Journal of Exercise and Health Science, Vol. 02, No. 03, Summer 2022, Page 81-94

Research Paper

Association between Relative Total Hand Grip Strength and Cardiorespiratory Fitness in Steel Industry Workers [1]

Vazgen Minasian*[1], Volga Hovsepian[2]

1. Associate Professor, Department of Exercise Physiology, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran (Corresponding Author)
2. Department of Exercise Physiology, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran.

Received: 2022/06/13 **Accepted: 2022/09/18**

Abstract

Background: Hand-grip strength has an important role in daily activities and serves as a reliable indicator of overall strength of body and health.

Aims: The purpose of present study was to determine the association between relative total hand grip strength and cardiorespiratory fitness of individuals who joined in Isfahan Steel Factory recruitment tests.

Methods: Data were collected from 1010 men aged 20-35 years that participated in this study. The right and left-hand strength was evaluated by dynamometer, cardiorespiratory fitness with 20m shuttle run test, push-ups, curl-ups, trunk strength and body fat percentage with valid tests and protocols. Relationship between relative overall hand-grip and cardiorespiratory index of individuals and other variables were examined using multiple linear regression.

Results: The regression analysis showed significant association between relative total handgrip strength (THGS) and cardiorespiratory fitness of participants adjusted by body mass index (r= 0.482; p=0.001) and body surface area (r= 0.207; p=0.001).

Conclusions: Data analysis revealed that hand-grip strength adjusted by body max index and body surface area could be an indicator of physical health and moderately reflect cardiorespiratory fitness in healthy young adults.

Keywords: Hand grip, Cardiorespiratory fitness, Body mass index, Body surface area.

1. Email: v.minasian@spr.ui.ac.ir
2. Email: hovsepian.v@yahoo.com

Introduction

Physical fitness is the ability to perform daily activities with optimal performance and manage illness and stress. It is related to genetic and environmental factors (Roberts et al., 2011). Physical fitness consists of various elements that can be further grouped into health-related and skill-related components. Health-related physical fitness includes cardiorespiratory endurance, muscular endurance and strength, body composition and flexibility. Research has shown that among these components muscular strength and cardiorespiratory fitness have a strong relationship with health outcomes (Ortega, et al., 2012). The assessment of physical fitness for a job activity is defined as whether a person is ready to perform his duties without endangering himself and others. Therefore, there should be sufficient knowledge about both working and health conditions. On the other hand, due to the changing nature of these two variables, physical fitness for a specific job is considered a dynamic concept (Serra et al., 2007). Therefore, physical evaluations should be done at the beginning of employment relationships, after transferring job positions during employment, after the occurrence of some physical discomforts and periodically, especially in potentially dangerous jobs that require special physical abilities (Calderwood et al., 2020).

Muscle strength was measured in a variety of formats, including 1 repetition maximum (1 RM), handgrip dynamometry, isometric assessments with a chain device, and electromechanical dynamometry or isokinetic dynamometry (Rantanen et al., 2000). One of the suggested methods to measure overall muscular strength of body is hand grip strength (HGS). Measurement of isometric HGS is a simple method to indicate physical strength and is correlated with upper, lower, and overall body strength. Previous studies have suggested that HGS is correlated with some anthropometric characteristics such as body composition, age, sex (Ingrová et al., 2017), health and fitness scores (Cooper et al., 2017), and risk of premature mortality (Bohannon, 2008). There is high heterogeneity of HGS in different populations and makes it difficult to compare them. To reduce this heterogeneity, it is suggested to adjust HGS for body surface area and body mass index (Crump et al., 2017).

The measurement of maximum oxygen consumption ($\dot{V}O_{2max}$) is another key factor in assessing health. World Health Organization (WHO) reported that $\dot{V}O_{2max}$ could be a standard indicator for the assessment of cardiovascular fitness (CRF). It has been demonstrated that higher CRFs are associated with better health outcomes, such as a lower risk of heart problems, diabetes and cancer (Kodama et al., 2008; Sui et al., 2010). There are a number of direct and indirect methods to determine or estimate $\dot{V}O_{2max}$ including treadmill-based aerobic testing so as to specify $\dot{V}O_{2max}$ or $\dot{V}O_{2peak}$, 1-mile walk/Run, 20-m multistage shuttle run, Cooper's 12-minute run, a two-minute arm ergometer assessment at 50 W, a six-minute cycling, and six-minute step test (Grant et al., 1999; Shephard et al., 1968). Direct measurement of $\dot{V}O_{2max}$ using laboratory equipment in epidemiological studies or with a large number of participants is expensive and time-consuming. Therefore, introducing an alternative method to prediction of cardiovascular fitness seems favorable in such study. There is a dearth of research in this area. As an example, in a study, it was found that low aerobic fitness, low muscle strength and obesity at age ≥18 were associated with increased mortality in adulthood, and that there were interactive effects between aerobic fitness and muscle strength (Crump et al., 2017).

In order to predict the occupational performance of employees, it appears that a wide range of fitness tests is required. Other important measures include muscle strength, endurance and power, agility and anaerobic capacity, although aerobic fitness tests are the most widely studied and closely related to occupational performance. To this end, efforts should be made to base fitness assessments on occupational demands which are unique to each individual, both in terms of environment and in terms of occupational requirements. The aim of this study was to determine the relationship between total HGS and $\dot{V}O_{2max}$ in young healthy Iranian adults. It was hypothesized that there was a strong association between aerobic fitness and muscular strength in these populations.

Methods

The present study was a prospective and cross-sectional in design. The data were obtained at the University of Isfahan. The ethics approval was obtained from the University of Isfahan (No: IR.UI.REC.097.1400). Participants were individuals who joined in Isfahan Steel Factory recruitment test. A number of 1010 healthy, male individuals aged 20-35 years participated in this study. Individuals with a history of any cardiovascular diseases (n=1), Asthma (n=1), Breath problems (n=1), Diabetic (n=1), Hypertension (n=1) and smoking (n=11), which may affect the outcomes of the exercise tests were excluded. Before the exercise tests were administered, participants were informed with methodology of the study and written informed consent was obtained. Anthropometric parameters including height (cm), weight (kg), and body mass index (BMI, kg/m^2) are measured by a valid stadiometer (Seca 220-gauge stadiometer, Hamburg, Germany) to the nearest 0.1 cm and 0.1 kg, respectively. Wight (kg) divided by height (m^2) was used to calculate the BMI and Body surface area (BSA) was calculated using the following equation:

$$\boldsymbol{x} = \frac{\sqrt{\textbf{hight (cm)} \times \textbf{weight(kg)}}}{\textbf{3600}} \quad \text{(Zhou et al., 2021)}$$

Body fat percentage measured using the caliper (Lange, UK) including triceps, thigh, supra-iliac, and subscapular sits (Eston et L., 2018).
The maximum isometric strength of hand and forearm muscles were measured by a hand-grip dynamometer (Baseline, Masan 630nd Korea). Trunk strength (kg) was measured by a trunk dynamometer (SEAHAN, Korea). Abdominal muscle endurance and chest and shoulder muscle endurance were assessed using the curl-up and push-up tests (Gibson et al., 2019). Lifestyle habits, such as smoking (current smoker or nonsmoker), and physical activity (sedentary, daily exercise less than 30 min, 31-45 min, 46-60 min, 60-90 per day) were assessed with the questionnaire.

Handgrip Strength Test

Following the methodology outlined in prior research (Celis-Morales et al., 2017), the participant assumed an upright seated position with the elbow flexed at a 90° angle and resting on a table. Holding the hand dynamometer, the participant exerted maximal handgrip effort three times on each side, with the results indicated in kilograms (kg). A one-minute interval was observed between measurements to allow for the recovery of muscle strength. The average of three measurements was then recorded for both the left-hand grip strength (LHGS) and right-hand grip strength (RHGS). The total hand grip strength (THGS) was calculated as the mean of the right and left side values.
Body size affected the HGS (Nevill et al., 2003); therefore, we adjusted the left and right handgrip for BMI and BSA and reported them as HGS/BMI and HGS/BSA.
The 20m shuttle run test has been performed for estimation of $\dot{V}O_{2max}$ in the participant. This aerobic capacity field test consisted of a reciprocal run between two lines 20 meters apart at a starting speed of 8.5 km per hour. Participants were encouraged to continue the test as much as possible. The test terminated when the participant couldn’t keep the running speed or was unable to reach the end line three times according to the audible warning. The velocity obtained in the last step was recorded and placed in the following formula instead of x: $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1}) = 6(x)-24.4(x) (Kilding et al., 2006). During the testing period, if there was dizziness or chest pain the test stopped, and the participant was lied to a supine position and done under medical care.
The demographic characteristics of participants were summarized in Table 1. The correlation between THGS/BMI, THGS/BSA, and other variables were analyzed by Pearson correlation coefficient statistics showed in Table 2. Multivariate linear regression analysis was used to explore factors independently correlated with THGS/BMI and THGS/BSA (Table 3). Data analyses were performed using SPSS software, version 24.0 (Armonk, NY: IBM Corp.).

Figures were performed using Graph Pad Prism version 8.01 (San Diego, USA). Two-sided p-values < 0.05 were considered statistically significant.

Results

A number of 1010 young healthy male adults participated in this study. After excluding subjects with smoking, heart disease, diabetes, asthma, hypertension, respiratory problems, 994 young healthy male adults with the mean age of (24.22±2.34 years) participated in testing protocols. Table 1 summarizes the characteristics of those participants.

Table 1-Characteristics of the participants in the study

Variable	Mean± SD	Variable	Mean± SD
Age(year)	24.22±2.34	RHGS/BMI	2.14±0.48
Weight(kg)	76.63±13.30	THGS/BMI	3.10± 0.65
Height(m)	179.25±6.02	THGS/BSA	37.82 ±6.50
BMI (kg/m^2)	23.83±3.89	TRS	139.49±31.48
BF%	24.80± 5.61	TRS/BMI	5.94± 1.43
BSA(m^2)	1.94± 0.18	TRS/BSA	71.82± 15.72
LHGS (kg)	47.93±9.38	Curl ups(n)	29.31±8.23
RHGS (kg)	50.24±9.98	Pushups(n)	20.28±10.32
THGS (kg)	72.65±13.58	VO_{2max} (ml.kg/min)	39.42± 5.48
LHGS/BMI	2.02±0.44		

Note: SD: standard deviation; BMI: body mass index; BSA: body surface area; BF%: body fat percent;
LHGS (left hand-grip strength); RHGS (right hand-grip strength); THGS (total hand-grip strength); TRS
(Trunk strength); VO2max (maximal oxygen uptake); n (number).

Table 2 shows the results of the correlation analysis. The measured variables such as weight, height, BMI, BSA, BF%, THGS/BSA, TS/BMI, TS/BSA, $\dot{V}O_{2max}$, curl-ups (abdominal muscle endurance), and push-ups (shoulder and chest muscle endurance) were correlated with THGS/BMI and THGS/BSA ratios (p=0.05). These results showed that THGS/BMI and THGS/BSA were associated with health-related factors and had a potential reflection of health conditions.

Table 2- Correlations between participants' characteristics, THGS/BMI and THGS/BSA

Variables	THGS/BMI r (*p*- value)	THGS/BSA r (*p* -value)
Weight(kg)	-0.362 (0.001)	-0.130 (0.001)
Height(m)	0.312 (0.001)	0.054 (0.08)
VO_{2max} (ml.kg/min)	0.483 (0.001)	0.207 (0.001)
BF%	-0.541(0.001)	0.258 (0.001)
THGS/BSA	0.888 (0.001)	-
TS/BMI	0.551(0.001)	0.888 (0.001)
TS/BSA	0.345 (0.001)	0.424 (0.001)
Push-ups (n)	0.290 (0.001)	0.336 (0.001)
Curl-ups (n)	0.145(0.001)	0.133 (0.001)

Note: BMI: body mass index; BF%: body fat percentage; BSA: body surface area; BF%: body fat
Percentage; THGS (total hand grip strength); TS (trunk strength); VO2max (maximum oxygen uptake); r: Pearson's correlation coefficient.

Multiple regression analysis was conducted to determine the association between independent variables THGS/BMI and THGS/BSA with dependent variables $\dot{V}O_{2max}$, BF%, BMI, BSA, push-up, and curl-up. Based on the results of correlation analyses and checking the collinearity, the dominant factors were selected for multiple linear regression. As shown in Table 3, THGS/BMI is positively associated with $\dot{V}O_{2max}$, BSA, and push-up, and negatively associated with BF%. Additionally, THGS/BSA is positively associated with push-up and negatively associated with BF%.

Table 3- Multivariate regression analysis on the associations between measured variables and THGS/BMI and THGS/BSA

Models	THGS/BMI β (95% CI)	*p*- value	THGS/BSA β (95% CI)	*p*-value
VO_{2max} (ml.kg/min)	0.332 (0.029- 0.050)	0.001	0.048 (-0.084-0.199)	0.425
BF%	-0.401 (-0.055 - 0.039)	0.001	-0.201 (-0.0332, - 0.134)	0.001
BMI (kg/m^2)	–	–	0.082 (-0.064 - 0.340)	0.181

Table 3- Multivariate regression analysis on the associations between measured variables and THGS/BMI and THGS/BSA

Models	THGS/BMI β (95% CI)	*p*- value	THGS/BSA β (95% CI)	*p*-value
BSA(m^2)	0.216 (0.518 -1.059)	0.001	–	–
Push up (n)	0.139 (-0.005- 0.013)	0.001	0.291 (0.140-0.227)	0.001
Curl up (n)	-0.052 (-0.002-0.001)	0.074	-0.036 (-0.080- 0.023)	0.274

Note: VO_{2max} (Maximum oxygen uptake); BMI: body mass index; BSA: body surface area; BF%: body fat percentage.

The results of the linear regression analyses (Figure 1) showed that THGS/BMI ratio represented 23.3% of the variance of $\dot{V}O_{2max}$ (r^2=0.233, p<0.001), THGS/BSA ratio represented 4.3% of the variance of $\dot{V}O_{2max}$ (r^2=0.042, p<0.001).

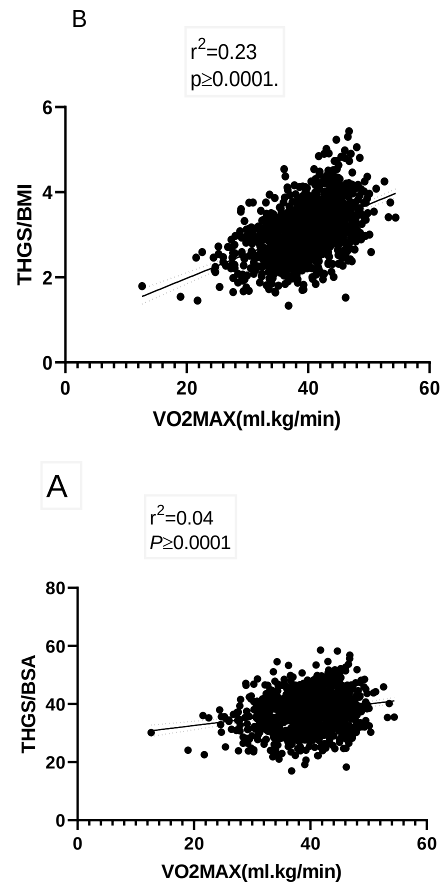

Figure 1- Correlation between THGS/BSA and Vo2max (A) and THGS/BMI and Vo2max (B)

Note: Vo2max positively correlated with THGS/BSA (A) and THGS/BMI (B). THGS: Total Hand Grip Strength; BSA: Body Surface Area; BMI Body Mass Index; Vo2max; maximal O2 consumption.

Discussion

This study aimed to explore the relationship between hand grip strength (HGS) and various health-related factors, particularly $\dot{V}O_{2max}$, among individuals volunteering for employment in the Steel Company. It should be noted that the peak range of hand grip strength was typically observed between the ages of 24 and 39, with a subsequent decline by ages (Kallman et al., 1990). To mitigate age-related effects on HGS, our study focused on a narrow age range

(24.22±2.34). Additionally, recognizing that BMI and body size have been reported to positively correlate with HGS (Alahmari et al., 2017; Dag et al, 2021)), researcher adjusted hand grip measurements for BMI and body surface area (BSA) to ensure statistical comparability across different body weights and sizes.
The findings of this study indicate that health-related factors such as weight and body fat percentage (BF %) are negatively associated with HGS/BMI ratio, while height, $\dot{V}O_{2max}$, THGS/BSA, TS/BMI, TS/BSA ratios, push-ups, and curl-ups show a positive correlation with HGS/BMI ratio. Given that high BF% is linked to atherosclerosis and cardiovascular disease (Pettersson-Pablo et al., 2019), the negative association between BF% and HGS/BMI and THGS/BSA ratio in this study suggests a potential link between low HGS and cardiovascular diseases (Shah et al., 2016).
The present study reveals that THGS/BMI ratio correlates with TS/BMI, push-ups, and curl-ups, reflecting shoulder, chest, and abdominal strength and endurance, respectively. Trunk strength, adjusted for BMI, emerges as a statistically comparable marker across different body weights and sizes. These findings align with previous studies, indicating that hand grip strength is influenced by upper body strength (Ruprai et al., 2016). Moreover, earlier research has indicated a correlation between handgrip strength (HGS), curl-ups, and push-ups, suggesting its potential as a predictive test for muscular strength and endurance (Trosclair et al., 2011). In contrast to the study's findings, it has been proposed that there is no correlation between HGS and the strength and endurance of upper body muscles in young, healthy men (Thomas et al., 2021). These disparities in statistical outcomes may be attributed to variations in the number of participants among these studies.
In this study, THGS/BMI correlates with $\dot{V}O_{2max}$ in young men, with multivariate regression analysis establishing the independent relationship between $\dot{V}O_{2max}$ and THGS/BMI ($r=0.48$, $p\leq0.001$) and THGS/BSA ($r=0.20$, $p\leq0.001$). These results support the notion that HGS can serve as an indicator of physical health in healthy young men. The similar findings have been reported in studies involving diabetic patients (Wallymahmed et al., 2007). Additionally, prior research has demonstrated a connection between handgrip strength (HGS) and $\dot{V}O_{2max}$ in patients with coronary artery disease (CAD) (Thomaes et al., 2012). There is also evidence suggesting a strong association between HGS and heart structure and function (Artero et al., 2011; Ramírez-Vélez et al., 2016). Moreover, it is reported that a significant relationship exists between HGS and the 6-minute walk test in elderly participants (Zhang et al., 2017). These associations contribute to establishing a robust foundation for understanding the link between HGS and $\dot{V}O_{2max}$ as an indicator of cardiorespiratory fitness.

The exact mechanism underlying the association between HGS and $\dot{V}O_{2max}$ remains unclear. One plausible scenario is related to pyruvate dehydrogenase, where pyruvate dehydrogenase activity is linked to muscle aerobic capacity (Wong et al., 2008). Studies have revealed that individuals with low HGS exhibit reduced muscular pyruvate dehydrogenase activity (Xu et al., 2020), and aerobic training can enhance this activity, improving the muscles' maximal capacity to use carbohydrates (LeBlanc et al., 2004).

The clinical significance of our research lies in the relatively strong relationship between THGS/BMI and $\dot{V}O_{2max}$, suggesting HGS as a predictor for cardiovascular disease risk. Furthermore, it supports the idea that strength training can enhance cardiorespiratory fitness. HGS, as a simple indicator, can reflect cardiorespiratory fitness levels in communities where direct measurement of $\dot{V}O_{2max}$ is challenging. Occupational health is defined as the development and maintenance of the highest levels of physical and social health of employees in all occupations. In fact, this is very necessary to prevent the reduction of health resulting from different working conditions and to protect employees in their specific jobs and against the risks caused by threatening factors in the workplace (Serra et al., 2007). Further, to select employees for various jobs, it is very important to pay serious attention to the physiological and psychological needs of people, and in general, a person's job should be proportional to his physical and psychological characteristics. In different countries of the world, many programs and serious measures have been carried out regarding increasing the productivity levels of people in different jobs (Prince et al., 2021), while in our country, less attention has been paid to this issue. One of the duties of employees in different departments is to do administrative work in a sitting position, which requires many physical and physiological abilities (Prince et al., 2021).

However, this study has limitations. It focused solely on young male adults within a narrow age range, limiting generalizability to other age groups or female populations. Future studies should consider a broader age range and include both genders. Additionally, variations in participants' daily physical activity levels and the exclusion of unhealthy individuals from the study population may affect the generalizability of the findings. In conclusion, our study suggests THGS/BMI and THGS/BSA ratios as potential indicators of physical health and recommends further research to strengthen these findings.

Conflict of Interest

The authors have no conflicts of interest associated with the materials presented in this study.

Funding

There were no sources of funding for this research.

Author contribution

Conceptualization, Vazgen Minasian & Volga Hovsepian.; Methodology, Vazgen Minasian & Volga Hovsepian; Formal data analysis Vazgen Minasian.; Writing (original draft), Volga Hovsepian & Writing (review and edit) Vazgen Minasian. All authors have read and confirmed the published version of the manuscript.

References

1. Alahmari, K. A., Silvian, S. P., Reddy, R. S., Kakaraparthi, V. N., Ahmad, I., & Alam, M. M. (2017). Hand grip strength determination for healthy males in Saudi Arabia: A study of the relationship with age, body mass index, hand length and forearm circumference using a hand-held dynamometer. *Journal of International Medical Research, 45*(2), 540-548.
2. Artero, E. G., Ruiz, J. R., Ortega, F. B., España‐ Romero, V., Vicente‐ Rodríguez, G., Molnar, D., Moreno, L. A. (2011). Muscular and cardiorespiratory fitness are independently associated with metabolic risk in adolescents: the HELENA study. *Pediatric diabetes, 12*(8), 704-712.
3. Bohannon, R. W. (2008). Hand-grip dynamometry predicts future outcomes in aging adults. *Journal of geriatric physical therapy, 31*(1), 3-10.
4. Calderwood, C., ten Brummelhuis, L. L., Patel, A. S., Watkins, T., Gabriel, A. S., & Rosen, C. C. (2020). Employee Physical Activity: A Multidisciplinary Integrative Review. *Journal of Management, 47*(1), 144-170. doi:10.1177/0149206320940413
5. Celis-Morales, C. A., Lyall, D. M., Anderson, J., Iliodromiti, S., Fan, Y., Ntuk, U. E., Gill, J. M. (2017). The association between physical activity and risk of mortality is modulated by grip strength and cardiorespiratory fitness: evidence from 498 135 UK-Biobank participants. *European heart journal, 38*(2), 116-122.
6. Cooper, A., Lamb, M., Sharp, S., Simmons, R., & Griffin, S. (2017). Bidirectional association between physical activity and muscular strength in older adults: Results from the UK Biobank study. *International journal of epidemiology, 46*(1), 141-148.
7. Crump, C., Sundquist, J., Winkleby, M. A., & Sundquist, K. (2017). Interactive effects of aerobic fitness, strength, and obesity on mortality in men. *American journal of preventive medicine, 52*(3), 353-361.
8. Dag, F., Tas, S., & Cimen, O. B. (2021). Hand-grip Strength is Correlated with Aerobic Capacity in Healthy Sedentary Young Females. *Montenegrin Journal of Sports Science and Medicine, 10*(1), 55-60.

9. Eston, R. G., & Parfitt, G. (2018). Perceived Exertion, Heart Rate, and other Non-Invasive Methods for Exercise Testing and Intensity Control. *Kinanthropometry and Exercise Physiology*, 464-499.
10. Gibson, A. L., Wagner, D., & Heyward, V. (2019). *Advanced fitness assessment and exercise prescription, 8E*: Human kinetics.
11. Grant, J. A., Josepeh, A., & Campagna, P. D. (1999). The prediction of VO_2max: a comparison of 7 indirect tests of aerobic power. *The Journal of Strength & Conditioning Research*, *13*(4), 346-352.
12. Ingrová, P., Králík, M., & Bártová, V. (2017). Relationships between the hand grip strength and body composition in Czech and Slovak students. *Slovenská antropológia*, *20*(1), 30-43.
13. Kallman, D. A., Plato, C. C., & Tobin, J. D. (1990). The role of muscle loss in the age-related decline of grip strength: cross-sectional and longitudinal perspectives. *Journal of gerontology, 45*(3), M82-M88.
14. Kilding, A. E., Aziz, A. R., & Teh, K. (2006). Measuring and predicting maximal aerobic power in international-level intermittent sport athletes. *Journal of sports medicine and physical fitness, 46*(3), 366.
15. Kodama, S., Saito, K., & Tanaka, S. (2009). Healthy Men and Women: A Metaanalysis All-Cause Mortality and Cardiovascular Events in Healthy Men and Women: A Meta-analysis. *JAMA*, *301*(19), 2024-2035.
16. LeBlanc, P. J., Peters, S. J., Tunstall, R. J., Cameron‐ Smith, D., & Heigenhauser, G. J. (2004). Effects of aerobic training on pyruvate dehydrogenase and pyruvate dehydrogenase kinase in human skeletal muscle. *The Journal of Physiology, 557*(2), 559-570.
17. Nevill, A. M., & Holder, R. L. (2003). Modelling handgrip strength in the presence of confounding variables: results from the Allied Dunbar National Fitness Survey. In *Advances in Sport, Leisure and Ergonomics* (pp. 291-302): Routledge.
18. Ortega, F. B., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2012). Muscular strength in male adolescents and premature death: cohort study of one million participants. *Bmj, 345*, e7279.
19. Pettersson-Pablo, P., Nilsson, T. K., Breimer, L. H., & Hurtig-Wennlöf, A. (2019). Body fat percentage is more strongly associated with biomarkers of low-grade inflammation than traditional cardiometabolic risk factors in healthy young adults–the Lifestyle, Biomarkers, and Atherosclerosis study. *Scandinavian Journal of Clinical and Laboratory Investigation, 79*(3), 182-187.
20. Prince, S. A., Rasmussen, C. L., Biswas, A., Holtermann, A., Aulakh, T., Merucci, K., & Coenen, P. (2021). The effect of leisure time physical activity and sedentary behaviour on the health of workers with different occupational physical activity demands: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *18*, 1-17.
21. Ramírez-Vélez, R., Tordecilla-Sanders, A., Correa-Bautista, J. E., Peterson, M. D., & Garcia-Hermoso, A. (2016). Handgrip strength and ideal cardiovascular health among Colombian children and adolescents. *The Journal of pediatrics, 179*, 82-89. e81.

22. Rantanen, T., Harris, T., Leveille, S. G., Visser, M., Foley, D., Masaki, K., & Guralnik, J. M. (2000). Muscle strength and body mass index as long-term predictors of mortality in initially healthy men. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55*(3), M168-M173.
23. Roberts, H. C., Denison, H. J., Martin, H. J., Patel, H. P., Syddall, H., Cooper, C., & Sayer, A. (2011). A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age and ageing, 40*(4), 423-429.
24. Ruiz, J. R., Sui, X., Lobelo, F., Morrow, J. R., Jackson, A. W., Sjöström, M., & Blair, S. N. (2008). Association between muscular strength and mortality in men: prospective cohort study. *Bmj, 337*.
25. Ruprai, R. K., Tajpuriya, S. V., & Mishra, N. (2016). Handgrip strength as determinant of upper body strength/physical fitness: a comparative study among individuals performing gymnastics (ring athletes) and gymnasium (powerlifters). *Int. J. Med. Sci. Public Health, 5*, 1167-1172.
26. Serra, C., Rodriguez, M. C., Delclos, G. L., Plana, M., López, L. I. G., & Benavides, F. G. (2007). Criteria and methods used for the assessment of fitness for work: a systematic review. *Occupational and environmental medicine, 64*(5), 304.
27. Shah, R. V., Murthy, V. L., Colangelo, L. A., Reis, J., Venkatesh, B. A., Sharma, R., . . . Rana, J. S. (2016). Association of fitness in young adulthood with survival and cardiovascular risk: the Coronary Artery Risk Development in Young Adults (CARDIA) study. *JAMA internal medicine, 176*(1), 87-95.
28. Shephard, R. J., Allen, C., Benade, A., Davies, C., Di Prampero, P., Hedman, R., Simmons, R. (1968). The maximum oxygen intake: An international reference standard of cardio-respiratory fitness. *Bulletin of the World Health Organization, 38*(5), 757.
29. Sui, X., Lee, D.-c., Matthews, C. E., Adams, S. A., Hébert, J. R., Church, T. S., . . . Blair, S. N. (2010). The influence of cardiorespiratory fitness on lung cancer mortality. *Medicine and science in sports and exercise, 42*(5), 872.
30. Thomaes, T., Thomis, M., Onkelinx, S., Goetschalckx, K., Fagard, R., Cornelissen, V., & Vanhees, L. (2012). Muscular strength and diameter as determinants of aerobic power and aerobic power response to exercise training in CAD patients. *Acta cardiologica, 67*(4), 399-406.
31. Thomas, E., Gennaro, V., Battaglia, G., Bellafiore, M., Iovane, A., Palma, A., & Bianco, A. (2021). Upper body strength endurance evaluation: A comparison between the handgrip strength and three body weight tests. *Isokinetics and Exercise Science, 29*(2), 185-191.
32. Trosclair, D., Bellar, D., Judge, L., Smith, J., Mazerat, N., & Brignac, A. (2011). Hand-grip strength as a predictor of muscular strength and endurance. *The Journal of Strength & Conditioning Research, 25*, S99.
33. Wallymahmed, M., Morgan, C., Gill, G., & MacFarlane, I. (2007). Aerobic fitness and hand grip strength in Type 1 diabetes: relationship to glycaemic control and body composition. *Diabetic Medicine, 24*(11), 1296-1299.

34. Wong, S. Y. S., Chan, F. W. K., Lee, C. K., Li, M., Yeung, F., Lum, C. C. M., Choy, D. T. (2008). Maximum oxygen uptake and body composition of healthy Hong Kong Chinese adult men and women aged 20–64 years. *Journal of sports sciences*, *26*(3), 295-302.
35. Xu, C., Kasimumali, A., Guo, X., Lu, R., Xie, K., Zhu, M., Wang, Q. (2020). Reduction of mitochondria and up regulation of pyruvate dehydrogenase kinase 4 of skeletal muscle in patients with chronic kidney disease. *Nephrology*, *25*(3), 230-238.
36. Zhang, Q., Lu, H., Pan, S., Lin, Y., Zhou, K., & Wang, L. (2017). 6MWT performance and its correlations with VO2 and handgrip strength in home-dwelling mid-aged and older Chinese. *International journal of environmental research and public health, 14*(5), 473.
37. Zhou, M., Zha, F., Chen, Y., Liu, F., Zhou, J., Long, J., Luo, D. (2021). Handgrip strength-related factors affecting health outcomes in young adults: association with cardiorespiratory fitness. *BioMed research international, 2021*.