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Relationship Between Estimated VO₂max and Handgrip Strength in Healthy Young Nigerian Adults

Abstract

Purpose: This study investigated the relationship between estimated oxygen consumption (VO₂max) and handgrip strength (HGS) among healthy young Nigerian adults. **Methods:** This was a cross sectional study, which involved 400 volunteers (171 males; 229 females) aged between 18–40years. Participants' HGS was assessed using a CAMRY EH-101 hand dynamometer while VO₂max was estimated using a standard formula that includes measurement of resting heart rate. Demographic data was summarized using percentages, mean and standard deviation. Physical activity level of the participants was assessed using long form of the International Physical Activity Questionnaire. Independent t-test was used to compare the mean values of the variables between male and female participants. Pearson's correlation was used to determine the strength of relationship between estimated VO₂max and HGS, while multiple regression analysis was conducted to determine the predictors of estimated VO₂max using HGS as well as body mass index (BMI), physical activity (PA) level, age and sex as co-variates. Level of significance was set at $p < 0.05$. **Results:** HGS, VO₂max and PA level were significantly ($p = 0.001$) different between male and female participants. There was a significant moderate correlation between HGS and VO₂max ($r = 0.40$, $p = 0.001$). The results of the regression analysis showed that HGS is not significant predictor of estimated VO₂max; whereas, sex, BMI and PA level were significant predictors of estimated VO₂max. **Conclusion:** Although HGS is moderately correlated with estimated VO₂max, HGS may not be a relevant tool for predicting estimated VO₂max in healthy young adults.

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ABSTRACT

Purpose: This study investigated the relationship between estimated oxygen consumption (VO₂max) and handgrip strength (HGS) among healthy young Nigerian adults. **Methods:** This was a cross sectional study, which involved 400 volunteers (171 males; 229 females) aged between 18–40years. Participants' HGS was assessed using a CAMRY EH-101 hand dynamometer while VO₂max was estimated using a standard formula that includes measurement of resting heart rate. Demographic data was summarized using percentages, mean and standard deviation. Physical activity level of the participants was assessed using long form of the International Physical Activity Questionnaire. Independent t-test was used to compare the mean values of the variables between male and female participants. Pearson's correlation was used to determine the strength of relationship between estimated VO₂max and HGS, while multiple regression analysis was conducted to determine the predictors of estimated VO₂max using HGS as well as body mass index (BMI), physical activity (PA) level, age and sex as co-variates. Level of significance was set at p<0.05. **Results:** HGS, VO₂max and PA level were significantly (p= 0.001) different between male and female participants. There was a significant moderate correlation between HGS and VO₂max (r= 0.40, p= 0.001). The results of the regression analysis showed that HGS is not significant predictor of estimated VO₂max; whereas, sex, BMI and PA level were significant predictors of estimated VO₂max. **Conclusion:** Although HGS is moderately correlated with estimated VO₂max, HGS may not be a relevant tool for predicting estimated VO₂max in healthy young adults.

Key words: handgrip strength, cardio-respiratory capacity, VO₂max, healthy adults

INTRODUCTION

Physical fitness is considered as an integrated measure of all body functions and structures during physical activity (PA) and/or exercise.¹ This measure, which is partly determined by genetic or environmental factors, could be classified as skill- or health-related, with the latter primarily related to functional health and disease prevention.² Among the five health-related fitness components, cardiorespiratory fitness (CRF) and muscular fitness are most widely studied due to their strong relationships with healthy outcomes.³ Cardiorespiratory fitness is the ability of the respiratory and cardiovascular systems of the body to carry out prolonged moderate to vigorous exercises, with factors such as, age, male sex, body mass index (BMI) and PA reported to influence CRF.^{2,4}

According to World Health Organisation (WHO), maximal oxygen consumption (VO₂max) is reported as the standard indicator for assessing CRF. During maximal or submaximal exercise, some direct methods have been identified for determining VO₂max, while several indirect methods have also been reported for estimating VO₂max.^{5,6} Following this, a plethora of studies have reported the relevance of higher CRF in improving health outcomes. For instance, increased CRF has been associated with decreased cardiovascular events and cancer, with muscular fitness adding to the protective outcomes of CRF against cancer deaths.⁷⁻⁹

Muscular fitness is a combined function of muscle strength, muscle endurance and muscle power.¹⁰ Assessment of isometric muscle strength using handgrip strength (HGS) is one of the most cited test batteries for assessing muscular fitness, and this could be due to its easy-to-use nature, high reliability and validity in healthy and unhealthy populations.^{3,11} Similarly, several studies have reported an association between stronger HGS and some health outcomes such as better health-related quality of life, increased lung function and decreased mortality from cardiovascular and respiratory diseases across different age groups.¹²⁻¹⁴

Previously, Sugie et al reported a moderate association between HGS and VO₂max in unhealthy older adults.¹⁵ Confirmation of this association in healthy and younger population may inform the predictive ability of HGS for VO₂max by allied health professionals and physical educators. However, in low to middle income countries (LMICs), direct assessment of VO₂max using expensive laboratory equipment and trained professionals may not be practicable due to financial constraints. This shortfall calls for consideration of alternative methods for estimating VO₂max in such countries. Therefore, the aim of this study was to investigate the relationship between HGS and estimated VO₂max in healthy young Nigerian adults. We also determined if HGS is a significant predictor of estimated VO₂max in these adults.

MATERIALS AND METHODS

This study was approved by the Health Research and Ethics Committee of the College of Medicine, University of Lagos. Written informed consent was obtained from each participant prior to participating in the study.

Participants

Participants were healthy young adults aged between 18 and 40 years, who were students at the University of Lagos (both Akoka and Idi-Araba campuses), Lagos State, Nigeria. Prior to data collection, students filled-out a short form to screen for their eligibility. Participants were considered "healthy" if they reported not having any chronic disease condition such as diabetes, hypertension etc. Also, students who had known respiratory disorders, upper limb deformity/injury, previous surgery in the hand or forearm in the last three months and neurological disorders of the upper limbs were excluded from the study.

Protocol

A cross-sectional design was adopted in this study. Random sampling technique using the Fish Bowl method was used to recruit the participants. From the list of all faculties in the University, two faculties were selected. From these two faculties, two departments each (four departments in total) were picked. Two levels of study were selected from each department (eight levels in total). Finally, 50 students were randomly selected (using computer generated numbers) from each level, which yielded a total of four hundred (400) students. Information on participants' demographics was obtained using a short form and variables such as weight, height and body mass index (BMI) were assessed. BMI was categorized as underweight (<18.5kg/m²), normal (18.5 – 24.9kg/m²), overweight (25 – 29.9kg/m²) and obese (≥30kg/m²).¹⁶

Assessment of Handgrip Strength

A digital hand dynamometer (CAMRY EH-101, USA) was used to assess the HGS (in kilograms). Previously, excellent test-retest reliability (0.91 – 0.98) has been reported for this device.¹⁷ Using the guidelines by the American Society of Hand Therapists, participants sat comfortably on a chair without an arm rest and those who wore wrist watches were advised to remove them before the test. While seated, the participants adducted their shoulders to the side, elbows flexed to 90°, forearms and wrists placed in neutral position, while their feet were placed flat on the ground.¹⁸ The researcher demonstrated the testing procedures to the participants. The participants were instructed to squeeze the dynamometer maximally up to six seconds. Three trials of HGS testing were conducted for only the dominant hand, with a 15-second rest period between trials. The

dominant hand was determined by asking the participants which hand they use more frequently in carrying-out their activities of daily living.

Estimation of VO₂max

Estimates of participant's VO₂max was determined using the Heart Rate Ratio method (HRR-method).¹⁹ After HGS assessment, participants remained seated for five minutes to allow their heart rates return to resting levels. Resting heart rate (HR_{rest}) was calculated by palpating for the radial pulse for 30 seconds, then multiplying the value by 2. However, a minimal error of 1.10 has been previously identified for determining HR_{rest} using this method.²⁰ The maximal heart rate (HR_{max}) was predicted using the participant's age (years) in the formula, $HR_{max} = 208 - (0.7 \times \text{Age})$ (years).²¹ A final computation for VO₂max in millilitre per kilogram per minute (mL/kg/min) was performed using the formula, $VO_{2max} \text{ (mL/kg/min)} = 15.3 \times (HR_{max}/HR_{rest})$.¹⁹ Previously, a study reported a good agreement (ranging up to 3.14 mL/kg/min) between the HRR-method and direct measurement of VO₂max in Indian university students.²² However, reliability reports using the HRR-method in Nigerian population is lacking.

Determination of Physical Activity Levels

The long form of the International Physical Activity Questionnaire (IPAQ-LF) was used to assess the PA levels of the participants. This IPAQ-LF consists of 27 questions, which could be interviewed through telephone, interviewed in person or self-administered to adults (aged 15 – 69 years) across different socio-economic groups.²³ This questionnaire provided information on activities conducted in the last seven days within four domains that may be related to physical activity.²³ Previously, a language-modified version of the IPAQ-LF has been reported to show a good reliability and moderate construct validity in assessing PA in Nigerian adults.²⁴ All IPAQ raw data (expressed in MET/minutes/week) of the participants was categorized into sedentary, moderate or high PA level using the cut-off points from the IPAQ scoring protocol.²⁵

Data Analysis

Demographic data were summarized using mean and standard deviations. Independent t-test was used to compare the mean values of the variables between male and female participants. Pearson's correlation coefficient was used to determine the strength of relationship between VO₂max and HGS. Pearson correlation coefficient (r) values of <0.3, 0.3-0.7 and >0.7 were interpreted as weak, moderate and strong relationships, respectively.²⁶ Multiple regression analysis was conducted to determine the prediction of VO₂max (dependent variable) using HGS with age, sex, BMI and PA level (independent variables) as co-variables. These co-variables were considered since prior studies have reported significant association with VO₂max.²⁶ Physical activity levels were initially coded as 1= high (active); 2=moderate (moderate) and 3=low (sedentary), however, dummy variables (PA_{high} and PA_{moderate}) were created for PA levels to fit into multiple regression analysis using PA_{low} as the reference variable. All assumptions of multiple regression analysis were met. All statistical tests were performed using SPSS version 22 (IBM, Chicago, USA) with the level of significance set at <0.05.

RESULTS

Demographic Data of the Participants

Four hundred (57% females) healthy adults aged 18-40 years, participated in the study. The mean age, height, weight, BMI, VO₂max and HGS of all participants are as shown on Table 1. Results of the BMI classification described 55 (14%) participants as underweight, 279 (70%) as normal and 66 (16%) as overweight. Further, independent t-test showed significant (p<0.05) differences in height, weight, VO₂max and HGS between males and females (Table 1).

Table 1. Demographic Characteristics, HGS, and Estimated VO₂max of the Participants

Variables	Total (n=400) Mean (SD)	Males (n=171) Mean (SD)	Females (n=229) Mean (SD)	t-value	p-value
Age (years)	22.95 (4.66)	23.44 (4.43)	22.58 (4.80)	1.849	0.065
Height (m)	1.70 (0.11)	1.76 (0.11)	1.66 (0.09)	9.229	0.001
Weight (kg)	63.05 (11.23)	67.13 (10.2)	60.00 (11.07)	6.609	0.001
BMI (kg/m ²)	21.73 (3.60)	21.82 (3.25)	21.6 (3.86)	0.414	0.679
PA low (n)	55	17	38		
PA Moderate (n)	279	132	147		
PA high (n)	66	22	44		
VO ₂ max (ml/kg/min)	38.35 (5.44)	40.97 (5.73)	36.38 (4.28)	8.690	0.001
HGS (kg)	31.78 (10.03)	38.84 (10.50)	26.50 (5.34)	15.210	0.001

Key: BMI - body mass index; HGS - handgrip strength; m – meters; kg - kilogram; VO₂max – estimated maximum oxygen consumption; SD - standard deviation; n - frequency; PA – physical activity; t-value - independent t-test values; ml/kg/min - millilitres per kilogram per minute; p – significance level at <0.05.

Prediction of VO₂max of the Participants using HGS Measurement:

Pearson correlation analysis showed that there was a moderate significant positive correlation between VO₂max and HGS ($r = 0.40$; $p = 0.001$; 95%CI: 0.28 - 0.52) for all the participants. Multiple regression analysis to predict VO₂max showed that HGS and age were not significant predictors, while sex, BMI and PA levels of the participants were shown to be significant predictors (Table 2). Coefficient of determination (R^2) involving sex, BMI and PA levels as predictors for VO₂max was 0.634, which indicated that about 63.4% of the variability in VO₂max can be explained by sex, BMI and PA levels of the participants. We generated the regression equation for predicting estimated VO₂max: $VO_{2max} = 34.769 + 1.786(\text{Sex}) - 0.113(\text{BMI}) + 12.651(\text{PA}_{high}) + 5.763(\text{PA}_{moderate})$ Note that the reference group for sex is females and for physical activity level is PA_{low}.

Table 2. Regression Variables for Predicting Estimated VO₂max using HGS and Other Covariates.

Variables	β	Std Error	B	p
Intercept	34.769	1.413		0.001
HGS	0.019	0.022	0.034	0.401
Age	-0.046	0.039	-0.038	0.243
Sex	1.786	0.444	0.159	0.001
BMI	-0.113	0.049	-0.073	0.022
PA _{high}	12.651	0.628	0.885	0.001
PA _{moderate}	5.763	0.471	0.502	0.001

Key: HGS - handgrip strength; BMI - body mass index; PA level physical activity level; β - unstandardized coefficient; Std Error - standard error of the coefficient; B - standardized coefficient; p - significance level at <0.05 .

DISCUSSION

This study was conducted to investigate the relationship between estimated VO₂max and HGS in healthy young adults. The findings of this study showed that HGS had a moderate correlation with estimated VO₂max. Despite the relationship between HGS and estimated VO₂max, HGS was not a significant predictor for estimated VO₂max. However, sex, BMI and PA levels were identified as significant predictors for estimated VO₂max. From our robust search of literature, no study has reported on the relationship between VO₂max and HGS in healthy young adults LMICs. The findings of this study showed that in healthy young adults living in a LMICs such as Nigeria, where indirect estimation of VO₂max is preferably conducted due to financial constraints, a cheaper and easy-to-use tool such as HGS may not be a suitable and quick indicator of estimated VO₂max.

Evaluation of HGS of the participants showed that males had significantly stronger HGS compared to the females. This finding was in accordance with results of previous studies (locally and internationally), which suggest that increased grip strength in males could be explained by a combined effect of genetic and environmental factors.^{27,28} Male sex hormones such as testosterone has been associated with increased satellite cells (precursors of skeletal muscle cells) and overgrowth of Type 1 and 2 muscles fibers, thereby yielding stronger muscle contraction during gripping.^{29,30} Lifestyle factors such as smoking, alcohol consumption, nutritional status and PA, where males are reported to be more likely involved in PA than females, have all been associated with HGS.^{31,32} Similarly, estimated VO₂max mean values were shown to be significantly higher in males than in females, which confirms the results of previous studies.³³⁻³⁵ This difference in estimated VO₂max could be explained by physiological and behavioural factors such as men having higher haemoglobin (Hb) levels, lower percentage body fat (%BF), higher lean body mass, larger size of heart and increased involvement in habitual PA than their female counterparts.³⁰

Evaluation of the relationship between HGS and estimated VO₂max showed a moderate association, and this agrees with previous finding in elderly community-dwellers.¹⁵ The reported associations in this study could be attributed to the PA levels of the students with a majority of the students engaged in low to moderate physical activities (81.5%). Reduced involvement in PA have been related to increased adiposity and increased systemic inflammatory biomarkers, such as interleukin-6 (IL-6) and creatinine reactive protein (CRP).³⁶ These biomarkers are inversely proportional to insulin-like growth factor-1, which causes reduced muscle mass and subsequently, weaker skeletal muscle strength.³⁷ Similarly, circulating levels of IL-6 and CRP have been linked with reduced VO₂max in adults, with engagement in PA reported to reverse the level of inflammatory markers.^{38,39}

Typically, direct assessment of VO₂max is conducted in exercise laboratories using standardized protocols with expensive equipment such treadmills and cycle ergometers. However, in LMICs, these direct tests are not usually practical, which warrant the use of other methods for estimating VO₂max in these countries. The current study showed that a simple test such as HGS is not a relevant tool in predicting estimated VO₂max in healthy young adults. This finding may be attributed to HGS being a more isolated (upper limb) strength test while estimated VO₂max is more holistic, which estimates the maximal oxygen uptake by the entire body during exercise. Further, identification of sex, BMI and PA levels as significant factors explaining 63.4% variability in VO₂max suggests that there are other factors such as ethnicity that could be contributing to this variation.⁴⁰ Therefore, a simple test like HGS may be of poor clinical relevance in predicting estimated VO₂max in healthy young adults.

Study Limitations

The cross-sectional design of this study and the involvement of students within 18 - 40 years may have limited the ability to predict estimated VO₂max and generalise our findings to other healthy adults of older ages and different ethnicities. Future research may consider conducting longitudinal studies across wider age ranges, while accounting for other covariates of VO₂max such as; Hb levels, %BF, lean body mass and ethnicity, in order to further explain the association between HGS and VO₂max and its predictability.

CONCLUSION

Handgrip strength is associated with estimated VO₂max, but not a significant predictor of the latter. Use of a simple and non-invasive tool such as HGS may not be suitable indicator of CRF in healthy young adults living in a low resource country.

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