design.

Differences between groups were evaluated using a *t* statistic at the *P* < .05 significance level. A test using orthogonal polynomial contrasts was used to test for linear trends by weight status, and the significance level was set at *P* < .05. All differences reported are statistically significant unless otherwise indicated. Statistical analyses were conducted using the SAS System for Windows (release 9.3; SAS Institute, Inc, Cary, NC) and SUDAAN (release 11.0; Research Triangle Institute, Research Triangle Park, NC).

RESULTS

Sample Demographics

The analyses for this report were based on 1224 boys and girls 6 to 15 years old who participated in the muscular strength tests and were classified in 1 of the 3 BMI categories (Table 1). All survey participants had BMI data, but 21 were missing plank data, 34 were missing knee extension data, 26 were missing grip strength data, and 29 were missing modified pull-up data. There were no significant gender differences in either the age or BMI distributions. A majority of girls and boys (62.7%) were normal weight or underweight, 18.2% were overweight, and 19.0% were obese (Table 1).

Performance on the Plank Test

There was a significant positive linear trend with increasing age for the length of time a child could hold the plank position, for both boys and girls (Table 2, *P* < .001). There were no significant differences between girls' and boys' performances on the plank when children were compared by single year of age (Table 2 and Supplemental Fig 9). Finally, the length of time the plank was held decreased

linearly as weight status increased for girls and boys ($P < .001$ for each gender) (Fig 1). Normal weight girls held the plank for 76.3 (SE 2.1) seconds, whereas overweight and obese girls held the plank 59.6 (SE 4.5) and 37.8 (SE 1.9) seconds, respectively. Normal weight boys held the plank for 83.0 (SE 3.8) seconds, but overweight and obese boys held the plank 69.6 (SE 4.1) and 43.9 (SE 1.9) seconds, respectively.

Performance on the Modified Pull-Up Test

There was a significant interaction between age and gender in terms of the number of modified pull-ups performed. Older boys completed more pull-ups than younger boys, but there was no difference by age in girls (Tables 2 and 3; Supplemental Fig 10). For example, the percentage of boys completing ≥ 8 pull-ups increased with age from 21.6% (SE 2.6) for 6- to 9-year-olds to 63.6% (SE 4.9) for 13- to 15-year-olds ($P < .001$). In contrast, there was no statistically significant change by age among girls; 22.5% (SE 3.1) of 6- to 9-year-olds and 14.7% (SE 2.8) of 13- to 15-year-olds completed ≥ 8 modified pull-ups ($P = .1076$).

There were significant associations between weight status and the number of modified pull-ups performed both for boys and girls (girls: $P < .001$; boys: $P < .001$) (Fig 2). As weight status increased, the number of modified pull-ups decreased. For example, 47.9% (SE 3.1) of normal weight girls performed ≥ 5 pull-ups, whereas only 30.9% (SE 5.4) of overweight and 4.2% (SE 2.1) of obese girls could perform this many pull-ups. For boys, 64.1% (SE 4.8) of normal weight boys performed ≥ 5 pull-ups, compared with 47.7% (SE 4.4) of overweight and 27.1% (SE 3.0) of obese boys.

Fifty-five percent (SE 3.9) of boys and 47% (SE 2.7) of girls met the *Fitness-*

TABLE 2 Mean (SE) and Median Seconds Plank Held and Number of Modified Pull-Ups, by Gender and Age, United States, 2012

| | Plank (s) ^a | | | Modified Pull-Up (number) ^a | | |
|-------------------------|------------------------|--------------|--------|--|-------------------------|------------------|
| | <i>n</i> | Mean (SE) | Median | <i>n</i> | Mean (SE) | Median |
| Boys (age in y) | | | | | | |
| 6 | 67 | 40.7 (3.5) | 39.0 | 70 | 3.3 (0.4) | 1.3 |
| 7 | 63 | 55.7 (4.4) | 50.4 | 62 | 5.8 (0.6) | 3.8 |
| 8 | 54 | 57.1 (5.4) | 58.0 | 54 | 4.9 (0.7) | 3.9 |
| 9 | 54 | 66.4 (11.1) | 52.5 | 52 | 5.3 (1.1) | 3.0 ^b |
| 10 | 59 | 69.2 (8.2) | 64.3 | 59 | 5.2 (1.0) | 3.2 |
| 11 | 55 | 72.0 (6.2) | 67.4 | 55 | 5.6 (0.6) | 4.0 |
| 12 | 64 | 72.7 (4.1) | 62.1 | 64 | 7.7 (0.8) ^c | 5.1 |
| 13 | 62 | 84.7 (10.1) | 80.5 | 61 | 8.6 (1.2) ^c | 8.1 |
| 14 | 57 | 93.0 (5.3) | 89.8 | 57 | 11.1 (1.1) ^c | 9.5 |
| 15 | 61 | 115.9 (12.5) | 97.9 | 60 | 12.4 (1.1) ^c | 10.3 |
| Girls (age in y) | | | | | | |
| 6 | 61 | 48.3 (4.8) | 40.4 | 61 | 3.4 (0.4) | 1.9 |
| 7 | 63 | 58.1 (5.4) | 54.6 | 62 | 4.5 (0.6) | 2.8 |
| 8 | 70 | 63.0 (6.9) | 56.7 | 70 | 5.3 (0.7) | 3.3 |
| 9 | 51 | 67.2 (5.2) | 63.7 | 50 | 4.1 (0.4) | 3.2 |
| 10 | 64 | 55.4 (4.4) | 52.3 | 64 | 3.8 (0.6) | 2.0 |
| 11 | 64 | 71.1 (5.1) | 66.4 | 63 | 4.4 (0.7) | 3.4 |
| 12 | 58 | 73.3 (4.7) | 69.7 | 58 | 4.7 (0.5) | 3.6 |
| 13 | 65 | 73.4 (5.8) | 64.9 | 64 | 3.0 (0.3) | 1.0 |
| 14 | 69 | 78.6 (6.1) | 74.7 | 68 | 3.8 (0.9) | 1.2 ^b |
| 15 | 42 | 86.8 (6.4) | 69.7 | 41 | 3.5 (0.6) | 1.7 |

Source: CDC/NCHS, NHANES National Youth Fitness Survey.

^a Significant linear trends by age ($P \leq .001$) for both gender-specific measures except modified pull-up among girls ($P = .27$).

^b Relative SE $\geq 30\%$ but $< 40\%$.

^c Significant difference compared with girls ($P < .003$).

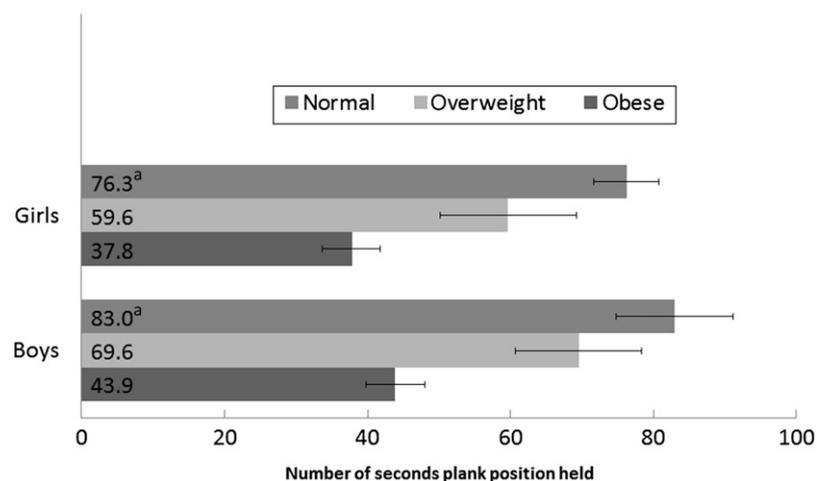


FIGURE 1

Mean number of seconds plank position held among children and adolescents aged 6 to 15 years, by gender and BMI categories, United States, 2012. ^aSignificant linear trend across age-specific BMI categories, $P < .0001$. Note: The normal weight category also includes underweight children and adolescents. Source: CDC/NCHS, National Health and Nutrition Examination Survey, National Youth Fitness Survey.

gram Modified Pull-Up: Standards for Healthy Fitness Zone.²¹

Performance on the Knee Extension

Similar to the plank test, there was a significant positive linear trend with

increasing age for the knee extension test for both boys and girls (Table 4). With increasing age boys and girls were able to generate more pounds or kilograms of force in the knee extension test ($P < .001$ for each gender). There were also

TABLE 3 Percentage of Youth Completing Modified Pull-Ups by Number of Pull-Ups, Gender, and Age, United States, 2012

| Gender and age | N | Number of Pull-Ups | | | | | | | |
|----------------|-----|--------------------|------------|--------|------------|--------|------------|--------|------------|
| | | 0 | | 1–4 | | 5–7 | | >8 | |
| | n | % (SE) | n | % (SE) | n | % (SE) | n | % (SE) | |
| Girls | | | | | | | | | |
| Total | 601 | 179 | 27.7 (2.2) | 218 | 34.2 (1.8) | 104 | 19.1 (2.6) | 100 | 19.0 (2.0) |
| 6–9 y | 243 | 61 | 22.3 (3.0) | 97 | 37.2 (2.7) | 37 | 18.0 (3.5) | 48 | 22.5 (3.1) |
| 10–12 y | 185 | 51 | 24.4 (2.6) | 68 | 34.6 (3.4) | 38 | 22.5 (3.2) | 28 | 18.5 (2.8) |
| 13–15 y | 173 | 67 | 38.5 (3.0) | 53 | 29.9 (3.2) | 29 | 16.9 (2.2) | 24 | 14.7 (2.8) |
| Boys | | | | | | | | | |
| Total | 594 | 94 | 14.7 (2.4) | 193 | 32.3 (3.1) | 86 | 15.3 (1.1) | 221 | 37.6 (3.2) |
| 6–9 y | 238 | 43 | 16.2 (3.4) | 100 | 42.8 (2.9) | 41 | 19.4 (2.9) | 54 | 21.6 (2.6) |
| 10–12 y | 178 | 32 | 15.6 (2.5) | 64 | 35.0 (7.1) | 24 | 14.2 (3.3) | 58 | 35.2 (5.6) |
| 13–15 y | 178 | 19 | 11.6 (2.8) | 29 | 14.2 (3.1) | 21 | 10.5 (2.6) | 109 | 63.6 (4.9) |

Source: CDC/NCHS, NHANES National Youth Fitness Survey.

Boys: Statistically significant association between age group and number of modified pull-ups completed, $P < .001$.

Girls: Statistically significant association between age group and number of modified pull-ups completed, $P = .01$.

6- to 9-y-olds: No significant association between gender and number of modified pull-ups completed, $P = .5427$.

10- to 12-y-olds: Significant association between gender and number of modified pull-ups completed, $P < .001$.

13- to 15-y-olds: Significant association between gender and number of modified pull-ups completed, $P < .001$.

linear trend with increasing age for the grip strength test for both boys and girls (Table 4). With increasing age boys and girls were able to achieve more pounds or kilograms of force on the combined grip strength test ($P < .001$ for each gender). There were also significant differences between girls' and boys' performances on the grip strength test among youth 13 to 15 years old (Table 4 and Supplemental Fig 12).

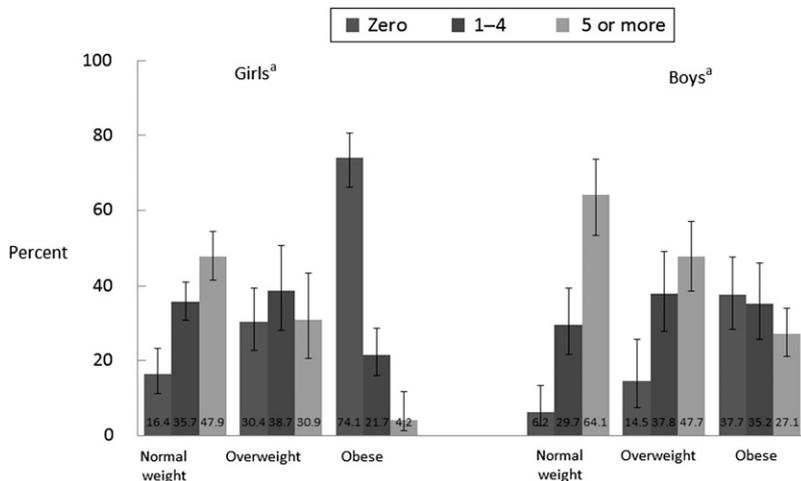
Similar to the knee extension test, grip strength increased as weight status increased (Fig 4). Overweight and obese girls achieved 94.6 (SE 4.1) and 98.4 (SE 4.7) pounds, respectively, whereas normal weight girls achieved 81.4 (SE 1.5) pounds (linear trend: $P = .004$). Overweight and obese boys achieved 106.6 (SE 5.0) and 109.6 (SE 5.5) pounds, respectively, whereas normal weight boys achieved 93.7 (SE 3.7) pounds (linear trend: $P = .008$). There was no significant difference in scores between overweight and obese girls and boys.

DISCUSSION

This report provides the first nationally representative measurements of muscular strength for US youth 6 to 15 years of age by gender, single year of age, and weight status. Consistent with other research, gender, age, and weight status were all important predictors of performance on measures of muscle strength, but their impact varied with the test performed. Performances on the measures of muscular strength became stronger with increasing age except for girls performing the modified pull-up. The association between weight status and measures of muscle strength varied with the type of test being performed. As weight status increased, children and adolescents had more difficulty performing tests that involved moving their body mass or holding it in position. Performances on the plank and modified pull-up were lower for overweight and obese youth

FIGURE 2

Percentage of children and adolescents aged 6 to 15 years completing 0, 1 to 4, or ≥ 5 modified pull-ups, by gender and BMI categories, United States, 2012. ^aSignificant association between number of pull-ups completed and age-specific BMI categories, $P < .001$. Note: The normal weight category also include underweight children and adolescents. Source: CDC/NCHS, National Health and Nutrition Examination Survey, National Youth Fitness Survey.



significant differences between girls' and boys' performance on the knee extension test among youth 15 years of age (Table 4 and Supplemental Fig 11).

In contrast to the plank test, scores on the knee extension increased as weight status increased (Fig 3). Overweight and obese girls generated 62.5 (SE 6.1) and 70.6 (SE 5.9) pounds, respectively, whereas normal weight girls generated 52.8 (SE 3.7) pounds (linear trend: $P = .002$). Overweight and obese boys gen-

erated 69.5 (SE 7.0) and 70.2 (SE 8.2) pounds, respectively, whereas normal weight boys generated 54.2 (SE 4.1) pounds (linear trend: $P = .005$). There was no significant difference in scores between overweight and obese girls and boys.

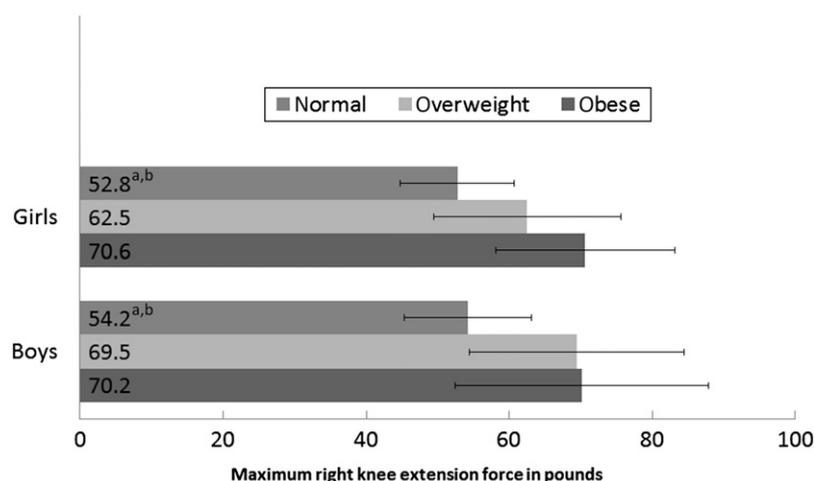
Performance on the Grip Strength Test

Parallel to the plank and knee extension tests, there was a significant positive

TABLE 4 Mean (SE) and Median Force Exerted in the Knee Extension and Grip Tests,^a by Gender and Age, United States, 2012

| | n | Knee Extension (lb) | | Knee Extension (kg) | | n | Grip (lb) | | Grip (kg) | |
|--------------|----|--------------------------|--------|---------------------|--------|----|--------------------------|--------|------------|--------|
| | | Mean (SE) | Median | Mean (SE) | Median | | Mean (SE) | Median | Mean (SE) | Median |
| Boys | | | | | | | | | | |
| 6 | 67 | 25.7 (2.7) | 25.9 | 11.7 (1.2) | 11.8 | 69 | 49.4 (1.1) | 48.5 | 22.4 (0.5) | 22.0 |
| 7 | 61 | 34.3 (2.0) | 35.0 | 15.5 (0.9) | 15.9 | 62 | 58.1 (2.2) ^b | 55.9 | 26.3 (1.0) | 25.4 |
| 8 | 53 | 39.6 (2.7) | 41.3 | 17.9 (1.2) | 18.7 | 55 | 65.0 (1.4) | 65.5 | 29.5 (0.6) | 29.7 |
| 9 | 53 | 45.0 (4.6) | 45.3 | 20.4 (2.1) | 20.5 | 55 | 75.0 (2.0) | 73.3 | 34.0 (0.9) | 33.3 |
| 10 | 59 | 51.5 (4.5) | 52.2 | 23.4 (2.1) | 23.7 | 57 | 83.7 (1.9) ^b | 83.3 | 38.0 (0.9) | 37.8 |
| 11 | 54 | 69.6 (4.7) ^b | 69.6 | 31.6 (2.1) | 31.6 | 55 | 100.4 (3.7) | 95.2 | 45.5 (1.7) | 43.2 |
| 12 | 64 | 73.4 (4.3) | 70.6 | 33.3 (1.9) | 32.0 | 64 | 113.9 (2.2) | 107.6 | 51.7 (1.0) | 48.8 |
| 13 | 62 | 83.5 (5.7) | 84.4 | 37.9 (2.6) | 38.3 | 62 | 133.0 (4.9) ^b | 132.2 | 60.3 (2.2) | 59.9 |
| 14 | 57 | 90.2 (8.2) | 85.9 | 40.9 (3.7) | 39.0 | 58 | 153.5 (3.3) ^b | 150.3 | 69.6 (1.5) | 68.2 |
| 15 | 60 | 99.7 (10.7) ^b | 104.5 | 45.2 (4.8) | 47.4 | 60 | 175.6 (4.4) ^b | 178.4 | 79.7 (2.0) | 80.9 |
| Girls | | | | | | | | | | |
| 6 | 55 | 29.4 (2.7) | 30.0 | 13.3 (1.2) | 13.6 | 56 | 47.7 (1.5) | 47.8 | 21.6 (0.7) | 21.7 |
| 7 | 63 | 36.9 (3.0) | 37.6 | 16.7 (1.3) | 17.1 | 63 | 51.8 (1.3) | 51.2 | 23.5 (0.6) | 23.2 |
| 8 | 70 | 43.3 (3.8) | 43.6 | 19.6 (1.7) | 19.8 | 70 | 61.7 (1.5) | 60.6 | 28.0 (0.7) | 27.5 |
| 9 | 51 | 46.5 (4.2) | 45.5 | 21.1 (1.9) | 20.6 | 50 | 69.5 (2.7) | 66.7 | 31.5 (1.2) | 30.3 |
| 10 | 65 | 48.3 (5.4) | 50.2 | 21.9 (2.4) | 22.8 | 65 | 76.7 (2.5) | 71.8 | 34.8 (1.1) | 32.6 |
| 11 | 63 | 58.9 (4.3) | 57.8 | 26.7 (2.0) | 26.2 | 64 | 92.4 (2.0) | 89.3 | 41.9 (0.9) | 40.5 |
| 12 | 58 | 69.0 (5.4) | 73.8 | 31.3 (2.4) | 33.5 | 58 | 109.2 (3.6) | 106.5 | 49.5 (1.6) | 48.3 |
| 13 | 65 | 79.9 (7.2) | 80.5 | 36.2 (3.2) | 36.5 | 64 | 116.9 (3.9) | 112.8 | 53.0 (1.8) | 51.2 |
| 14 | 68 | 81.7 (5.8) | 87.4 | 37.1 (2.6) | 39.6 | 68 | 117.8 (1.9) | 114.7 | 53.4 (0.9) | 52.0 |
| 15 | 42 | 76.7 (8.1) | 82.3 | 34.8 (3.7) | 37.3 | 43 | 121.2 (2.9) | 118.3 | 55.0 (1.3) | 53.7 |

Source: CDC/NCHS, NHANES National Youth Fitness Survey.

^a Significant linear trends by age ($P \leq .001$) for both gender-specific measures.^b Significant difference compared with girls ($P < .05$).**FIGURE 3**

Mean knee extension force in pounds among children and adolescents aged 6 to 15 years, by gender and BMI categories, United States, 2012. ^aSignificant linear trend by age-specific BMI categories, $P < .01$. ^bNormal weight category significantly different from overweight and obese categories, $P < .01$. Notes: The normal weight category also includes underweight children and adolescents. Mean values in kilograms, girls: 23.9, 28.4, 32.0 kg, normal, overweight and obese categories. Boys: 24.6, 31.5, 31.8 kg, normal, overweight and obese categories. Source: CDC/NCHS, National Health and Nutrition Examination Survey, National Youth Fitness Survey.

compared with normal weight youth. The opposite effect was true for the knee extension and grip strength tests. As weight status increased, the forces

exerted on the knee extension and grip strength tests also increased. The overweight and obese groups performed better than the normal weight group.

Other researchers have reported that gender, age, height, and weight are all important predictors of performance on measures of muscle strength. There is little difference in strength between boys and girls <12 years of age. After that age boys appear to be stronger than girls.^{12–14,20} The gender and age differences are probably the result of physical changes that occur during puberty. Researchers have attributed these differences in strength to changes in height and weight and to the amount of muscle mass in puberty.^{12,14,23} Gender differences in strength may also, in part, reflect differences in the activity preferences of girls and boys.²⁴

Weight also is a significant predictor of performance on measures of strength.^{25–27} On physical tests requiring propulsion or lifting body mass, obese youth performed worse than normal weight youth because excess body fat is an extra load they have to move in these types of physical tests. In contrast, obese youth have greater strength than normal weight youth on the grip strength test.^{25,26} This may be because of their greater fat-free mass.²⁶ At least for some obese children, there is a greater lean body mass along with a greater amount of fat, because they carry additional weight.^{27,28}

International comparisons with grip strength results from NNYFS, the first US national survey in youth, show some similarities and some differences. In Canada (2007–2009) mean grip strength (based on the combined maximum score from both hands) among youth 6 to 10, 11 to 14, and 15 to 19 years was greater in boys than girls.¹⁷ For example, among 11- to 14-year-olds, mean grip strength was 51 kg in boys and 42 kg in girls.¹⁷ The gender differences in Canada are similar to those in the United States, but, mean grip strength in the United States was higher than in Canada. Previously published data show that mean grip

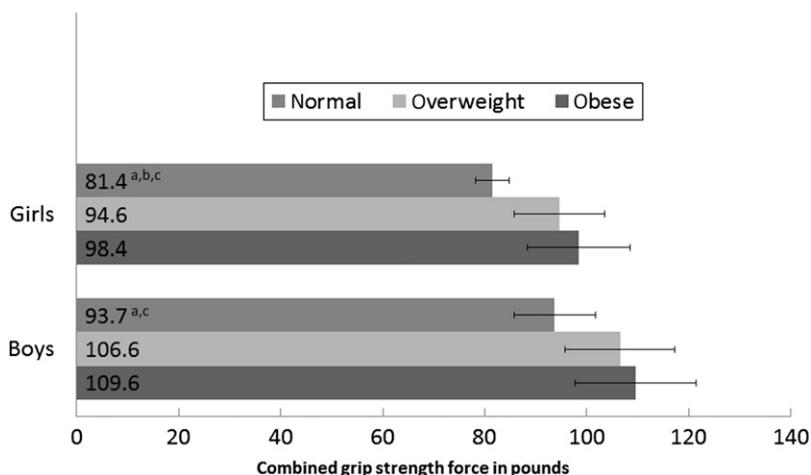


FIGURE 4

Mean grip strength force in pounds among children and adolescents aged 6 to 15 years, by gender and BMI categories, United States, 2012. ^aSignificant linear trend by age-specific BMI categories, $P < .01$. ^bNormal weight category significantly different from overweight category, $P < .01$. ^cNormal weight category significantly different from obese category, $P < .01$. Notes: The normal weight category also includes underweight children and adolescents. Mean values in kilograms, girls: 36.9, 42.9, 44.7 kg, normal, overweight and obese categories. Boys: 42.5, 48.3, 49.7 kg, normal, overweight and obese categories. Source: CDC/NCHS, National Health and Nutrition Examination Survey, National Youth Fitness Survey.

strength of 12- to 15-year-old boys was 143 pounds (65 kg), and that of girls was 116 pounds (53 kg).² Published centile values for median grip strength based on the average for the 2 hands among Australian youth are very similar to median values in the United States. The reference median grip strength for 9-year-old boys in Australia is 16.5 kg,

compared with 33 kg (average $33.3/2 = 16.65$ kg) in the United States.²⁹ In Flemish youth in 1997, similar to our results, obese youth had greater grip strength than did nonobese youth.²⁶

There are several limitations of this study. First, the cross-sectional study design does not allow measurement of muscular changes in individual chil-

dren and adolescents over time. Second, there is lack of data on biological maturation for children and adolescents at these ages. Finally, the sample was not sufficient to report on the underweight children separately.

There were strengths of this study. These data provide nationally representative reference values of muscular strength for US boys and girls. The muscular strength tests were collected in a systematic way, with the same measurement technicians and the same equipment. In addition, height and weight were measured.

In conclusion, this report presents nationally representative reference values by gender and single year of age for selected tests of core, upper, and lower body muscle strength in youth 6 to 15 years of age. Increasing weight status had a negative association with measures of strength that involved lifting the body but was associated with better performance on tests that did not require supporting body weight or using body mass to exert force. Clinicians and researchers may find the reference values useful, especially in light of the high prevalence of childhood obesity.

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