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# Independent and combined effects of handgrip strength and adherence to a Mediterranean diet on blood pressure in Chilean children

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*Objective:* The aim of the study was to examine the combined associations between handgrip strength (HGS) and adherence to a Mediterranean diet with blood pressure (BP) in Chilean children.
*Methods:* This cross-sectional study enrolled 1140 children (794 boys and 346 girls) 8 to 12 y of age. HGS was measured using a hand dynamometer with an adjustable grip. Adherence to a Mediterranean diet was assessed with the Kidmed score. Resting BP was measured by an automated monitor using an appropriately sized cuff. Elevated BP was defined as ≥90th percentile, and high HGS was defined as sex- and age-specific normative ≥80th percentile for the HGS.
*Results:* The prevalence of elevated systolic BP, diastolic BP, and overall BP were 16.6%, 12.9%, and 8.1%, respectively. HGS was negatively associated with BP parameters in an unadjusted and adjusted model after considering potential confounders (age, sex, body mass index z-score, and HGS). Regarding diet adherence, the unadjusted model reveals that children with high adherence to the Mediterranean diet showed lower BP levels (systolic, diastolic, and mean arterial pressure) compared with children with low–medium adherence; however, these differences disappear after considering potential confounders. The combination of high HGS and optimal adherence to a Mediterranean diet was negatively associated with BP.
*Conclusions:* Children with a high HGS levels (i.e., ≥80th percentile) may somewhat overcome the deleterious effects of low adherence to a Mediterranean diet. Therefore, these findings suggest that the combination of these two components of a healthy lifestyle, especially HGS may be beneficial to children's BP.


## Introduction

Growing evidence indicates that hypertension, which is one of the major modifiable risk factors for cardiovascular disease (CVD), is established in early life [1] and is increasingly becoming a problem in the developed world [2]. The recent global obesity epidemic has led to an increase in hypertension in children [3]. Similar to adult hypertension, childhood hypertension is typically asymptomatic but is capable of producing pathophysiological changes that promote atherosclerosis [4], and this disease tracks from childhood into adult life [5].

The initial management of childhood hypertension is through nonpharmacologic lifestyle changes [4]. Therefore, its prevention should begin as early as possible and should be based on lifestyle modifications, including management of body weight, an increase in physical activity, and adoption of a diet low in sodium but rich in fresh fruit, vegetables, fiber, and low-fat dairy [6,7]. The relationship between diet and blood pressure (BP) in children has been

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studied less frequently; however, several studies have revealed the protective effect of a Mediterranean diet on BP levels [8,9]. For example, Lazarou et al. suggested that adherence to a Mediterranean diet was inversely related to diastolic BP (DBP) levels in 622 children 10 to 13 y of age [9]. Muscular strength also has been associated with health benefits in young people [10] and is considered to be a marker of a healthy lifestyle and a predictor of morbidity and mortality from CVD and all causes [11]. Studies examining the association between muscular strength and BP in children have reported inconsistent results, with some showing that higher levels were associated with lower BP or a reduced risk for hypertension [12–14] and others finding a positive association between muscular strength and BP [15].

Only one study has investigated the combined effects of muscular strength and dietary patterns on CVD risk factors [16]; however, the combined association of diet and muscular fitness on BP in children is largely unknown. Recent data indicated that adherence to a Mediterranean diet is moderate among Chilean children [17]; therefore, it would be interesting to analyze the combined effect of this dietary pattern with a modifiable lifestyle variable, such as muscular strength. Therefore, this study sought to explore the combined associations between handgrip strength (HGS) and adherence to a Mediterranean diet with BP in Chilean children 8 to 12 y of age.

## Material and methods

### *Study design and participants*

Data were collected from 2016 to 2017 and analyzed in 2018. A subsample from a larger cross-sectional study was used to evaluate the research hypothesis and consisted of 1140 children 8 to 12 y of age (grades 3–6; 794 boys and 346 girls). The children were of low–middle socioeconomic status and were enrolled in eight randomly selected public schools in the commune of Santiago (Municipality of Santiago). Children were excluded if they had any type of dysfunction that limited their physical activity (i.e., any disease or problem) or if they had not lived in Santiago for at least a full school year. None of the children were taking any drug treatments. Exclusion from the study was made effective a posteriori without the students being aware of their exclusion so as to avoid any undesired situations.

The study protocol was approved by the University of Santiago Ethics Committee and complied with the principles of the Declaration of Helsinki. A letter was sent to parents of all school children inviting them to a meeting where the objectives were explained, after which they signed an informed consent for their children to participate in the study.

### *Anthropometric parameters*

All data were collected at the same time in the morning, between 0900 and 1100 h. Body weight was measured to the nearest 0.1 kg using a portable electronic scale (Seca 769, Hamburg, Germany), and height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 220, Hamburg, Germany). Body mass index (BMI) was subsequently derived, and the BMI z-score was determined using the International Obesity Task Force age- and sex-specific thresholds [18]. Anthropometric measurements were made with students barefoot and wearing light clothing.

### *Resting BP*

Resting BP was measured by an automated BP monitor using an appropriately sized cuff (Omrom HEM 705 CP, Health-care Co, Kyoto, Japan). BP was measured when the children were seated in a quiet room for 10 min with their back supported and feet on the ground. Two measures were completed, with the second BP measurement being taken 5 min after the initial assessment. The average of the two measurements for systolic BP (SBP) and diastolic BP (DBP) was recorded. Mean arterial pressure (MAP) was subsequently calculated using DBP + [0.333 × (SBP − DBP)].

Categorization of BP was done using sex-, age-, and height-specific cutoff points using the newly revivers Centers for Disease Control and Prevention Growth Charts (www.cdc.gov/growthcharts/) [19]. Stage 1 high BP was defined as SBP or DBP ≥95th percentile but <99th percentile, stage 2 high BP was defined as SBP or DBP ≥99th percentile, and borderline BP was defined as SBP or DBP ≥90th percentile but <95th percentile. To obtain more accurate results, the criteria were simplified into two BP categories: normotensive (<90th percentile) and elevated BP (stage 1 and 2, ≥90th percentile).

### *Handgrip strength*

Handgrip was measured using a standard adjustable JAMAR hydraulic dynamometer (Hydraulic Hand Dynamometer® Model PC-5030 J1, Fred Sammons, Inc., Burr Ridge, IL, USA). Children were given a brief demonstration and verbal instructions for the test, and the dynamometer was adjusted to the child's hand size according to predetermined protocols if necessary [20]. The dynamometer was periodically calibrated against known weights and no evidence of drift was found. HGS was measured with the child in a standing position with the shoulder adducted and neutrally rotated and the arms parallel but not in contact with the body. The participants were asked to squeeze the handle for a maximum of 3 to 5 s and no verbal encouragement was given during the test. Two trials were allowed for each limb, and the average peak HGS (kg) was recorded. Thus the handgrip values presented here combine the results of left- and right-handed children without considering hand dominance. There is no universally agreed lower cutoff for handgrip; therefore, sex- and age-specific scores [21] <80th percentile were classified as "low–moderate" and those ≥80th percentile were classified as "very high–good" [22].

### *Mediterranean diet adherence*

Dietary intake and food consumption were assessed by the Mediterranean Diet Quality Index for Children and Adolescents (Kidmed) questionnaire [23]. This tool consists of 16 questions related to the principles of Mediterranean dietary patterns. The Kidmed score ranges from −4 to 12 points, as questions with negative connotations with respect to the Mediterranean diet are assigned a value of −1 point (e.g., frequent intake of fast food, increased consumption of sweets, skipping breakfast, and frequent intake of pastries for breakfast). Parameters with positive connotations are assigned a value of +1 point (e.g., taking fruit or fruit juice every day or consuming fish at least two to three times a week as indicated previously [23]). Participants scoring ≥8 points were categorized as having an ideal healthy diet (adherence), whereas children and adolescents scoring <8 points were classified as having a non-ideal healthy diet (the first two categories combined "improvement is needed" and "very low-quality diet").

### *Statistical analysis*

Descriptive data are presented as means and SE for continuous variables and frequencies and percentages for categorical variables. To assess the differences between sexes, the independent Student's *t* test was used for continuous variables and the $\chi^2$ test was used for categorical variables. All model assumptions were checked (i.e., normality and homoscedasticity). SBP, DBP, MAP, and HGS had skewed distributions and were log transformed before analyses. To aid interpretation, data were back transformed from the log scale for presentation in the results.

Preliminary analyses showed no significant interactions between sex, diet, and HGS (all $P > 0.1$); therefore, all analyses were performed with boys and girls together to increase statistical power. Analyses of covariance (ANCOVA) were used to assess the following:

- Differences between mean BP parameters (SBP, DBP, and MAP) across HGS and Kidmed categories (low–medium and high).
- Differences between mean HGS and the Kidmed score across BP categories (normotensive and elevated BP).
- Differences between mean values of BP parameters (SBP, DBP, and MAP) across groups of HGS (low–medium and high) and adherence to the Mediterranean diet (low and high).

Covariates included were age, sex, BMI z-score, and HGS or the Kidmed score according to the dependent variable included in the model.

Data analyses were performed using the SPSS version 21software (IBM, Armonk, NY, USA). $P < 0.05$ was considered statistically significant.

## Results

Table 1 shows the descriptive characteristics of the children. Boys had higher BMI z-score, HGS, SBP, and MAP values than girls ($P < 0.05$). The prevalence of elevated SBP, DBP, and overall BP were 16.6%, 12.9%, and 8.1%, respectively.

Table 2 shows the differences between mean BP parameters by HGS and Kidmed categories (low–medium versus high). In both models, children with high HGS had lower SBP and DBP levels compared with those in the medium–low handgrip category ($P < 0.05$). Regarding diet adherence, the unadjusted model reveals that children with high adherence to the Mediterranean diet had lower BP levels (SBP, DBP, and MAP) compared with children with

**Table 1**
Participant characteristics

| | Boys (n = 794) | Girls (n = 346) | *P*-value |
|---|---|---|---|
| Age (y) | 10.01 (0.46) | 9.97 (0.06) | 0.592 |
| Weight (kg) | 42.31 (0.47) | 41.39 (0.58) | 0.249 |
| Height (cm) | 1.42 (0.03) | 1.42 (0.05) | 0.430 |
| BMI | 20.67 (0.16) | 20.17 (3.72) | 0.073 |
| BMI z-score | 1.36 (0.04) | 1.03 (0.06) | <0.001 |
| Handgrip strength (kg) | 16.20 (0.20) | 14.36 (0.27) | <0.001 |
| Systolic blood pressure (mm Hg) | 101.38 (0.54) | 98.47 (0.77) | 0.003 |
| Adverse values ≥P90* | 139 (17.6) | 54 (15.6) | 0.141 |
| Diastolic blood pressure (mm Hg) | 61.34 (0.42) | 60.10 (10.63) | 0.094 |
| Adverse values ≥P90* | 115 (14.6) | 39 (11.3) | 0.476 |
| Mean arterial pressure (mmHg) | 74.68 (0.42) | 72.88 (0.56) | 0.015 |
| Elevated blood pressure ≥P90* | 59 (7.5) | 30 (8.7) | 0.428 |
| Kidmed score (−4 to 12) | 6.42 (0.12) | 6.39 (0.16) | 0.857 |
| Mediterranean diet adherence (≥8) | 115 (32.5) | 57 (31.1) | 0.753 |

Data are mean (SE) or number and proportions (%)
*According to the National High Blood Pressure Education Program Working Group.

low–medium adherence ($P < 0.05$); however, these differences disappeared after consideration of potential confounders.

Table 3 shows the differences between mean HGS and the KIDMED score by BP categories (normotensive: <90th percentile; adverse BP: ≥90th percentile). In the unadjusted model, normotensive children showed higher HGS ($P < 0.01$) and Kidmed scores ($P < 0.05$) than those with adverse BP levels (overall BP, SBP, and DBP). However, after considering potential confounders, the results only showed higher values in HGS for overall BP and SBP in normotensive children compared with those with adverse BP levels ($P < 0.05$).

ANCOVA showed a significant difference between low adherence to a Mediterranean diet and low–medium HGS, low adherence to a Mediterranean diet and high–medium HGS, and high adherence to a Mediterranean diet and high HGS groups ($P < 0.05$) for all BP parameters after adjusting for age, sex, and BMI z-score. Significant differences also were found between low HGS and high adherence to a Mediterranean diet and high HGS and high adherence to a Mediterranean diet groups ($P < 0.001$; Fig. 1).

## Discussion

The present study explored the effect of HGS and adherence to a Mediterranean diet, both independently and combined, on BP in children. The results suggested that HGS was negatively associated with BP parameters, even after considering potential confounders such as age, sex, BMI z-score, and the Kidmed score. However, the Kidmed score was negatively associated with SBP and DBP parameters only in unadjusted model. The data also showed that children with high HGS and high adherence to a Mediterranean diet had the lowest BP levels. Conversely, children with low HGS and low–medium adherence to a Mediterranean diet had increased BP levels. Therefore, the cross-sectional design of this study (handgrip and Mediterranean diet) seems to have a powerful combined and cumulative association with BP in children.

These findings expand the current scientific knowledge on the benefits of a traditional Mediterranean diet on BP levels among children. The present study showed that adherence to a Mediterranean diet was significantly and negatively associated with lower BP, which was in line with a recent study in Cypriot children (the CYprus KIDS study) [9], which suggested a protective effect of a

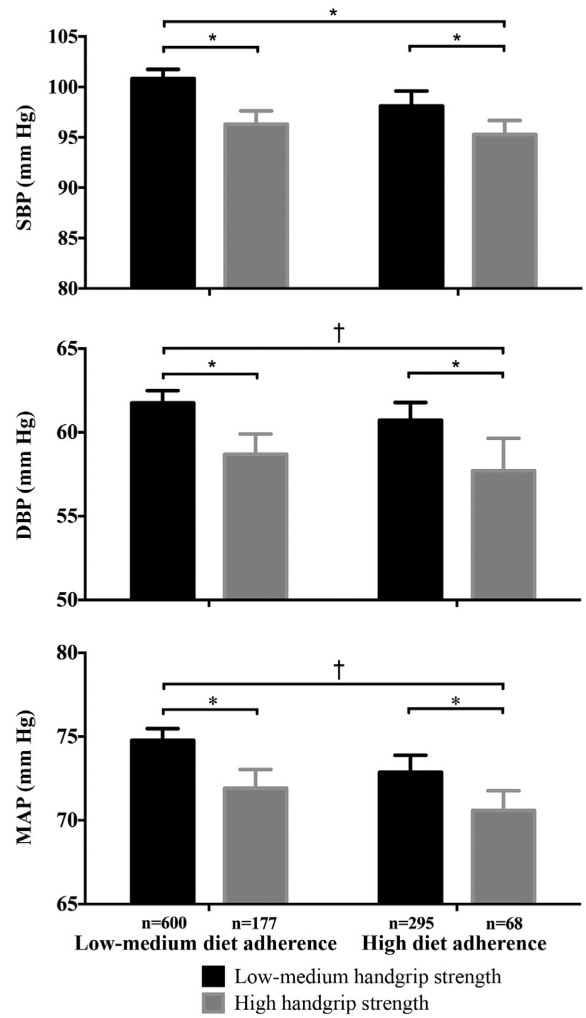


**Fig. 1.** Mean values (and SE) of BP parameters (SBP, DBP, and MAP) in categories of handgrip strength (low–medium and high) and low–medium (<8 points) and high (≥8 points) adherence to the Mediterranean diet. Adjusted for age, sex, and body mass index z-score. *Differences calculated using one-way analysis of covariance: $P < 0.05$. †Differences calculated using one-way analysis of covariance: $P < 0.001$. BP, blood pressure; DPB, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.

**Table 2**
Differences between mean blood pressure parameters according to handgrip strength and Kidmed score categories

| | Handgrip strength | | | | Diet adherence | | | |
|---|---|---|---|---|---|---|---|---|
| | High | Medium-Low | *P*-value | *P*-value* | High | Medium-Low | *P*-value | *P*-value† |
| Systolic blood pressure (mm Hg) | 100.25 (0.51) | 103.37 (0.95) | 0.009 | 0.015 | 97.85 (1.04) | 100.52 (0.69) | 0.033 | 0.098 |
| Diastolic blood pressure (mm Hg) | 60.87 (0.39) | 63.32 (0.72) | 0.031 | 0.035 | 59.33 (0.82) | 61.28 (0.54) | 0.048 | 0.215 |
| Mean arterial pressure (mm Hg) | 72.98 (0.38) | 74.65 (0.72) | 0.383 | 0.341 | 72.15 (0.80) | 74.34 (0.53) | 0.023 | 0.116 |

Data are mean (SE)
*Analysis adjusted by age, sex, BMI z-score, and Kidmed score.
†Analysis adjusted by age, sex, BMI z-score, and handgrip strength.

**Table 3**
Differences between mean handgrip strength and Kidmed score according to blood pressure categories

| | Blood pressure | | | Systolic blood pressure | | | Diastolic blood pressure | | |
|---|---|---|---|---|---|---|---|---|---|
| | <P90 | ≥P90 | *P* | <P90 | ≥P90 | *P* | <P90 | ≥P90 | *P*-value |
| Unadjusted | | | | | | | | | |
| Handgrip strength (kg) | 15.85 (0.18) | 14.45 (0.37) | 0.001 | 15.80 (0.17) | 14.42 (0.42) | 0.004 | 15.71 (0.17) | 14.43 (0.56) | 0.010 |
| Kidmed score (-4 to 12) | 6.47 (0.10) | 6.02 (0.25) | 0.050 | 6.47 (0.09) | 5.87 (0.29) | 0.020 | 6.45 (0.10) | 5.79 (0.33) | 0.044 |
| Adjusted by age, sex and BMI z-score | | | | | | | | | |
| Handgrip strength (kg) | 15.91 (0.22) | 14.73 (0.52) | 0.036 | 15.90 (0.21) | 14.42 (0.59) | 0.020 | 15.81 (0.21) | 14.91 (0.71) | 0.227 |
| Kidmed score (−4 to 12) | 6.49 (0.10) | 5.97 (0.24) | 0.084 | 6.49 (0.10) | 5.79 (0.38) | 0.059 | 6.46 (0.09) | 5.77 (0.33) | 0.053 |

BMI, body mass index
Data are mean (SE)
*According to the National High Blood Pressure Education Program Working Group.

Mediterranean diet on BP levels in the young population. The results are also in accordance with the current evidence from adults; for example, a meta-analysis of randomized controlled trials found that a Mediterranean diet had beneficial effects on average SBP and DBP levels [24]; however, after considering potential confounders, such as age, sex, BMI z-score, and HGS, this relationship disappeared. This may have been due to the masking effects of other factors, such as increased body weight and BMI, on which macronutrient intake exerts a more pronounced effect [25].

Children's muscular strength is associated with overall health, bone health, and self-esteem [26] and inversely associated with metabolic and CVD biomarkers [27]. The findings from this study suggest that muscular strength has protective effects on BP that are independent of dietary habits and other potential confounders, thus confirming previous data reported in European [13,28] and Colombian [14] children. The findings of Cohen et al. in Colombian [14] and English [28] children suggest that the protective effects of HGS on BP are greater with regard to DBP; however, the mechanisms that elicit the protective effect of muscular strength on BP in children remains to be established. In young adults, muscular strength and muscle mass are related to better endothelial function [29], lower central arterial stiffness, and vascular hypertrophy [30]. Previous work also suggested that inflammation may act as a potential link that adversely affects both muscular function and vascular health [31]. Therefore, it is possible that these biological pathways are transferable to the younger population.

Finally, the present study matched the HGS status to the Mediterranean diet adherence groups. This allowed a comparison of differences in the BP levels of the two Mediterranean diet groups (low–medium and high adherence) by HGS levels. Children with higher HGS levels showed the lowest BP levels regardless of their adherence to a Mediterranean diet. Similar results were described by Agostinis-Sobrinho et al. [16] in 467 adolescents from Portugal. Their results suggested that the combination of poor dietary habits, assessed by the Southern European Atlantic Diet, and low muscular strength levels were associated with a poor cardiometabolic profile. Taken together with the results presented here, these results suggest that muscular strength may play a key role in cardiometabolic health in the young population. Although a cross-sectional design was used, the data presented here also seem to suggest that having high HGS levels (i.e., sex- and age-specific ≥80th percentile) may somewhat overcome the deleterious effects of low adherence to healthy dietary patterns.

### *Limitations*

The limitations of this study included the cross-sectional design and the use of BMI in the analyses because this does not distinguish between fat and lean mass. The pubertal status also was not considered and thus a confounding effect may have been introduced. Nevertheless, the differences also were observed in prepubertal children (8–9 y of age) and in both sexes. Another potential weakness of this study was the evaluation of muscular fitness using only an indirect field measure. The Kidmed questionnaire has inherent limitations of precision because of its reliance on self-reported data. Also, consumption is limited to the frequency but not the volume (e.g., how many fruits per day). Therefore, choice of research method precluded independent verification. Finally, we cannot exclude the possibility that the present findings are explained by unmeasured confounders such as level of physical activity, intake of sodium, calcium, and potassium; and stress.

## Conclusions

These findings suggest that HGS is negatively associated with BP parameters even after considering potential confounders. The combination of high HGS and optimal adherence to a Mediterranean diet is also negatively associated with BP. These data suggest that high HGS levels (i.e., ≥80th percentile) may somewhat overcome the deleterious effects of low adherence to healthy dietary patterns. Therefore, these associations highlight the importance of including physical fitness testing in health-monitoring systems. Finally, the results show that a simple, cheap, and feasible muscle fitness test, such as the handgrip test, might predict adverse BP.

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