Hand grip strength is associated with cardiopulmonary function in Chinese adults: Results from a cross-sectional study

Rong Zhu [a, 1], Wei Li [a, 1], Lili Xia [a], Xinghua Yang [a], Biao Zhang [b], Feng Liu [c], Jingang Ma [c], Zhiping Hu [c], Yajun Li [c], Dongxue Li [a], Jiajia Jiang [a], Yan He [a, d, *], Guangliang Shan [b, **]

[a] Department of Epidemiology and Biostatistics, School of Public Health, Capital Medical University, No. 10, Xitoutiao, You'anmen Wai, Fengtai District, Beijing, 100069, China
[b] Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, No. 3, Dongdan, Dongcheng District, Beijing, 100005, China
[c] Shanxi Provincial Disease Prevention and Control Center, No. 3, Building East Street, Beilin District, Xi'an, Shaanxi, 710054, China
[d] Municipal Key Laboratory of Clinical Epidemiology, Beijing, China

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ABSTRACT

Background: The objective of this population-based study was to examine whether there was association of hand grip strength (HGS) with cardiopulmonary function in population without cardiopulmonary disease.
Methods: Data were derived from an ongoing cross-sectional survey of the National Physique and Health in Shanxi Province. There were 908 participants with the cardiac function tests and 380 participants with the pulmonary function tests. Multiple linear regression analysis was used to assess the association of HGS with cardiopulmonary function.
Results: Among participants with the cardiac function tests, HGS was positively associated with left ventricular end diastolic diameter in both genders (male: $b = 0.010$ (0.005, 0.015), $P < 0.001$; female: $b = 0.008$ (0.002, 0.014), $P = 0.01$) and left ventricular ejection fraction in males ($b = 0.114$ (0.027, 0.201), $P = 0.01$). Among participants with the pulmonary function tests, HGS was positively associated with vital capacity (male: $b = 0.033$ (0.021, 0.045); female: $b = 0.033$ (0.021, 0.045)), forced expiratory volume in 1 s (male: $b = 0.023$ (0.014, 0.032); female: $b = 0.019$ (0.010, 0.028)) and maximal voluntary ventilation (male: $b = 1.186$ (0.665, 1.708); female: $b = 0.965$ (0.453, 1.476)) in both genders (all $P < 0.001$).
Conclusions: These results suggested that greater HGS was associated with favorable cardiopulmonary function in Chinese adults, thus HGS might be an indicator of cardiopulmonary function.

Introduction

Muscle is one of the major tissues in the human body, and skeletal muscle accounts for approximately 40% of total body weight. It is well known that the contraction of skeletal muscle is responsible for the successful performance of numerous activities.[1] In the global recommendations on physical activity for health, the World Health Organization recommends that adults have at least two separate days of muscle strengthening activity per week. As a simple and inexpensive measurement, hand grip strength (HGS) is currently recommended to measure muscle function in clinical practice.[2]

Previous studies have shown that HGS is a strong predictor of mortality and disability.[3–10] Recently, there has been considerable interest in the association of HGS with disease. For example, the Prospective Urban-Rural Epidemiology (PURE) study, which is a large longitudinal population study performed in 17 countries, showed that decreased HGS is a risk factor for the incidence of cardiovascular disease and can predict the risk of death in people who develop either cardiovascular or non-cardiovascular diseases.[5] A Swedish cohort study demonstrated that HGS was associated with chronic obstructive pulmonary diseases (COPD) disease

* Corresponding author. Department of Epidemiology and Biostatistics, School of Public Health, Capital Medical University, No. 10, Xitoutiao, You'anmen Wai, Fengtai District, Beijing, 100069, China.
** Corresponding author.
E-mail addresses: yanhe1220@126.com (Y. He), guangliang_shan@hotmail.com (G. Shan).
[1] These authors contributed equally to this work and share the first authorship.

severity.[11]

Grip strength was reported to differ between men and women, with men having higher HGS than women, but there was no difference in the relative loss of HGS over a 4-year period.[12] In addition, there was also no difference between men and women when HGS was used to predict mortality.[13] However, it is still unclear whether there is a gender difference in the relationship between HGS and both cardiopulmonary function and cardiopulmonary disease.

As mentioned above, although HGS is associated with some cardiovascular diseases and pulmonary diseases, the underlying mechanisms of how these associations are mediated by the influence of cardiopulmonary function are not clear. In this study, we aim to examine the association between HGS and cardiopulmonary function in the general population without heart disease or COPD.

Methods

Participants and study design

An ongoing population-based cross-sectional survey of Chinese individuals encompassing health and basic physiological parameters was conducted from the beginning of 2013, in which five provinces were covered (Shanxi, Hainan, Qinghai, Gansu and Jiangxi). The present study is based on the data from Shanxi Province, and the sampling procedure for this province was as follows: first, four administrative regions (Xi'an City, Hanzhong City, Qishan County and Hu County) were obtained by random sampling from the 104 districts in Shanxi province, with two located in urban areas, one in a suburban area and one in a rural area, respectively. After that, six residential communities and six natural villages in those four regions were randomly chosen, based on the list provided by the Centers for Disease Control of Shanxi province.[14] We randomly selected 2 of the 12 sites for cardiac function tests and 1 site for pulmonary function tests.

From June to July 2014, all participants were invited to complete a detailed questionnaire and physical examination. The cardiac function of 1097 participants was measured, and the pulmonary function of 506 participants, was measured. Among the 1097 participants with cardiac function tests, 145 participants younger than 18 years, 40 participants with heart disease and four participants lacking all necessary information needed for statistical analysis, were excluded, resulting in the inclusion of 908 participants (22 of them lacked heart rate data); among the 506 participants with pulmonary function tests, 58 participants younger than 18 years, 64 participants with COPD and four participants lacking all necessary information needed for statistical analysis, were excluded, resulting in the inclusion of, 380 participants. This study was approved by Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences. Written informed consent was obtained from all study participants.

Data collection

Information on demographics, history of disease and corresponding medication use, smoking status, and drinking status, were collected using a questionnaire. Smoking status was divided into three categories: current smoker, previous smoker (people who have given up smoking for more than 12 months) or nonsmoker. Drinking status was also divided into three categories: current drinker, previous drinker (people who have given up drinking for more than 12 months) or nondrinker.

Body mass, height, blood pressure (BP) and HGS were obtained through physical examination. Height was measured barefoot to the nearest 0.1 cm using a flexible anthropometer.[15] Body mass was measured using a SECA 813 digital scale to the nearest 0.1 kg (Seca Vogel & Halke GmbH &Co, Hamburg, Germany). Body mass index (BMI) was calculated as body mass divided by height squared (kg/m^2). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured three times using an Omron electronic sphygmomanometer (Omron Healthcare Co. Ltd., Kyoto, Japan), with at least 10 min allocated between each measurement as a resting period, and the mean value of the three readings was recorded.

HGS and cardiopulmonary measurement

HGS was measured using a hand grip Takei dynamometer (Takei Scientific Instruments Co. Ltd., Niigata, Japan). During each measurement, participants were asked to stand with the arms extended straight down to the side. Participants were measured twice with their dominant hand, and the maximum measurement was recorded as their HGS in kilograms.

Cardiac function, which was represented by heart rate, left ventricular end diastolic diameter (LVEDD) and left ventricular ejection fraction (LVEF), was measured using a Siemens CV70 device (Siemens Medical Solutions, USA), and standard echocardiographic assessment was performed according to the guidelines published by the American Society of Echocardiography.[16]

Pulmonary function, including vital capacity (VC), forced expiratory volume in 1 s (FEV$_1$) and maximal voluntary ventilation (MVV), was measured using a Pneumoscreen II spirometer (Jaeger, Wurtzburg, Germany), according to the standards set by the European Respiratory Society/American Thoracic Society.[17]

Definitions of heart disease and COPD

Heart disease was defined as having a history of at least one of the following diseases: heart failure, pericardial disease, coronary heart disease, myocardial ischemia, myocardial infarction or angina pectoris. Non-heart disease was defined as the absence of any of these diseases and LVEF$\geq$50%. In this study, we excluded 40 participants with heart disease among those who had completed the cardiac function tests.

According to the Global Strategy for the Diagnosis, Management and Prevention of COPD,[18] COPD was defined as FEV$_1$/(best of slow vital capacity [SVC] or forced vital capacity [FVC]) <0.70. Non-COPD was defined as FEV$_1$/(best of SVC or FVC) $\geq$0.70. In this study, we excluded 64 participants with COPD among those who had completed the pulmonary function tests.

Statistical analysis

All analyses were conducted using the IBM Statistical Package for Social Sciences (SPSS version 20.0, IBM Corp, Chicago, IL, USA). The data were expressed as the mean $\pm$ standard deviation (SD) for continuous variables and the number (percentage) for categorical variables. Independent t-tests were used to compare the differences in the continuous variables between the male and female groups, and chi-square tests were used to compare categorical variables. Pearson correlation coefficients were used to assess the correlation between HGS and cardiopulmonary function. The association of HGS with cardiopulmonary function was further evaluated by multiple linear regression analysis in the total sample and gender groups. With HGS as the independent variable, cardiac function (heart rate, LVEDD, LVEF) and pulmonary function (VC, FEV$_1$, MVV) were respectively taken as the dependent variables and substituted into the multiple linear regression model, in which age, BMI, SBP, DBP, muscle mass, smoking and drinking status imputed as potential confounding variables. An α level of 0.05 (two-tailed) was considered significant.

Results

Characteristics of the participants

The baseline characteristics of participants with cardiac or pulmonary function tests, stratified by gender, are shown in Tables 1 and 2, respectively. In total, 908 participants with cardiac function tests had a mean age of 42.7 ± 13.6 years, and 45.7% (n = 415) were males; 380 participants with pulmonary function tests had a mean age of 43.7 ± 14.3 years, and 49.2% (n = 187) were males. In both groups, the participants underwent cardiac or pulmonary function tests, and compared to females, males exhibited higher BMI, HGS, SBP, DBP, LVEDD, VC, FEV$_1$, MVV, lower LVEF and slower heart rate ($P < 0.001$ or $P < 0.05$) and were more likely to be current smokers and drinkers (all $P < 0.001$). The comparison of included and excluded participants is shown in Table S1 and Table S2.

HGS was associated with cardiac function in the participants without heart disease

According to Table 3, HGS was moderately correlated with LVEDD ($r = 0.42$, $P < 0.001$) and negligibly correlated with LVEF ($r = -0.07$, $P = 0.03$), with the strength (LVEDD) and direction (LVEF) of correlation differing between males and females (LVEDD: $r = 0.21$ in males, $r = 0.13$ in females; LVEF: $r = 0.08$ in males, $r = -0.08$ in females). Similarly, after adjusting for potential confounding factors, HGS was positively associated with LVEDD in both genders (male: $b = 0.010$ (0.005, 0.015), $P < 0.001$; female: $b = 0.008$ (0.002, 0.014), $P = 0.01$) and LVEF in males ($b = 0.114$ (0.027, 0.201), $P = 0.01$). With every 1 kg increase in HGS, LVEDD increased by 0.009 cm among all participants (or by 0.01 cm in males and 0.008 cm in females), and LVEF increased by 0.11% in males. HGS was not significantly associated with heart rate in males ($P = 0.27$) or females ($P = 0.39$) (Table 4).

HGS was associated with pulmonary function in participants without COPD

Table 3 shows there were very strong, positive correlations between HGS and VC ($r = 0.76$, $P < 0.001$), FEV$_1$ ($r = 0.75$, $P < 0.001$) and MVV ($r = 0.72$, $P < 0.001$) when all participants were considered, with the strength of the correlations reduced to moderate when split by gender (all $P < 0.001$). After adjusting for potential confounding, HGS was still positively associated with VC, FEV$_1$ and MVV in both genders (all $P < 0.001$). With every 1 kg increase in HGS, VC increased by 0.03 L among all participants (0.03 L in both genders), FEV$_1$ increased by 0.022 L (0.023 L in males and 0.019 L in females), and MVV increased by 1.099 L (1.186 L in males and 0.965 L in females) (Table 4).

Discussion

In this population-based study, we demonstrated that among participants with cardiac function tests, greater HGS was associated with improved cardiac function of LVEDD in both genders and LVEF in males. Additionally, increased HGS was associated with improved pulmonary function of VC, FEV$_1$ and MVV among participants with pulmonary function tests. Taken together, these results suggested a strong association between HGS and cardiopulmonary function among Chinese adults. To the best of our knowledge, this study is the first to investigate the association between HGS and cardiopulmonary function.

In this study, the population was divided into two groups according to gender to explore whether there was a gender difference in the association between HGS and cardiorespiratory function. The results showed that although the HGS of males was significantly higher than that of females (37.7 kg vs. 22.1 kg in participants with cardiac function tests; 36.9 kg vs. 21.5 kg in participants with pulmonary function tests), the correlation between HGS and cardiopulmonary function was similar. This is consistent with a Danish study which found that although the initial level of HGS of males was higher than that of females, the effect of predicting mortality was similar.[13]

Several large population studies have observed the association between HGS and heart disease,[19–23] but studies that further investigated the association between HGS and cardiac function have been conducted only in patients with COPD,[24] but not in the general population, in which the association between HGS and impaired cardiac function appears to be lower. Similar to the results from patients with COPD, this study shows that HGS was also positively associated with the systolic (LVEF) and diastolic function (LVEDD) of myocardium among the participants without heart disease. To further explore the association between HGS and cardiac function, we added muscle mass as a covariate in multiple linear regression models, and the results showed that only LVEDD

Table 1
Baseline Characteristics of participants with the cardiac function tests according to gender.

Variables	Total (n = 908)	Male (n = 415)	Female (n = 493)	P
Age (y)	42.7 ± 13.6	44.3 ± 13.6	41.3 ± 13.4	0.001
BMI (kg/m^2)	22.8 ± 3.0	23.7 ± 2.9	22.1 ± 2.9	<0.001
HGS (kg)	29.2 ± 9.7	37.7 ± 6.7	22.1 ± 5.0	<0.001
Smoking, n (%)				<0.001
Current smoker	237 (26.1)	235 (56.6)	2 (0.4)	
Previous smoker	38 (4.2)	38 (9.2)	0 (0)	
Nonsmoker	633 (69.7)	142 (34.2)	491 (99.6)	
Drinking, n (%)				<0.001
Current drinker	231 (25.4)	200 (48.2)	31 (6.3)	
Previous drinker	25 (2.8)	24 (5.8)	1 (0.2)	
Nondrinker	652 (71.8)	191 (46.0)	461 (93.5)	
SBP (mmHg)	117.2 ± 15.3	122.0 ± 13.4	113.1 ± 15.5	<0.001
DBP (mmHg)	74.1 ± 9.8	76.9 ± 9.7	71.8 ± 9.3	<0.001
Heart rate (beats/min)	69.9 ± 9.1	69.1 ± 9.5	70.6 ± 8.6	0.012
LVEDD (cm)	4.5 ± 0.4	4.7 ± 0.4	4.4 ± 0.3	<0.001
LVEF (%)	63.1 ± 5.3	62.6 ± 5.7	63.6 ± 4.9	0.003

Data are expressed as mean ± SD or as number and percentage as indicated in the table. P-values were derived from t-tests or chi-squared test.
HGS: Hand grip strength; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; LVEDD: Left ventricular end diastolic diameter; LVEF: Left ventricular ejection fraction.

Table 2
Baseline Characteristics of participants with the pulmonary function tests according to gender.

Variables	Total (n = 380)	Male (n = 187)	Female (n = 193)	P
Age (y)	43.7 ± 14.3	43.0 ± 14.3	44.3 ± 14.2	0.385
BMI (kg/m^2)	24.0 ± 3.4	24.8 ± 3.5	23.1 ± 3.1	<0.001
HGS (kg)	29.1 ± 9.8	36.9 ± 7.0	21.5 ± 5.2	<0.001
Smoking, n (%)				<0.001
Current smoker	98 (25.8)	97 (51.9)	1 (0.5)	
Previous smoker	25 (6.6)	24 (12.8)	1 (0.5)	
Nonsmoker	257 (67.6)	66 (35.3)	191 (99.0)	
Drinking, n (%)				<0.001
Current drinker	106 (27.8)	91 (48.6)	15 (7.8)	
Previous drinker	7 (1.8)	7 (3.7)	0 (0)	
Nondrinker	267 (70.3)	89 (47.6)	178 (92.2)	
SBP (mmHg)	116.5 ± 13.2	120.8 ± 11.6	112.4 ± 13.4	<0.001
DBP (mmHg)	73.6 ± 9.2	76.3 ± 8.4	71.0 ± 9.1	<0.001
VC (L)	3.8 ± 0.9	4.4 ± 0.7	3.1 ± 0.5	<0.001
FEV$_1$ (L)	2.9 ± 0.7	3.4 ± 0.6	2.5 ± 0.4	<0.001
MVV (L)	110.8 ± 30.6	130.0 ± 27.3	92.2 ± 20.7	<0.001

Data are expressed as mean ± SD or as number and percentage as indicated in the table. P-values were derived from t-tests or chi-squared tests.
HGS: Hand grip strength; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; VC: Vital capacity; FEV$_1$: Forced expiratory volume in 1 s; MVV: Maximal voluntary ventilation.

Table 3
Pearson's correlation between HGS and cardiopulmonary function.

Variables	Total		Male		Female	
	r	P	r	P	r	P
Cardiac function						
Heart rate	−0.02	0.62	0.11	0.01	0.06	0.09
LVEDD	0.42	<0.001	0.21	<0.001	0.13	0.002
LVEF	−0.07	0.03	0.08	0.06	−0.08	0.05
Pulmonary function						
VC	0.76	<0.001	0.44	<0.001	0.46	<0.001
FEV$_1$	0.75	<0.001	0.43	<0.001	0.44	<0.001
MVV	0.72	<0.001	0.39	<0.001	0.36	<0.001

P: from Pearson Correlation. HGS: Hand grip strength; LVEDD: Left ventricular end diastolic diameter; LVEF: Left ventricular ejection fraction; VC: Vital capacity; FEV$_1$: Forced expiratory volume in 1 s; MVV: Maximal voluntary ventilation.

in males remained statistically correlated with HGS ($P = 0.02$), while other cardiac function indicators were no longer statistically associated with HGS (Table S3). This suggests that the association between HGS and cardiac function can be partly explained by muscle mass.

Spirometry provides a global functional evaluation of the lungs, and the parameters of VC, FEV$_1$ and MVV are used to diagnose lung diseases such as COPD.[25] A number of studies have demonstrated the association between HGS and COPD.[21,22,26] Previous observations have shown that HGS was associated with FEV$_1$ among participants with COPD.[11,27] While in non-COPD participants, the

associations between HGS and respiratory parameters were inconsistent. One study included 60 years or older male residents of a nursing home found that HGS was not associated with FVC or FEV$_1$.[28] Conversely, some recent studies from Nigeria (included FVC and FEV$_1$), USA (included FEV$_1$) and Korea (included FVC and FEV$_1$) showed that pulmonary function parameters are related to HGS.[29–31] In this study, we found that HGS was associated with VC, FEV$_1$ and MVV among participants without COPD in both genders, which is consistent with the conclusion of the latter. This may be due to the age difference in theses study participants, as the Danish study included people over 60 years old, while the Nigerian study (16–30 years old) and our study (mean age 42.7 years old) were younger. Thus, we may infer that HGS is closely related to pulmonary function in the general population.

Grontved et al.[32] demonstrated that the muscle strength of the abdomen and back was moderately related to cardiorespiratory fitness. However, the testing procedure of the maximal muscle strength of the abdomen and back[33] was complex and not suitable for a large-scale population study. As a simple and inexpensive measurement, HGS reflected the cardiopulmonary function to some extent, especially for pulmonary function (VC: r = 0.44 in males and 0.46 in females).

One of the strengths of this study was that we recruited the study population using stratified multistage random sampling, thus avoiding selection bias and ensuring representativeness. Second, compared to previous studies, we had a relatively large sample size. However, the present study also has limitations. First, the

Table 4
Association of HGS with cardiopulmonary function in participants with cardiac or pulmonary function tests.

Variables	Total			Male			Female		
	N	P	b (95%CI)	N	P	b (95% CI)	N	P	b (95% CI)
Cardiac function									
Heart rate (beats/min)	886	0.16	0.077(−0.031, 0.185)	411	0.27	0.084 (−0.066, 0.233)	475	0.39	0.070 (−0.090, 0.230)
LVEDD (cm)	908	<0.001	0.009 (0.005, 0.013)	415	<0.001	0.010 (0.005, 0.015)	493	0.01	0.008 (0.002, 0.014)
LVEF (%)	908	0.10	0.052 (−0.009, 0.113)	415	0.01	0.114 (0.027, 0.201)	493	0.56	−0.027 (−0.115, 0.062)
Pulmonary function									
VC (L)	380	<0.001	0.033 (0.025, 0.041)	187	<0.001	0.033 (0.021, 0.045)	193	<0.001	0.033 (0.021, 0.045)
FEV$_1$ (L)	380	<0.001	0.022 (0.015, 0.028)	187	<0.001	0.023 (0.014, 0.032)	193	<0.001	0.019 (0.010, 0.028)
MVV (L)	380	<0.001	1.099 (0.742, 1.456)	187	<0.001	1.186 (0.665, 1.708)	193	<0.001	0.965 (0.453, 1.476)

P, b (coefficients) and 95% CI (95% confidence interval): from multiple linear regression, in which age, BMI, SBP, DBP, smoking, drinking status was adjusted. HGS: Hand grip strength; LVEDD: Left ventricular end diastolic diameter; LVEF: Left ventricular ejection fraction; VC: Vital capacity; FEV$_1$: Forced expiratory volume in 1 s; MVV: Maximal voluntary ventilation.

information for heart disease was self-reported, and we lacked physiological measures for some heart diseases, such as heart failure. Second, we did not measure grip strength using the procedures recommended by the American Society of Hand Therapists or the South Hampton group. Finally, because this was a cross-sectional study, causation cannot be determined, but can be verified by prospective studies in the future.

Conclusion

We found that HGS was positively associated with cardiopulmonary function among Chinese adults. Given its simplicity, HGS might be used as a suitable predictor of cardiopulmonary function in large-scale population studies. Since HGS and cardiopulmonary function are physiologically related through reciprocal causation, an increase in HGS through resistance training exercise might be a promising strategy for improving cardiopulmonary function.

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Declaration of competing interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesf.2019.12.001.

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