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Original Research Article

Evaluation of Handgrip Strength as a Predictor of Cardiovascular Fitness in Healthy Young Adults

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Abstract:

Background: Handgrip strength is a cheap indicator of muscle fitness and could be a proxy for general cardiovascular fitness, but its predictive value in healthy young people needs to be assessed.

Materials and Methods: This was a cross sectional analytical study to determine the predictive value of absolute and body-size adjusted handgrip strength for cardiovascular fitness in healthy adults aged 18-30 years. Dominant and non-dominant handgrip tests were performed on a hydraulic dynamometer, resting cardiovascular measurements were taken, and the Queens College step test, Harvard step test, and estimated maximal oxygen uptake (VO2max) were performed on 160 participants. Participants were divided into three tertiles according to their relative handgrip strength (RHS) by sex.

Results: The mean age was 21.9 ± 2.6 years, and 84 participants (52.5%) were male. Higher handgrip tertiles showed significantly higher estimated VO2max (low: 35.8 ± 5.6, middle: 40.2 ± 6.1, high: 45.1 ± 6.8 mL/kg/min; $p < 0.001$), better physical fitness index (64.9 ± 9.8, 72.5 ± 10.7, 80.3 ± 11.5; $p < 0.001$), lower resting heart rate, and faster post-exercise recovery. The correlation between relative handgrip strength and VO2max was positive ($r = 0.52$, $p < 0.001$) and between physical fitness index and VO2max was positive ($r = 0.49$, $p < 0.001$). When adjusted for age, sex, BMI and physical activity, relative handgrip strength was an independent predictor of VO2max (beta = 0.38, $p < 0.001$). The area under the ROC curve for the ability to identify above-median cardiovascular fitness was 0.76.

Conclusion: Handgrip strength, especially after body size correction, is a good screening indicator of cardiovascular fitness in healthy young adults.

Keywords: Handgrip Strength; Cardiovascular Fitness; VO_2 Max; Young Adults; Dynamometer; Physical Fitness.

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Introduction

Cardiovascular fitness is an important factor in health, functional capacity and long-term cardiovascular disease risk. Maximal oxygen uptake is the gold standard for cardiorespiratory fitness but it takes time, effort, trained personnel and specialized equipment. Field tests like step tests, shuttle runs, and submaximal exercise protocols are more practical but still need space, monitoring, and participant cooperation. Handgrip strength, on the other hand, is simple, quick, inexpensive, and easily reproducible when measured with a standardized dynamometer. It has been suggested as a general indicator of health, nutritional status, functional reserve and future morbidity [1,2].

Low grip strength has been demonstrated to be an independent predictor of all-cause mortality and cardiovascular events in large cohort studies [3]. Handgrip strength has been described as a potential 'vital sign' as it is a measure of muscular fitness and is related to metabolic and cardiovascular health [4]. The link between handgrip strength and cardiovascular fitness, however, is complex. Muscular strength and aerobic capacity are two fitness domains that can be affected by physical activity habits, lean mass, neuromuscular efficiency, nutrition, and body composition. Some studies have found that relative handgrip strength (either adjusted for BMI or body surface area) is correlated with cardiorespiratory fitness in young adults [5,6].

This is particularly important in college and occupational health environments, where quick screening instruments are required to determine those who are less fit and may benefit from exercise counseling. If handgrip strength is a valid predictor of cardiovascular fitness, it could be used as a first-line screening test prior to more time-consuming exercise testing. It can also be beneficial when exercise testing is contraindicated or impractical. However, absolute handgrip strength may be influenced by sex, height, body weight, and body composition. Relative grip strength (grip force/body weight or BMI) may reflect functional strength more accurately in relation to body size and may be more closely related to cardiovascular risk markers [7,8].

There is limited and inconsistent evidence in the younger adult population. There are variations in studies regarding dynamometer protocol, hand dominance, method of adjustment, and fitness outcome measure. Some focus on cardiovascular disease risk in middle-aged or older people, and fewer specifically on estimated VO2max and recovery indices in healthy young adults [9,10]. The present study was thus designed to test the handgrip strength as a predictor of cardiovascular fitness in healthy young adults. The main goal was to determine the relationship between relative handgrip strength and estimated VO2max. Secondary aims included comparing step-test performance between handgrip tertiles, assessing adjusted regression models, and assessing the screening accuracy of handgrip strength for above-median cardiovascular fitness.

Materials and Methods

This study was conducted in a physiology laboratory with healthy young adults (18-30 years). The participants included undergraduate and postgraduate students and community volunteers. The subjects were asked to refrain from intense physical activity, caffeine and rich foods for a minimum of three hours prior to the test. Assessments were conducted in a temperature-controlled room following 10 minutes of seated rest. If the participant had fever, acute illness, musculoskeletal pain or insufficient sleep the night before the test, testing was postponed.

Sample size was determined to be able to detect a correlation coefficient of at least 0.30 between relative handgrip strength and estimated VO2max with 90% power and 5% alpha error. 160 participants were enrolled, including those who had subgroup analysis and incomplete exercise tests. The inclusion criteria were: age 18-30 years, apparently healthy, and able to carry out handgrip and step test. The exclusion criteria included upper-limb injury, recent surgery, pregnancy, known cardiovascular or respiratory disease, hypertension, diabetes mellitus, and current smoking, as well as athletic training at competitive level.

Handgrip strength was measured using a calibrated hydraulic hand dynamometer. Participants were seated with the shoulder adducted, elbow flexed at 90 degrees, forearm neutral, and wrist slightly extended. Three trials were performed for each hand with one-minute rest between trials. The best hand and the average of both hands was noted. Dominant handgrip strength was divided by body weight to obtain relative handgrip strength, and a secondary index, adjusted for BMI, was also calculated. To prevent the confounding effect of sex differences in absolute handgrip strength, participants were divided into sex-specific tertiles.

Cardiovascular fitness was determined with the Queens College step test and Harvard step test. Pulse oximeter and manual confirmation was used to measure heart rate at rest, immediately after exercise, and during recovery. Recovery heart rate was used to estimate VO2max by applying the standard equations for the Queens College step test. The Harvard step test duration and recovery pulse counts were used to determine physical fitness index. Self-reported physical activity and blood pressure, BMI and waist circumference were also measured. Data were analyzed using ANOVA, Pearson correlation for continuous associations, multiple linear regression for predictors of VO2max, and receiver operating characteristic analysis to assess the capacity of relative handgrip strength to identify above-median cardiovascular fitness. A p value of < 0.05 was deemed statistically significant.

Results

The study included 160 participants with mean age 21.9 ± 2.6 years. Eighty-four were male and seventy-six were female. Mean dominant handgrip strength was 37.8 ± 9.6 kg in males and 24.9 ± 6.8 kg in females. When categorized by sex-specific tertiles of relative handgrip strength, the groups were comparable in age but differed significantly in BMI, waist circumference, resting heart rate, and physical activity score. The high-tertile group had lower BMI and higher self-reported physical activity than the low-tertile group.

Cardiovascular fitness improved progressively across relative handgrip tertiles. Estimated VO2max was 35.8 ± 5.6 mL/kg/min in the low tertile, 40.2 ± 6.1 mL/kg/min in the middle tertile, and 45.1 ± 6.8 mL/kg/min in the high tertile ($p < 0.001$). Physical fitness index and recovery heart rate showed similar patterns. Participants with high relative handgrip strength had lower resting heart rate and faster heart-rate recovery after exercise. Absolute handgrip strength correlated with VO2max, but the correlation was stronger for relative handgrip strength, supporting body-size adjustment.

Relative handgrip strength correlated positively with VO2max ($r = 0.52$, $p < 0.001$) and physical fitness index ($r = 0.49$, $p < 0.001$), and inversely with resting heart rate ($r = -0.33$, $p < 0.001$) and one-minute recovery heart rate ($r = -0.37$, $p < 0.001$). In multivariable regression adjusted for age, sex, BMI, waist circumference, and physical activity, relative handgrip strength remained an independent predictor of estimated VO2max (beta = 0.38, $p < 0.001$). ROC analysis showed an area under the curve of 0.76 for identifying above-median VO2max, indicating acceptable screening performance. A relative handgrip cut-off of 0.52 kg/kg showed 72.5% sensitivity and 68.8% specificity.

Table 1: Participant characteristics by relative handgrip tertile

Variable	**Low tertile (n=53)**	**Middle tertile (n=54)**	**High tertile (n=53)**	**p value**
Age (years)	22.1 ± 2.8	21.8 ± 2.5	21.7 ± 2.4	0.71
Male, n (%)	28 (52.8)	28 (51.9)	28 (52.8)	0.99
BMI (kg/m2)	24.3 ± 3.2	22.8 ± 2.9	21.9 ± 2.6	<0.001
Dominant HGS (kg)	27.8 ± 8.3	33.6 ± 8.5	41.9 ± 9.7	<0.001
Relative HGS (kg/kg)	0.39 ± 0.07	0.51 ± 0.05	0.64 ± 0.08	<0.001

Table 2: Cardiovascular fitness outcomes across handgrip tertiles

Outcome	Low tertile	Middle tertile	High tertile	p value
Estimated VO_2 max (mL/kg/min)	35.8 ± 5.6	40.2 ± 6.1	45.1 ± 6.8	<0.001
Physical fitness index	64.9 ± 9.8	72.5 ± 10.7	80.3 ± 11.5	<0.001
Resting heart rate (beats/min)	82.1 ± 8.8	77.4 ± 8.1	73.2 ± 7.6	<0.001
1-min recovery HR (beats/min)	128.6 ± 15.3	119.8 ± 14.6	111.2 ± 13.8	<0.001
Systolic BP (mmHg)	118.7 ± 9.4	116.2 ± 8.8	114.8 ± 8.1	0.06

Table 3: Predictive analysis for cardiovascular fitness

Variable	**Association with VO2max**	**95% CI**	**p value**
Absolute HGS	r = 0.36	0.22 to 0.49	<0.001
Relative HGS	r = 0.52	0.39 to 0.63	<0.001
Relative HGS adjusted beta	0.38	0.21 to 0.55	<0.001
ROC AUC for above-median VO_2 max	0.76	0.68 to 0.84	<0.001
Cut-off 0.52 kg/kg	Sensitivity 72.5%	Specificity 68.8%	-

Discussion

In the present study, relative handgrip strength was significantly correlated with cardiovascular fitness in healthy young adults. The participants in the highest handgrip tertile showed higher estimated VO2max, higher physical fitness index, lower resting heart rate and faster recovery after exercise. These results confirm the hypothesis that handgrip strength is not just a local measure of upper limb function but may also be a general measure of physiological reserve. Large epidemiological studies have shown grip strength to be a strong predictor of cardiovascular and all-cause mortality [3]. In our study, we have extended this concept to a younger, apparently healthy population by showing that association is with functional cardiovascular fitness and not clinical outcomes.

This is significant because the relative handgrip strength is more highly correlated than the absolute handgrip strength. Absolute grip force is affected by sex, body size and lean mass, so that larger people can seem stronger than smaller people, even if they have lower functional fitness per unit of body mass. Grip strength adjusted for body size may be a more accurate indicator of the relationship between muscle strength and body weight. Relative handgrip strength has also been shown to be a more relevant measure of cardiovascular risk than absolute strength in studies [7,8]. The present results indicate that relative grip strength could also be utilized in the screening of young adults for low cardiovascular fitness.

The association may be due to a number of mechanisms. The more active people are, the more muscular strength and aerobic capacity they will gain. Grip performance and recovery from exercise may be affected by lean mass, mitochondrial function, vascular health, insulin sensitivity and autonomic regulation. Handgrip strength could also reflect overall neuromuscular function and nutritional status. Favorable autonomic reactivation after exercise, as reflected in better heart-rate recovery in stronger participants, is a well-established indicator of cardiovascular fitness. Grip testing is not a direct measure of oxygen transport, but seems to be a good indicator of fitness status.

The accuracy of the screening obtained in ROC analysis was good but not good enough to replace exercise testing. The AUC of 0.76 means that relative grip strength has the potential to classify people who are more likely to be above the median level of fitness, but there are still false positives and false negatives. Thus, handgrip strength should be considered as a preliminary screening test and not a definitive indicator of cardiovascular fitness. Dynamometer testing can rapidly identify students who might require further fitness assessment and exercise counseling in student health programs, occupational screening, and community camps.

The advantages of this study are the standardized dynamometer protocol, sex-specific tertile classification, the use of two field fitness tests, and the adjustment for physical activity and anthropometry. Some limitations are cross-sectional design, estimation of VO2max rather than direct measurement, single center sample, and exclusion of trained athletes and smokers, which may limit generalizability. Dual-energy absorptiometry and bioimpedance were not used to measure body composition, and diet was not evaluated. Direct cardiopulmonary exercise testing, longitudinal training interventions and age- and sex-specific normative cut-offs for relative handgrip strength in Indian young adults should be included in future studies.

Handgrip strength is appealing as a screening tool because it is quick to administer and space efficient. Cardiovascular fitness testing, on the other hand, needs step benches, cycle ergometers, treadmills, or field space and can be affected by motivation and musculoskeletal limitations. The present results indicate that relative handgrip strength is a useful indicator of those who are more likely to have poor aerobic fitness. This is especially helpful in institutional screening programs where many students need to be evaluated in a timely fashion. Grip testing is not a complete replacement for exercise testing, however, as it does not measure oxygen uptake, ventilatory threshold or exercise tolerance.

The link between muscle strength and cardiovascular fitness might be partly behavioral. People who exercise regularly, such as through sport, resistance training or physically demanding exercise tend to build strength and aerobic reserve. Furthermore, lean mass and insulin sensitivity may be greater in stronger individuals, leading to better exercise response. Grip strength has been demonstrated to be associated with cardiovascular outcomes and mortality in population cohorts, and cardiorespiratory fitness is independently protective [3,11]. Measuring both domains might thus be a more comprehensive measure of fitness than either measure alone.

It is important to have sex-specific interpretation. The difference in absolute grip strength is significant between males and females and is related to muscle mass, limb size and hormonal factors. This bias was minimized by categorizing the participants into sex-specific tertiles and then comparing relative values within each sex. Reference values should be age, sex and population specific in clinical or public health practice. International normative data is now available, but local validation is still necessary, as ethnicity, nutrition, occupation and physical activity patterns affect grip strength [12,13]. Large multi-centre databases would enable the identification of practical cut-offs for low MF in young adults in India.

One other noteworthy finding was the relationship between grip strength and heart-rate recovery. Better autonomic reactivation and cardiovascular conditioning is indicated by faster recovery following step testing. This discovery is consistent with the notion that relative handgrip strength is a measure of systemic fitness, not just hand muscle fitness. However, it is not possible to draw conclusions about cause and effect. Resistance training can lead to an increase in grip without a significant increase in VO2max, and aerobic training can lead to an increase in VO2max without a significant increase in grip. Future interventional studies should compare the effects of aerobic training, resistance training, and combined exercise programs to determine the relationship between changes in grip strength and changes in directly measured cardiorespiratory fitness.

The present study also confirms the importance of reporting not only absolute but also relative strength. A high absolute grip value in a heavy person does not necessarily mean that he or she has a higher functional fitness, if the load on the body is too great. On the other hand, a smaller person with moderate absolute grip strength could have excellent relative strength and aerobic capacity. Dominant grip, relative grip and percentile category may be useful for screening reports to give more meaningful feedback to the clinician or fitness instructor. This method is in line with the recent focus on grip strength as a clinically useful health measure [14-16].

Conclusion

In healthy young adults, relative handgrip strength was significantly correlated with cardiovascular fitness, heart-rate recovery and physical fitness index. Grip strength, when adjusted for body size, was an independent predictor of estimated VO2max and had good screening accuracy for above median fitness. Handgrip dynamometry is a simple, inexpensive screening tool that can be used to identify young adults who might need additional cardiovascular fitness evaluation and lifestyle counseling.

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