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ORIGINAL ARTICLE

Association Between Handgrip Muscle Strength and Cardiometabolic z-Score in Children 6 to 19 Years of Age: Results from the Canadian Health Measures Survey

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Abstract

Background: It is unclear if muscle strength, another index of fitness, which confers the protection from cardiometabolic risk in adults, is associated with similar protection in children and youth. The purpose of this study was to investigate the association between handgrip strength and cardiometabolic health in a large Canadian sample of children and youth.

Methods: We performed a cross-sectional analysis of the Canadian sample of children and youth aged 6 to 19 years ($n = 1376$) studied in the Canadian Health Measures Survey (cycles 1 and 2) between 2007 and 2011. The primary exposure variable, handgrip strength, was measured using a handgrip dynamometer. The primary outcome measure was a composite measure of cardiometabolic risk calculated as the sum of z-scores of the following variables: triglycerides, low high-density lipoprotein cholesterol, systolic and diastolic blood pressures, and hemoglobin A_{1c}. All of the analyses were adjusted for confounders.

Results: The sample was on average 12.8 ± 3.5 years and displayed a body mass index (BMI) z-score of 0.5 ± 1.2. In unadjusted analyses, handgrip strength was negatively associated with cardiometabolic z-score (estimate = –0.013; $P < 0.001$). When results were adjusted for age, BMI z-score, and cardiorespiratory fitness, the association was no longer significant; however, an interaction between handgrip strength, sex, and cardiometabolic z-score was observed (estimate = –0.042; $P < 0.001$). When analyses were stratified by sex, handgrip strength was negatively associated with cardiometabolic z-score (estimate = –0.038; $P < 0.001$) in girls, but not in boys (estimate = 0.008; $P = 0.150$).

Conclusion: In a large sample of Canadian children and adolescents, handgrip strength was associated with cardiometabolic health in girls, but not in boys.

Keywords: lifestyle modification, metabolic syndrome, obesity

Introduction

In children and youth, cardiorespiratory fitness is a strong protector of cardiometabolic risk factors.[1,2] In fact, Janssen and Cramp observed, in a cross-sectional study, a lower likelihood of cardiometabolic risk factors clustering in the highest tertile of cardiorespiratory fitness.[1] Both cross-sectional[3] and prospective data[4] provide evidence of cardiorespiratory fitness being protective against cardiometabolic risk factors. In fact, prospective cohort studies found that independent of moderate-to-vigorous physical activity, poor cardiorespiratory fitness was associated with the development of obesity[5] and cardiometabolic risk factors in children and youth.[6]

With rising rates of obesity over the last 30 years,[7] a growing number of children and adolescents are exhibiting cardiometabolic risk factors, including hypertension, dyslipidemia, and dysglycemia.[8] Modifiable risk factors, including cardiorespiratory fitness and a healthy diet protect youth against cardiometabolic risk factors.[9] However, another less studied modifiable risk factor in children and youth is muscle strength.

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Among adults, high muscle strength is associated with better cardiometabolic risk profiles.[10] Some data suggest a similar association in children and youth.[11,12] For example, Benson et al. showed that independent of cardiorespiratory fitness, body weight, and central adiposity, children in the middle and highest tertiles of muscle strength were 98% less likely to have insulin resistance compared with the lowest tertile of muscle strength.[12] Between 1981 and 2007–2009[13] muscle strength decreased by as much as 23%, in parallel with a threefold increased prevalence of obesity and cardiometabolic risk factors in Canada. Limitations of previous studies of muscle strength and cardiometabolic risk factors in children and youth include: small sample size,[11,12] population of low/middle socioeconomic status youth,[14] failure to include clinically relevant outcome measures, such as insulin resistance,[15] and failure for not adjusting for relevant confounders.[11]

To the best of our knowledge, no study has yet examined handgrip strength and its association with cardiometabolic risk factors in a large sample of Canadian children and youth. To address this gap in the literature, we analyzed data from the cross-sectional Canadian Health Measures Survey (CHMS) to investigate the association between handgrip strength and cardiometabolic risk factors in children and youth aged between 6 and 19 years, independently of age, BMI z-score, and cardiorespiratory fitness. The primary working hypothesis of this study was that handgrip strength, measured by handgrip dynamometer, would be negatively associated with a composite cardiometabolic z-score in a large sample of Canadian children and youth.

Materials and Methods

Study design and participants

To test the primary study hypothesis, we performed a cross-sectional analysis of handgrip strength and cardiometabolic risk factors in children and adolescents that participated in cycles 1 or 2 of the CHMS. The CHMS recruited a random sample of the Canadian population aged 3 to 79 years living in private households. Residents of First Nations Reserves or Crown lands, institutions, some remote regions, and full-time members of the Canadian Forces were excluded from the survey. The survey involved a home interview and a visit to a mobile examination center, where physical measurements were performed. Briefly, a multistage, cluster sampling strategy was used to identify sites across Canada, where data were collected from March 2007 through February 2013. Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board. Children ≥14 years provided written consent, while a parent or legal guardian provided written consent for younger children in addition to a written assent from the child. Data presented here were restricted to a subsample of 1376 boys and girls aged 6 to 19 years, who participated in the CHMS cycles 1 or 2, and provided all data for both the primary exposure variable and the primary outcome measures, and the main confounders [age, body mass index (BMI) z-score, and cardiorespiratory fitness].

Primary exposure variable

Handgrip strength. Handgrip strength was measured using a Smedley III handgrip dynamometer (Takei Scientific Instruments, Japan) twice on each hand (alternating) and by combining the maximum score for each hand (kg) into one final score.

Primary outcome measure

Cardiometabolic risk factors. Several cardiometabolic risk factors were measured in the CHMS[16] and were available for the present study. In this study, we only included the subset of children who had data collected when fasted in the analysis or variables that are not affected by nonfasting state, such as glycosylated hemoglobin (HbA_{1c}). The variables that were used included: high-density lipoprotein cholesterol (HDL-C; mmol/L), triglycerides (mmol/L), HbA_{1c} (%), and systolic and diastolic blood pressures (mmHg). Blood samples were analyzed at the Health Canada Laboratory, Bureau of Nutritional Sciences, Nutrition Research Division using standard operating procedures as previously described.[16]

To create a single composite measure of cardiometabolic risk for Canadian children, we created a composite z-score using two strategies. The first strategy included a multiple linear regression model with the individual variables of interest as outcome measures and age and sex as independent variables. Regression residuals were kept and used as individual cardiometabolic z-scores. This strategy was used with HDL-C, triglycerides, and HbA_{1c}, since no normative data are available for these variables. Second, systolic and diastolic blood pressure z-scores were calculated using normative values provided by the National Institutes of Health (NIH), National Heart, Lung, and Blood Institute *Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents*. All cardiometabolic z-scores described above were summed to create a single cardiometabolic composite z-score. To account for the inverse association between HDL-C and cardiovascular risk, HDL residuals were multiplied using a negative constant (−1) before being added to the composite score.

Confounding variables. Body weight was measured to the nearest 0.1 kg with a METTLER TOLEDO VLC with PANTHER PLUS terminal scale (METTLER TOLEDO Canada, Mississauga, Canada). Height was obtained using a ProScale M150 digital stadiometer (Accurate Technology, Inc., Fletcher, NC). All anthropometric measures were taken in duplicate, and the mean of the two measures was used in the final analysis. BMI was calculated with the following formula: body weight (kg)/height (m^2). Absolute BMI was converted to a BMI z-score by using two related methods based on the age of the child. For those aged 6 to 10 years, we used representative age- and sex-specific reference data published by the World Health Organization.[17] For those older than 10 years, we used the method proposed by Rodd et al., which is an extension to the WHO approach for children older than 10 years.[18]

Cardiorespiratory fitness was measured using the Canadian Aerobic Fitness Test (mCAFT), during which participants had to complete one or more 3-minute ''stepping'' stages at predetermined speeds, based on their age and sex. Children aged 6 to 14 years started at what is Stage 5 for women, to a maximum of three stages. Participants' heart rate was recorded after each stage, and the test was completed at the stage when participants reached 85% of their age-predicted maximal heart rate (220—age). Heart rate was measured with a Polar (Polar Electro Canada, Inc., Lachine, Canada) heart rate monitor. Predicted VO_{2max} was determined using the formula provided by The Canadian Physical Activity, Fitness, and Lifestyle Approach (CPAFLA). Age, sex, and ethnicity were self-reported from the home interview. Ethnicity was categorized into two groups: White or other from the 12 ethnic groups reported in the CHMS. Since there was no association between handgrip strength and ethnicity ($P > 0.05$), ethnicity was not kept in the final model.

Statistical analyses. To investigate the association between handgrip strength and cardiometabolic risk factor composite z-score, a multivariable linear regression was used. An interaction variable between sex and handgrip strength was created to investigate the modifying effect of sex on the primary outcome variable. The interaction variable was tested in an adjusted model and found to be significant ($P < 0.001$). Therefore, all analyses were performed stratified by sex. A linear regression and a multiple linear regression model were performed to investigate the association (unadjusted and adjusted) between handgrip strength and composite cardiometabolic z-score. Logistic regressions were performed to investigate the odds of having a high handgrip strength according to low cardiometabolic composite z-score. Low cardiometabolic risk score was defined as a score above the median and treated as a dichotomous variable. To permit sensitivity testing, we also created a dichotomous variable based on the 80th percentile of cardiometabolic risk score, as this percentile would make a strong distinction between low and high handgrip strength. Then the same analysis was replicated with this threshold. All analyses were adjusted for the main confounders, including age, BMI z-score, and cardiorespiratory fitness.[19] All analyses were performed without the survey weights and the recommended bootstrapping[20] mainly because of a significant reduction in the utilized sample from the total survey sample and consequently the purpose of this subanalysis was not aiming to estimate population parameters, but looking at an association in this subsample. Data management and statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). Statistical significance level was set at $P \leq 0.05$.

Results

Table 1 presents the descriptive characteristics of the sample stratified by sex. Most of the participants were white (77%) and 51.5% were boys. No significant sex differences were observed for age and ethnicity, whereas body weight, height, and BMI z-score were significantly different between boys and girls (all $P < 0.001$). Handgrip strength was significantly greater in boys compared with girls ($P < 0.001$), whereas no significant difference was observed for cardiorespiratory fitness (boys: 52.1 ± 5.2 vs. girls: 47.2 ± 5.1; $P > 0.05$).

The cardiometabolic composite z-score was not different between boys and girls (-1.3 ± 2.4 vs. -1.1 ± 2.3; $P = 0.133$). When cardiometabolic risk factors were examined separately, systolic blood pressure and HbA_{1c} were significantly higher in boys compared with girls (systolic blood pressure: 97.3 ± 8.8 mmHg vs. 95.3 ± 7.6 mmHg; $P < 0.001$; HbA_{1c}: $5.5\% \pm 0.04\%$ vs. $5.4\% \pm 0.03\%$; $P < 0.001$). No sex differences were observed for diastolic blood pressure, HDL-C, and triglycerides (all $P > 0.05$).

Table 2 describes the bivariate associations between handgrip strength and cardiometabolic risk factors. In girls, all cardiometabolic risk factors were significantly associated with handgrip strength ($P < 0.05$). In boys, all cardiometabolic risk factors were significantly associated with handgrip strength ($P < 0.05$), except for HbA_{1c} and HDL-C ($P > 0.05$).

In unadjusted analyses, handgrip strength was negatively associated with cardiometabolic composite z-score (estimate: –0.0128; $P < 0.001$). This association was no longer significant after adjusting for confounders. In the fully adjusted model (age, BMI z-score, and cardiorespiratory fitness), a significant interaction effect was observed when sex was

Table 1. Characteristics of the Sample

General characteristics	*Total*	*Boys*	*Girls*	P
N (%)	1376	709 (51.5)	667 (48.5)	
Age (years)	12.8 ± 3.5	12.9 ± 3.5	12.6 ± 3.5	0.812
6–10, *n* (%)	423 (30.7)	213 (30.0)	210 (31.5)	0.310
11–15, *n* (%)	574 (41.7)	288 (40.6)	286 (42.8)	
16–19, *n* (%)	379 (27.5)	208 (29.3)	171 (25.6)	
Weight (kg)	51.3 ± 18.9	54.3 ± 20.9	48.2 ± 16.0	<0.001
Height (cm)	156.0 ± 16.5	159.3 ± 18.2	153.0 ± 13.9	<0.001
BMI (z-score)	0.52 ± 1.2	0.60 ± 1.3	0.44 ± 1.1	<0.001
Ethnicity, *n* (%)				
Non-White	314 (22.8)	156 (22.0)	158 (23.7)	0.460
White	1062 (77.2)	553 (78.0)	509 (76.3)	
Strength				
Combined handgrip strength (kg)	47.5 ± 22.9	55.10 ± 26.7	39.4 ± 14.2	<0.001
Cardiometabolic profile				
Systolic blood pressure (mmHg)	96 ± 8	97 ± 9	95 ± 8	<0.001
Diastolic blood pressure (mmHg)	62 ± 7	62 ± 7	62 ± 7	0.867
HDL-cholesterol (mmol/L)	1.4 ± 0.3	1.4 ± 0.3	1.4 ± 0.3	0.860
Triglycerides (mmol/L)	0.9 ± 0.4	0.9 ± 0.4	0.9 ± 0.4	0.366
Hemoglobin A_{1c} (%)	5.4 ± 0.04	5.5 ± 0.04	5.4 ± 0.03	<0.001
Composite-metabolic z-score	−1.3 ± 2.4	−1.3 ± 2.4	−1.1 ± 2.3	0.133
Cardiorespiratory fitness [mL/(kg·min)]	49.7 ± 5.7	52.1 ± 5.2	47.2 ± 5.1	0.520

Continuous data are presented as mean ± SD, whereas categorical variables are presented as *N* and (%).
BMI, body mass index; HDL, high-density lipoprotein.

Table 2. Pearson Correlation Coefficients Between Handgrip Muscle Strength and CardioMetabolic Risk Factors

	Handgrip muscle strength (kg)	
Variables	*Girls*	*Boys*
Systolic blood pressure (mmHg)	0.49 (<0.0001)	0.19 (<0.0001)
Systolic blood pressure (mmHg)	0.17 (<0.0001)	0.12 (0.002)
Hemoglobin A_{1c} (%)	–0.12 (0.001)	–0.06 (0.122)
Triglycerides (mmol/L)	0.11 (0.003)	0.10 (0.040)
HDL-cholesterol (mmol/L)	–0.36 (<0.0001)	–0.01 (0.710)

Data are present as *r* (*P*-value).

added to the model (estimate: –0.0425; $P < 0.001$). In separate sex-specific analyses, handgrip strength (estimate: –0.0380; $P < 0.001$) was negatively associated with cardiometabolic composite z-score in girls. This association was independent of age, BMI z-score, and, cardiorespiratory fitness. No such association was observed in boys (estimate: –0.0085; $P = 0.150$; Table 3).

For the logistic regression analysis, high handgrip strength was significantly associated with lower odds of a cardiometabolic composite z-score above the 50th percentile [odds ratio (OR) 0.97; confidence interval (95% CI) 0.96–0.99; $P = 0.009$] or the 80th percentile [OR 0.97; 95% CI 0.94–0.99; $P = 0.007$] independent of age, BMI z-score, and cardiorespiratory fitness, among girls. Handgrip strength was not associated with lower odds of cardiometabolic risk factor clustering among boys ($P > 0.05$).

Discussion

To the best of our knowledge, this is the first study to examine the association between handgrip strength and cardiometabolic risk factor clustering in a sample of Canadian youth and children. The main finding of our study suggests that independent of age, BMI z-score, and cardiorespiratory fitness, handgrip strength (measured by handgrip dynamometer) is negatively associated with cardiometabolic risk factors in girls only. These results are insightful, considering the large reduction in overall fitness levels observed in Canadian children and youth in recent decades.[13] Finally, similar to smaller studies, we found that handgrip strength may be an underappreciated modifiable determinant of cardiometabolic risk factors in girls.

The results from this study are in line with a large body of evidence in adults demonstrating a negative association between muscle strength and cardiometabolic risk factors as reported by our group[21] and others.[22] In children and youth, a negative association has been observed that shows a protective effect of muscle strength from cardiometabolic risk factors independently of cardiorespiratory fitness[23] and adiposity level.[24] Our results are aligned with these findings and are of great importance, as a prospective study that showed that low muscle strength in children was associated with insulin resistance and beta-cell dysfunction in adulthood.[25] Furthermore, in a prospective study of 737 children, high muscle strength was also associated with a decreased likelihood of developing cardiometabolic risk factor clustering 20 years later independently of cardiorespiratory fitness and adiposity.[26] Our results suggest that handgrip strength may be an underappreciated modifiable determinant associated with health outcomes in children. The current study's findings expand on previous research on muscle strength and cardiometabolic risk factors research by looking at this association in a large sample of Canadian boys and girls, and by providing information about this relationship specifically between boys and girls.

In contrast to other studies, handgrip strength was associated with cardiometabolic health only in girls after controlling for some confounding variables. Contrary to our results, a recent study showed an independent association between muscle strength and cardiometabolic risk factors in both boys and girls after adjusting for cardiorespiratory fitness and physical activity.[27] In fact, for each decrease of 5% in muscle strength, boys and girls were 1.48 and 1.45 times more likely to have a deleterious cardiometabolic risk factor profile.[27] However, no adjustment for adiposity was performed in their analyses. A previous study also reported that

Table 3. Adjusted Associations Between Handgrip Strength and CardioMetabolic z-Score by Sex

Parameter	*Estimate*	*SE*	*95% CI*		P
Intercept[a]	1.6749	0.9677	–0.2217	3.5715	0.084
Handgrip strength (kg)	–0.0085	0.0059	–0.0202	0.0031	0.150
Age (6–10 years)	0.2179	0.4175	–0.6003	1.0362	0.602
Age (11–15 years)	0.5297	0.2880	–0.0347	1.0941	0.066
Age (16–19 years)	Reference				
BMI z-score	0.5286	0.0757	0.3802	0.6770	<0.0001
Cardiorespiratory fitness [mL/(kg·min)]	–0.0068	0.0018	–0.0104	–0.0032	<0.001
Intercept[b]	–0.3637	0.9805	–2.2854	1.5580	0.711
Handgrip strength (kg)	–0.0380	0.0082	–0.0540	–0.0219	<0.0001
Age (6–10 years)	0.9314	0.3350	0.2748	1.5880	0.005
Age (11–15 years)	0.8005	0.2390	0.3319	1.2690	<0.001
Age (16–19 years)	Reference				
BMI z-score	0.6190	0.0828	0.4568	0.7812	<0.0001
Cardiorespiratory fitness [mL/(kg·min)]	–0.0039	0.0022	–0.0083	0.0005	0.081

[a]Model for boys.
[b]Model for girls.

the association between muscle strength and cardiometabolic risk factors was independent of sex.[28] Differences in study design, population size, confounders included in the analyses, handgrip muscle strength protocols, and how muscle strength was assessed (*e.g.*, handgrip vs. whole body muscle strength), may explain the disparate results.[26] Based on a recent systematic review, our study is timely, as the authors of this review concluded that there is a lack of comprehensive understanding of factors, such as sex that could impact cardiometabolic risk factors in youth and children.[29] Therefore, our study adds to the current literature by suggesting that sex might modify the association between muscle strength and cardiometabolic health in children. However, it remains unclear why an association between muscle strength and cardiometabolic risk factors is only observed in girls. Childhood is accompanied by several physiological changes that predispose youth to body weight gain and increased fat mass,[30] which put youth at greater risk for many cardiometabolic risk factors.[31] Some data suggest hormonal differences between boys and girls.[32] Interestingly, these differences have been associated with both muscle strength[33] and a better cardiometabolic risk profile.[34] Therefore, the difference observed between boys and girls in our study, could be the results of potential hormonal differences; however, no data available in CHMS allow us to rule out this hypothesis. More studies might want to explore why a different association was observed between boys and girls. As of now and based on our findings, different physical activity prescriptions might have to be encouraged to enhance the management cardiometabolic of risk factors in girls and boys.

Regular physical activity is a cornerstone strategy to manage cardiometabolic risk factors.[35] Even if our results show a significant association between cardiometabolic health and handgrip strength in girls only, many other health benefits can be acquired when doing regular strength training in both boys and girls.[36,37] Both boys and girls can improve muscle strength by as much as 30%–50% in only 8 to 12 weeks of strength training.[38] As a consequence, many known agencies, such as the Canadian Society for Exercise Physiology and the American College of Sports Medicine recommend that children aged between 5 and 17 perform activities that strengthen bones and muscle strength 2 to 3 days per week, which includes resistance training.[36,37] Another reason why muscle strength training should be considered in the management of cardiometabolic risk factors is because studies revealed that exercise training that aims to increase muscle strength in children was associated with a reduction in cardiometabolic risk factors.[39] For example, Lee et al. showed that strength training in children was associated with a reduction in visceral adiposity as well as in intrahepatic adiposity, two risk factors for Type 2 diabetes.[39] Furthermore, resistance exercise in children was associated with a 27% improvement in insulin sensitivity.[39] Unfortunately, no specific analysis was performed between girls and boys. These results suggest the need to promote increased muscle strength and investigate if these improvements are observed in boys and girls to better manage cardiometabolic risk factors in children and youth.

The present study has some limitations. First, the cross-sectional design, which prevents us from making causal conclusions. Second, the use of a subsample of the CHMS limits our external validity. However, this strategy has been used to allow adjustment for the main confounders, such as cardiorespiratory fitness, and adiposity, which were not available on the whole sample. Third, analyses were not performed using survey weights, which does not take into consideration the complex survey design and, therefore, does not allow us to generalize our results to the whole Canadian population. Despite these limitations, our study is strengthened by the use of a large sample size of Canadian children and youth. Furthermore, to maximize our sample size, the metabolic variables that might be impacted by the fasting state were only included when taken in a fasted state, whereas other variables, such as hemoglobin A_{1c} that were not affected by such a state were included as well. Finally, this subanalysis has been performed using all the main potential confounding variables; however, the hypothesis that other confounders not included in these analyses would have impacted the results could not be ruled out.

In conclusion, the present study demonstrated that handgrip strength, independent of available confounders, was negatively associated with cardiometabolic risk factors in girls only. This suggests that low handgrip strength may be a risk factor for cardiometabolic health in girls and, therefore, exercise interventions aiming at preserving or increasing muscle strength should be emphasized in girls to maintain cardiometabolic health. More studies using prospective experimental designs are needed to provide a more comprehensive understanding of the biological effect of muscle strength on cardiometabolic risk factors. However, our results support the importance of activities that promote and preserve muscle strength, especially in girls.

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Author Disclosure Statement

No conflicting financial interests exist.

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