ORIGINAL ARTICLE

Handgrip Strength and Blood Pressure in Children and Adolescents: Evidence From NHANES 2011 to 2014

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BACKGROUND
Previous studies have reported that handgrip strength, a measure of muscular fitness, is associated with cardiovascular risk factors. However, the association of handgrip strength with blood pressure (BP) in children has been inconsistent. We tested the association of handgrip strength with systolic and diastolic BP in children and adolescents from the National Health and Nutrition Examination Survey (NHANES) 2011–2014.

METHODS
The study included 3,929 participants aged 8–19 years who underwent a handgrip test. The sum of the maximum handgrip strength from both hands was used. General linear models were used to examine the associations between handgrip strength and the outcome variables.

RESULTS
After adjustment for age, race, sex, body mass index, and physical activities, handgrip strength was significantly and positively associated with systolic ($P < 0.0001$) and diastolic ($P = 0.01$) BP. There was an increasing trend in systolic BP as handgrip strength increased from the bottom quartile to the top quartile, with 2.1 mm Hg difference between the top and the bottom quartiles (P for trend <0.0001). Similar results were observed for diastolic BP.

CONCLUSIONS
Muscular fitness is positively associated with BP in children and adolescents. The implications and underlying mechanisms for these results need further examinations.

Keywords: blood pressure; children; handgrip strength; hypertension; NHANES.

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Hypertension is an important public health challenge due to its high prevalence and associated morbidity and mortality.[1] Adult hypertension has its origins in childhood.[2–6] Therefore, it is important to identify modifiable factors that may contribute to variations in blood pressure (BP) during childhood, in order to develop early prevention and intervention strategies.

Physical fitness has been increasingly recognized as an important predictor of morbidity and mortality.[7–9] In children and adolescents, the relationship between fitness and cardiovascular health has also been well documented.[10–12] Muscular fitness, as indicated by handgrip strength, has become an important cardiometabolic marker in children.[12–14] Although muscular fitness is overall associated with cardiometabolic health in children, some have questioned the association between muscular strength and cardiometabolic risk.[15] In terms of BP, recent studies have demonstrated that high muscle strength is associated with low BP,[16–18] however, with conflicting results,[19,20] in children and adolescents.

Clarifying the association between muscular fitness and BP in children and adolescents can improve the understanding of BP regulation and may have implications for early prevention. To this end, we examined the associations of handgrip strength with BP in 3,929 children and adolescents from the National Health and Nutrition Examination Survey (NHANES) 2011–2014.

METHODS

Participants

NHANES is a continuous program that examines a nationally representative sample to assess the health and nutritional status of adults and children in the noninstitutionalized general population of the United States. Surveys include standardized physical examinations and other health-related interviews. Information was self-reported during an interview on vigorous recreational physical

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activity (like running or basketball for at least 10 minutes continuously) and moderate recreational physical activity (such as brisk walking, bicycling, swimming, or volleyball for at least 10 minutes continuously) in a typical week (yes/no) and on time usually spent sitting on a typical day. In 2 survey cycles conducted between 2011 and 2014, a handgrip test was administered in participants aged 8 years or older. A total of 3,929 children and adolescents aged 8–19 years (1,983 boys and 1,946 girls) met the following inclusion criteria for the current study: (i) data available on age, race, and sex, and BP; (ii) the handgrip test performed on both hands; and (iii) no known diagnosed hypertension. The National Centers for Health Statistics Institutional Review Board reviewed and approved the study protocol.

Examinations

Body weight and height. Standardized measurement procedures were used for height and weight.[21] Standing height was measured using a stadiometer with a fixed vertical backboard and an adjustable head piece, and weight on a standard digital scale with the participant wearing only underpants and a standard disposable examination gown. Body mass index (BMI) was calculated as body weight in kilogram divided by height in meters squared (kg/m^2).

Handgrip test. After preparation that included explanation and demonstration of the test protocol, adjustment of the grip size of a dynamometer, and a practice trial, the participant was asked to use one of the hands to squeeze the dynamometer as hard as possible, exhaling while squeezing to avoid build-up of intrathoracic pressure. Each hand was tested 3 times, alternating hands between trials with a 60-second rest between measurements on the same hand. The combined grip strength was calculated as the sum of the largest reading from each hand.

BP assessment. BP was measured following a standardized protocol. In brief, examinees were asked to rest quietly in a seated position for 5 minutes. After the participants' maximum inflation level and appropriate cuff size were determined, trained and certified examiners used Baumanometer calibrated mercury true gravity sphygmomanometer to take 3 consecutive BP readings, with a fourth attempt made if 1 of the 3 BP measurements was interrupted or incomplete. The phase I and phase V BP readings were recorded as systolic and diastolic BP, respectively.

Statistical analysis

Characteristics of the study sample were presented as means (SDs) for continuous variables or percentage for categorical variables. General linear models were used to examine sex differences in continuous variables and a chi-square test in categorical variables. Partial Pearson's correlation was used to examine the relationship between handgrip strength and BP, adjusted for age and sex. General linear models were used to examine the association between handgrip strength and BP measures, adjusted for age, sex, race, BMI, and physical activities. We also performed the following sensitivity analyses: (i) using age- and sex-specific standardized *z*-scores of BMI, handgrip strength, systolic and diastolic BP; (ii) stratified analysis by sex; and (iii) further adjustment for height. All data analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

Among the participants, the average age was 13.1 years. Girls were less likely to engage vigorous recreational activity and had higher BMI and diastolic BP and lower handgrip strength and systolic BP than boys (Table 1).

Handgrip strength was significantly correlated to systolic BP ($r = 0.24$, $P < 0.0001$) and diastolic BP ($r = 0.07$, $P < 0.0001$

Table 1. Characteristics of the study sample

Variable	Boys (n = 1,983)	Girls (n = 1,946)	P
Age (years)	13.0 ± 3.5	13.1 ± 3.4	0.56
BMI (kg/m^2)	22.1 ± 5.9	22.6 ± 6.3	0.03
Race (%)			0.44
Non-Hispanic White	26.2	24.0	
Non-Hispanic Black	27.4	27.2	
Mexican American	20.1	21.6	
Other Hispanic	10.6	10.4	
Other	15.7	16.8	
Vigorous recreational PA (%)	42.3	26.5	<0.0001
Moderate recreational PA (%)	30.7	28.7	0.24
Handgrip strength (kg)	58.3 ± 25.1	46.1 ± 14.0	<0.0001
Systolic blood pressure (mg Hg)	107.6 ± 10.8	103.7 ± 9.3	<0.0001
Diastolic blood pressure (mg Hg)	53.9 ± 16.1	56.2 ± 13.9	<0.0001

Mean±SD is presented unless otherwise indicated. Abbreviations: BMI, body mass index; PA, physical activity.

excluding 54 participants with a reading of zero; r = 0.06, P = 0.0002 among all participants) (Figure 1). Handgrip strength was significantly and positively associated with both systolic and diastolic BP, independent of age, sex, race, vigorous recreational activity, moderate recreational activity, and BMI; each kilogram increase in handgrip strength was associated with 0.11 mm Hg increase in systolic BP (P < 0.0001) and 0.05 mm Hg increase in diastolic BP (P = 0.01) (Table 2). There was a significant increasing trend in systolic BP as handgrip strength increased from the bottom quartile to the top quartile, with 2.1 mm Hg difference between the top and the bottom quartiles (P for trend <0.0001, Figure 2); a similar trend was observed for diastolic BP, with 1.0 mm Hg difference between the top and the bottom quartiles (P for trend = 0.02, Figure 2).

Similar associations were observed in all sensitivity analyses for systolic BP. However, the association with diastolic BP was not significant in girls (P = 0.37) or with further adjustment for height (P = 0.17).

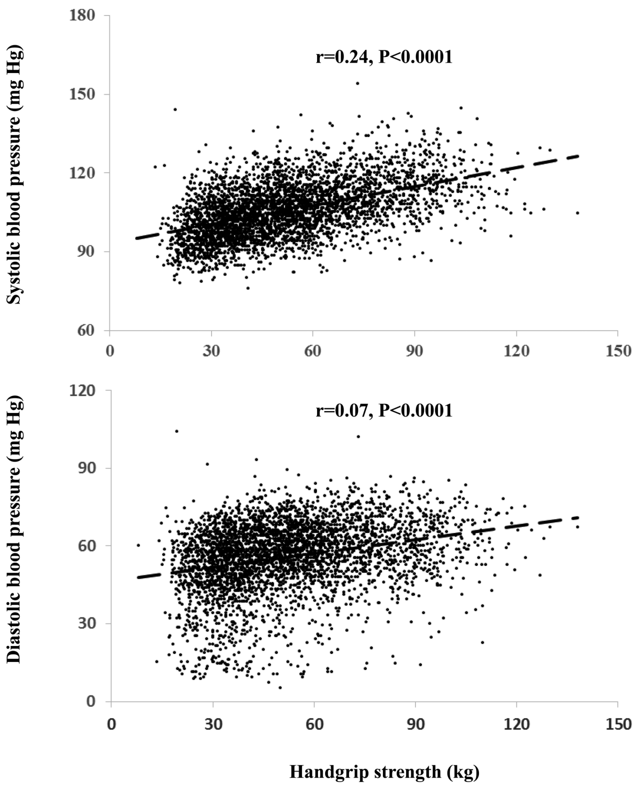

Figure 1. Scatter plots of handgrip strength with systolic blood pressure (top panel) and diastolic blood pressure (bottom panel, excluding 54 participants with a reading of zero). *P* values were adjusted for age and sex.

DISCUSSION

From a national sample of the United States, we demonstrated that handgrip strength was significantly and positively associated with BP levels in children and adolescents 8–19 years of age. Such a relationship was robust as it was independent of BMI and physical activities. The findings were in a contrast to the beneficial effects of increased muscular fitness on other cardiometabolic risk factors in both children and adults.

The association between handgrip strength and BP has been inconsistent, with some reporting an inverse association[16–18] while others a positive association.[19,20] Dong *et al.* reported that handgrip strength was positively associated with BP after adjustment for or stratified by BMI in 88,865 Chinese adolescents aged 13–17 years.[19] Demmer *et al.* reported similar results in both boys and girls at ages of 10, 14, and 17 years.[20] All these findings, along with ours, are in contrast to the findings of an inverse association[16–18] and by Diez-Fernandez *et al.* showing that the inverse associations are mediated by BMI.[15] The positive association we observed is opposite of what would be expected according to

Table 2. Regression coefficients of handgrip strength and other covariates for blood pressure

	Systolic blood pressure (mm Hg)		Diastolic blood pressure (mm Hg)	
Independent variable	**β ± SE**	***P***	**β ± SE**	***P***
Age (per year)	0.42 ± 0.07	<0.0001	1.12 ± 0.11	<0.0001
Female sex	−2.70 ± 0.31	<0.0001	2.76 ± 0.51	<0.0001
Race[a]				
Non-Hispanic White	0.02 ± 0.43	0.96	1.04 ± 0.72	0.15
Non-Hispanic Black	0.79 ± 0.43	0.07	−1.69 ± 0.72	0.02
Mexican American	−0.24 ± 0.45	0.60	−1.29 ± 0.75	0.09
Other Hispanic	−0.41 ± 0.54	0.45	−0.61 ± 0.89	0.50
BMI (per kg/m^2)	0.45 ± 0.03	<0.0001	0.17 ± 0.04	<0.0001
Vigorous PA (Yes)	−0.55 ± 0.34	0.11	0.49 ± 0.57	0.39
Moderate PA (Yes)	0.47 ± 0.33	0.15	−0.30 ± 0.55	0.58
Handgrip strength (per kg)	0.11 ± 0.01	<0.0001	0.05 ± 0.02	0.01

Abbreviations: BMI, body mass index; PA, physical activity.
[a]Relative to race reported as “other”.

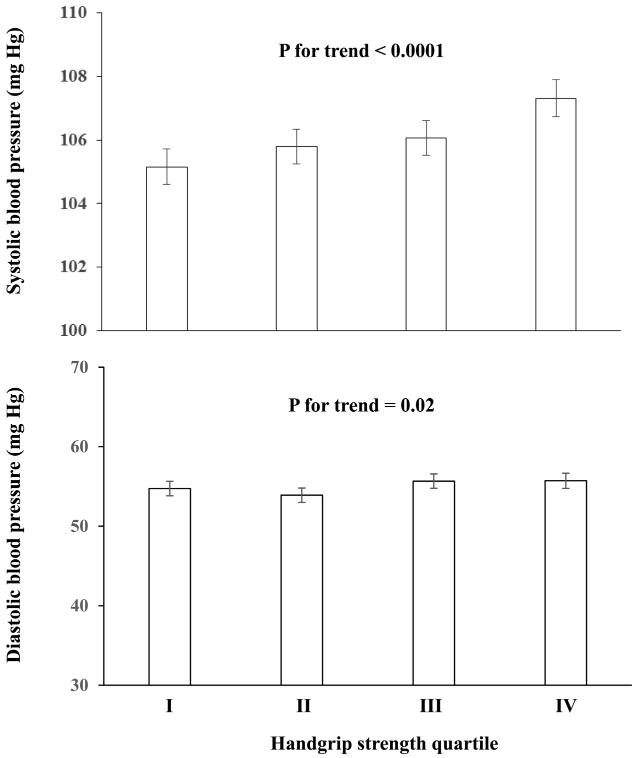

Figure 2. Least square means of systolic blood pressure (top panel) and diastolic blood pressure (bottom panel) by age- and sex-specific handgrip strength quartile. *P* values were adjusted for age, race, sex, body mass index, and physical activities.

the associations of muscular fitness with other cardiometabolic risk factors, in particular in adult population.[22–24]

Implications for the observed associations of handgrip strength with BP in children and adolescents remain unclear. It is known that childhood BP predicts future hypertension risk and cardiovascular disease,[2,25,26] and muscular strength is inversely associated with cardiometabolic risk.[23,27] Given the positive muscle strength–BP relationship in children and adolescents and the adverse effects of resistance training on central arterial compliance[28] and arterial stiffening,[29] the merit of resistance training has been questioned.[19] However, before the underlying mechanisms for the observed muscle strength–BP relationship are dissected, caution should be exercised in making recommendations for resistance training in children and adolescents, particularly when other benefits of resistance training are taken into account.[30]

Our study has important strengths and some limitations. The study included a large sample of 3,929 participants. NHANES data collection underwent robust quality assurance and control procedures. The observed associations of handgrip strength with BP were robust; the nonsignificant association with diastolic BP in girls or with further adjustment for height may be due to challenges in measuring the V phase diastolic BP in children. We recognize that our study was cross-sectional and observational in nature. Thus, causality of the observed associations cannot be established. We did not have data on cardiorespiratory fitness measures, which are import determinants of BP in children.[31] Finally, our study did not take into account the complex survey design. However, our aim was to examine associations in the available sample, not to estimate population parameters for the whole US population.

In conclusion, high handgrip strength is associated with increased BP in children and adolescents. This association is independent of BMI and other common covariates. Given the multifaceted benefits associated with muscular fitness, special caution is needed to interpret the findings of our study. Future studies should address the causal relationship between muscular fitness and BP and explore the underlying mechanisms.

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DISCLOSURE

All authors declare no conflict of interest.

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