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Original Article

Grip strength performance as a determinant of body composition, muscular strength and cardiovascular endurance

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Abstract
Problem statement: Numerous fitness tests are usually administered to determine either muscular strength or cardiovascular endurance. Even though an ample number of tests exist to measure upper body muscular endurance and lower body maximal muscular strength, a single test that assesses both could be beneficial in some circumstances. **Purpose:** The purpose of this study was to determine if a hand-grip strength test is a valid predictor of both muscular strength and cardiovascular endurance. **Methods:** Participants included 180 college students including both gender (male = 90, female = 90) (male, age 20.88 ± 2.85 yrs., height 170.14 ± 5.76 cm, weight 62.86 ± 10.06 kg), (female, age 20.41 ± 2.74 yrs, height 158.52 ± 5.91 cm, weight 54.97 ± 8.24 kg). Subjects performed the following tests of muscular strength and cardiovascular endurance: basketball throw for shoulder strength (B-Th), one-minute bent knee sit-ups for abdominal strength (SU), standing broad jump for leg strength (SBJ), and 600-meter run for cardiovascular endurance assessment. Subjects performed 3 trials of the dominant hand grip strength (HGS) test, after which the maximum value was recorded. Pearson bivariate correlation analyses were used to determine relationships between measures. Simple linear regression with enter method was performed to predict variation in hand grip strength performance through body composition, muscular strength, and cardiovascular endurance parameters.**Results:** In male participants, significant correlations were found between HGS and BMI ($r = .532$, $p = .000$), HGS and B-Th ($r = .467$, $P < 0.05$), HGS and SU ($r = .505$, $P < 0.05$), HGS and SBJ ($r = .425$, $P < 0.05$). A simple linear regression was calculated to predict BMI based on HGS. The regression was found statistically significant ($R^2 = .532$, $F(1, 88) = 34.69$, $P < 0.05$). Some similar outcomes were found in female participants. Statistically significant relationship was found between HGS and BMI ($r = .559$, $P < 0.05$), HGS and B-Th ($r = .703$, $P < 0.05$), HGS and SBJ ($r = .438$, $P < 0.05$). **Conclusions:** The hand grip dynamometer test was a predictor of muscular strength. No significant relationship was found between cardiovascular endurance and HGS of both genders. The correlations calculated implicate its usefulness as a method to predict muscular strength simply.
Key Words*: -* Grip strength, muscular strength, cardiovascular endurance, reference equation.

Introduction

Hand grip strength can be quantified by measuring the amount of static force that the hand can squeeze around a dynamometer. The force has most commonly been measured in kilograms and pounds, but also in milliliters of mercury and Newtons (Massy-Westropp et al., 2011a). Published normative data for hand grip strength are available from various countries and in most cases, data are divided into age and gender sub-groups(Angst et al., 2010; Bassey & Harries, 1993; Bohannon et al., 2006a; Massy-Westropp et al., 2011a; Mathiowetz et al., 1985). Analysis of grip strength by gender shows higher grip strength by males at all ages, and analysis by age group demonstrates a peak of grip strength in the fourth decade and then a gradual decline in grip strength for both genders.

Grip strength is also a marker of recovery during rehabilitation process. Application of ice is a valid and wide applied method in rehabilitation. The duration of ice application on body surface is depend on various factors, i.e., gender, deposition of adipose tissue, body mass index and so on. Significant relationship was observed between the grip sgrength and the duration of ice application (Maghfiroh et al., 2021). In sports aren's, grip strength is used as a performance determinant. The study conducted on different playing position in Basketball reported significant relationship between grip strength and verticle jump and other anthropometric variables (Gledson et al., 2018). In basketball game the young players with strong hands, longer arms and high

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stature exhibit advantage in ball handling ability (Apostolidis & Emmanouil, 2015).The throwing velocity of Hanball player was significantly related to grip strength (Tsakalou et al., 2015).

Grip strength is related to and predictive of other health conditions (Bohannon, 2008). Such prediction is important for identifying individuals who are at risk of untoward future events and for determining appropriate targets for risk-reducing efforts. Although muscle strength is an essential component of physical examination (Nara et al., 2022). Normal hand grip strength is positively related to bone mineral density (di Monaco et al., 2000) with some researchers suggesting that grip strength be a screening tool for women at risk of osteoporosis (Karkkainen et al., 2009). Longitudinal studies suggest that poor grip strength is predictive of increased mortality from cardiovascular disease and cancer in men, even when factors of muscle mass and body mass index are adjusted for(Gale et al., 2007)

Muscle strength is an important indicator of physical health and valunerability, inversely associated with the risk of death from all causes. Recently low muscle strength has been associated with poor mental health (Marconcin et al., 2021) including increased depression sytems (Ahlqvist et al., 2019; Ashdown-Franks et al., 2019; Marques et al., 2021).

The available studies are working on hand grip strength as a tool for early detection of old-age mortality as well as to assess the psychological status of an individual. While various studies reported the usefulness of hand grip strength to identify muscle mobility in patients after surgery. Sufficient literature on the global perspective is available on reference or normative values of hand grip strength (Amaral et al., 2019; Bohannon et al., 2006b; Kim et al., 2018; Tsang, 2005).

The above cited reports provided the orview and comprehensive of the existing literature on the given topics, i.e., rehabilitation, sports performance, general health, mental health and other psychological issues, and old age moratality as well. The disparity exists in the literature over the relationship between hand grip strength and overall muscular strength in the context of the young population of both genders. *Is hand grip strength could be a sole predictor of overall muscular health*? is a gap in the literature, which need to be identified. Few studies have reported reference equations to predict body composition and muscular strength of upper and lower extremities by hand grip strength (Y.-C. Wang et al., 2018). These equations can be used in schools and colleges to predict the overall muscular strength by hand grip strength.

The present study aimed to establish the relationship between hand grip strength and overall muscular strength and cardiovascular endurance. Moreover, to develop reference equations of overall muscular strength and cardiovascular endurance by hand grip strength.

Material & methods

Study design

An observational cross-sectional study was performed from January 2022 to May 2022. The work was performed in two colleges affiliated with Chaudhary Ranbir Singh University, Jind, i.e., Govt. College Jind, Priyadarshini Indira Gandhi College, for women, (PIGC) Jind as well as the university campus were randomly selected by the researcher. Before the study commences, approval for the research was obtained from the department of physical education, Chaudhary Ranbir Singh University, Jind, Haryana, India, and informed consent was obtained from each participant.

Subjects

The study included 180 college students of both genders (Male = 90, Female = 90). The age of the subjects ranged from 18 to 25 years with mean±SD of male subjects = 20.88±2.85 years, and female subjects = 20.41±2.74 as well. Students were selected from the colleges using the following criteria: physical normal, able to perform normal activities of daily living. Students were excluded if they had undergone orthopedic or neuromuscular surgery in their upper limbs, if they had a musculoskeletal problem that affects their upper extremities, or if they had visual, auditory, or vestibular defects.

Table 1 Descriptive statistics following mean and standard deviation of the selected variables with measuring units and abbreviation used

Variables	Measuring Unit	Abbreviation	Boys (N = 90)		Girls (N = 90)	
			M	*SD*	*M*	*SD*
Age	*Years*	Age	20.88	2.85	20.41	2.74
Height	*Centimeters*	Height	170.14	5.76	158.52	5.91
Weight	*Kilograms*	Weight	62.86	10.06	54.97	8.24
Body mass index	*kg/m^2*	BMI	21.49	2.71	21.79	2.25
Basketball Throw (sitting)	*Meters*	B-Th	7.47	1.07	5.33	0.50
Sit-ups	*One minute count*	SU	27	7.14	23	5.21
Standing Broad Jump	*Meters*	SBJ	1.71	0.20	1.20	0.13
600 Meter run	*Seconds*	600 M	159.30	19.41	193.12	25.40
Grip Strength	*Kilograms*	HGS	47.40	13.71	18.76	6.61

M = Mean *SD* = Standard Deviation

Measurement of hand grip strength

Measurement of hand grip strength was measured using a Baseline Camry 200 Lbs / 90 Kgs Digital Hand Dynamometer in kilogram with participants seated, their elbow by their side and flexed to right angles, and in a neutral wrist position. the dynamometer handle position II and provision of support underneath the dynamometer. This position, followed by the calculation of the mean of three trials of grip strength for the dominant hand, has been well-documented as reliable (Shechtman & Sindhu, 2016). Five assessors were trained in the use of the dynamometer according to this protocol and practiced the testing procedure before assessments. Participant's BMI was calculated following the measurement of each participant's height and weight using the following formula:

Body mass index (BMI) = $\frac{Weight\ in\ Kg}{Height\ in\ meter^2}$

Measurement of muscular strength and cardiovascular endurance

Basketball throw for distance in sitting position was performed to measure the strength of upper extremities and measured in meters. This is a simple test of upper body strength and power (Belhaidas et al., 2022; Fernandez-Santos et al., 2016). The students are asked to throw a basketball using both hands as far as possible. By keeping the back in contact with the wall the contribution of the torso is minimized. The distance from the wall to where the ball lands are recorded. The measurement is recorded to the nearest centimeter. The best result of three throws is used. The abdominal strength was measured through a one-minute *sit-up* test. This test forms part of the US Marine Physical Fitness Test (Bartlett et al., 2015; Kaster et al., 2020). The starting position is lying on your back with your knees bent and feet flat on the floor. The arms are folded across the chest and must maintain no gap between the forearms and the chest at all times. A second person is permitted to hold the lower legs or ankles. On the command 'go,' start the crunch by raising your upper body forward until the elbows or forearms touch the thighs, and then lower the torso until the shoulder blades touch the ground. This is one complete sit-up. The maximum number of correctly performed sit-ups is recorded. The explosive leg power was assessed through a *standing broad jump (SBJ)*. The students stand behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing are used, with the swinging of the arms and bending of the knees to provide forward drive. The subject attempts to jump as far as possible, landing on both feet without falling backward. The measurement is taken from the take-off line to the nearest point of contact on the landing (back of the heels) (See table 1). Cardiovascular endurance was measured using a *600m run test.* The test was administered on a standard 400m track. The students were asked to complete the 600m course in the quickest possible time. The total time taken to run 600m run was recorded in seconds.

Statistical Analysis All statistical analyses were performed using SPSS statistics for windows version 26.0 (IMB Corporation, Armonk, NY). High-resolution graphs were reproduced using 'OriginPro 2022' (OriginLab Corporation, Northampton, Massachusetts, USA). Descriptive statistics of selected variables were tabulated for relevant strata (See table 1). Before, initiating the final analysis, the obtained data were checked for assumptions of normality. Kolmogorov-Smirnov tests of normality were performed to ensure data distribution. No significant fluctuation among data was observed. Before generating the regression equations, Pearson correlation coefficients were used to explore the relationship between grip strength as an independent variable and other dependent variables of interest, mention in table no 1 as well. Mukaka guidelines (Mukaka, 2012) was used to interpret correlation coefficients in medical research: greater than 0.9 (very high), 0.7 to 0.9 (high), 0.5 to 0.7 (moderate), 0.3 to 0.5 (low) and less than 0.3 (negligible). Simple linear regression with enter method was used to generate explanatory equations for grip strength. Model fit was inspected using the overall F test for the regression model, individual *t*-test for each regression coefficient, and adjusted R^2. Bland-Altman plots were used to identify the systematic difference between observed and predicted values of equations or possible outliers. The mean difference is the estimated bias, and the SD of the differences measures the random fluctuations around this mean. It is common to compute 95% limits of agreement for each comparison (average difference ± 1.96 standard deviations of the difference), which tells us how far apart measurements by two methods were more likely to be for most individuals. To reduce the risk of type 1 error, a significant level of $P < 0.05$ was adopted as an indicator of statistical significance.

Table 2 Correlation matrix showing the relationship between hand grip strength and selected variables of male participants

	HGS	Age	Height	Weight	BMI	B-Th	SU	SBJ	600 M
HGS	1								
Age	.660**	1							
Height	.532**	.438**	1						
Weight	.645**	.623**	.663**	1					
BMI	.532**	.550**	.282**	.902**	1				
B-Th	.467**	.169	.482**	.310**	.134	1			
SU	.505**	.281**	.156	.074	.013	.157	1		
SBJ	.425**	.151	.291**	.166	.051	.417**	.186	1	
600 M	-.129	-.198	-.049	.114	.188	-.205	-.207	. -.367**	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)

Table 3 Correlation matrix showing the relationship between hand grip strength and selected variables of female participants

Female	**HGS**	**Age**	**Height**	**Weight**	**BMI**	**B-Th**	**SU**		**600 M**
HGS	1								
Age	.151	1							
Height	.571**	.412**	1						
weight	.636**	.271**	.739**	1					
BMI	.559**	.095	.317**	.870**	1				
B-Th	.703**	.195	.557**	.482**	.262	1			
SU	.094	-.177	-.120	-.218**	-.214	.106	1		
SBJ	.438**	-.081	.474**	.443**	.276	.351**	.037	1	
600 M	-.205	-.397**	-.164	.153	.325	-.151	.055	.039	1

Correlation is significant at the 0.01 level (2-tailed), Correlation is significant at the 0.05 level (2-tailed).

Results

Table no 1 summarize the descriptive statistics in terms of mean and standard deviation followed by measuring units and abbreviation used for the selected variables. Table no 2 summarize the correlation coefficients of male participants between grip strength and other variables of interest. Among demographic variables relationship with grip strength was significant and moderate for age (*r* = .660), height, (*r* = .532), weight (*r* = .645), BMI (*r* = .532), and SU (*r* = .505) while, significant and low for B-Th (*r* = .467), and SBJ (*r* = .425).

In the context of the female participant's table, no 3 summarizes correlation coefficients between hand grip strength (HGS) and other selected variables. Significant and high degree relationship was reported for B-Th (*r* = .703), significant and moderate for height (*r* = .571), weight (*r* = .636), and BMI (*r* = .559) significant and low degree for SBJ (.438), while negligible for age (*r* = .151) was reported. No significant relationship was observed between hand grip strength (HGS) and SU ((*r* = .001). In the case of both genders, 600m has a negative and not significant relationship with hand grip strength (HGS) [male, r = -.129, female, r = -.205] was reported.

Figure 1 and figure 2 are illustrating a scatter plot of male and female participants including regression equations and a summary of modal fit. Figure 3 shows percentile score of observed HGS score including the reference line of average HGS values as per global standards (Lee & Hwang, 2019; Massy-Westropp et al., 2011b) for both genders. Figure 4 Bland-Altman plot showing mean difference and 95% confidence interval of selected variables in the observed and predicted values calculated by reference equations.

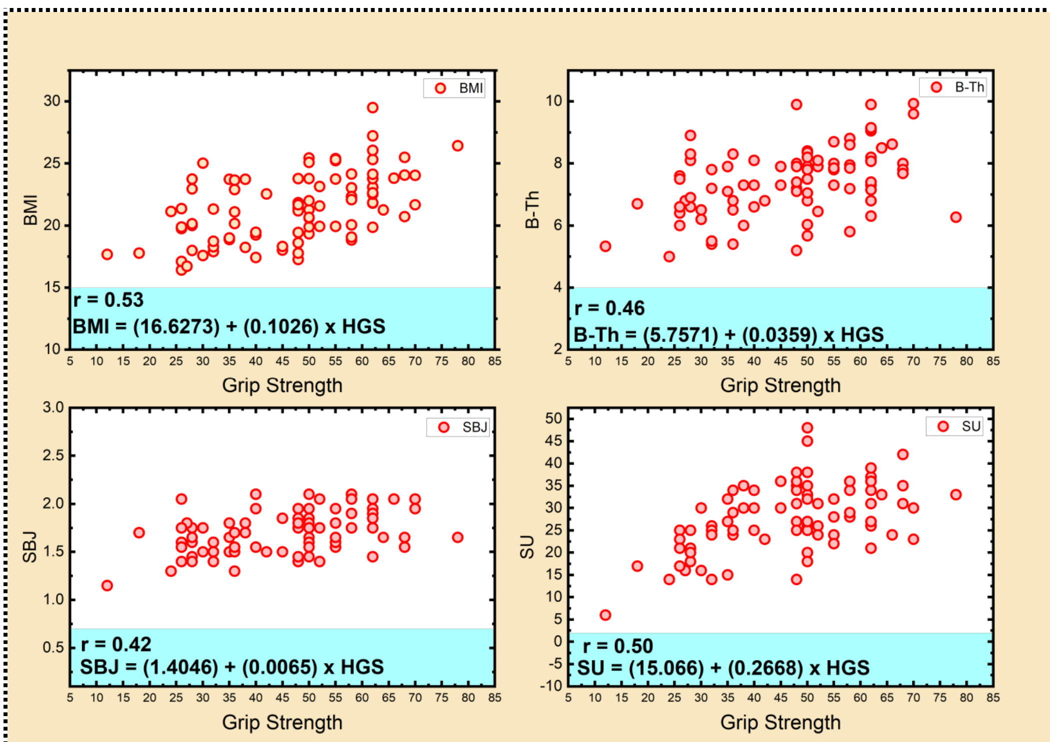

Figure 1: scatter plot illustrating the relationship between HGS with body composition and muscular strength variables with reference equations of prediction for dependent variables of male participants

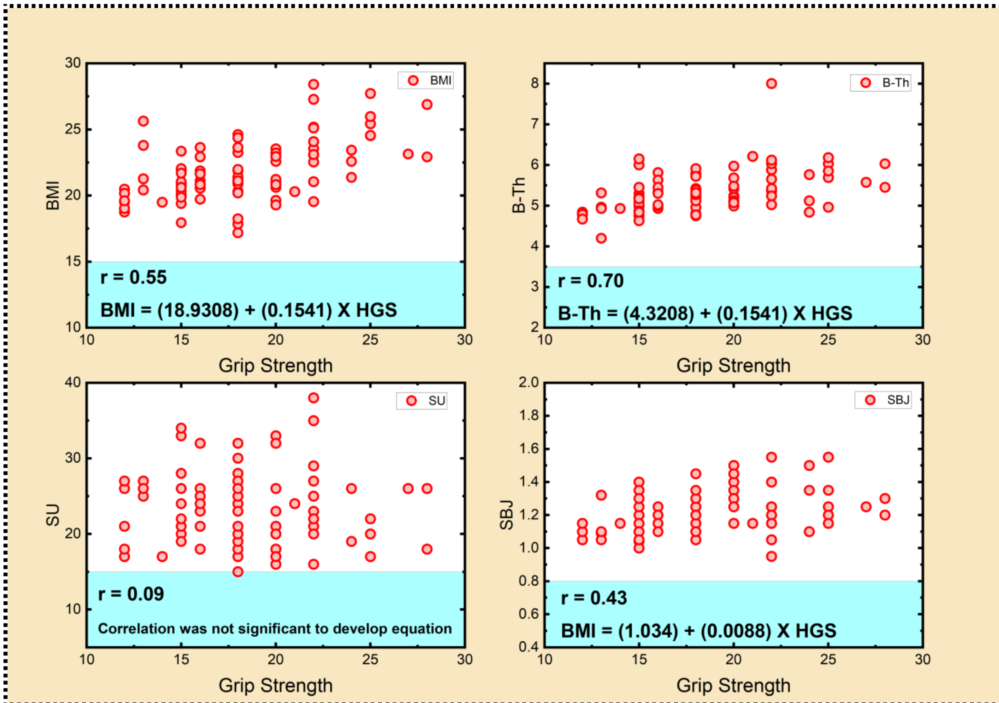

Figure 2: scatter plot illustrating the relationship between HGS with body composition and muscular strength variables with reference equations of prediction for dependent variables of female participants

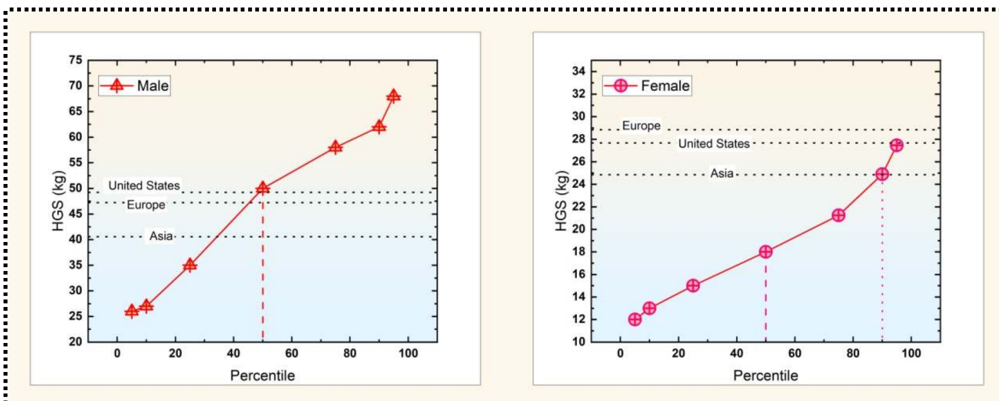

Figure 3 Line graph with reference line (dotted) showing mean score of observed HGS values in comparison of international reference values of HGS of both genders [Reference values retrieved from (Lee & Hwang, 2019).

Discussion

Handgrip strength has been suggested as a biomarker of muscular strength. It is a crucial and easily available indicator of current health status and predictor of future outcomes(Wiśniowska-Szurlej et al., 2021). This study presents normative reference equations of body composition and muscular strength by HGS. The particular equations are based on data obtained from Indian college youth ages ranging from 18 to 25 years. Normative reference equations provided in this study will be helpful for the assessment of the overall muscular strength of college students. Recently no reference equations are presented in the literature which predict the overall muscular strength of college students. The provided reference equations will be helpful to predict body composition based on the HGS values of an individual. Therefore, malnutrition, as well as obesity in an individual, could be identified as early stage, which can be diagnosed earlier. In this study, a significant relationship was reported between the parameters of muscular strength and HGS. Besides the particular study, sufficient literature evident the relationship between HGS and upper and lower body strength (Mizukami et al., 2022; Rhodes et al., 2022; Zhang et al., 2022). Shoulder strength and abdominal strength are significant markers of upper body muscular strength and general health status. It enhances body posture and creates more stability and an overall sturdier body structure. Whereas, explosive leg power is also a good indicator of lower extremities muscle power. These different parameters are a good indicator of muscular strength. The tests of the following parameters are difficult to administrate and need sufficient time to set up the test procedure. Therefore, normative reference equations provided in this study may be beneficial for diverse medical and ergonomic research, enabling clinicians and researchers to compare the grip-strength values in individuals with or without impairments to the reference values established based on the general, relatively healthy population. If someone is interested to attain the leg explosive power of an individual through provided equations. He/she just needs the HGS value of the particular individual. For example, the HGS values of subject is 40 kg, then their SBJ will be (1.4046) + (0.0065) × 40 = 1.66 meter respectively. Similarly, other equations provided in figure 1 and figure 2 may be used to predict the muscular strength of both genders.

The all-around development strategy of quality education makes college students not only pursue the improvement of academic achievement but also carry out physical exercise. Having a strong body helps students have the certain physical strength to study in other courses (J. Wang et al., 2022). Assessment of physical fitness in educational settings is a costly and complex task due to the strength of the subjects. In this situation, HGS is a valid tool to measure physical fitness.

Some significant outcomes were reported in female participants that no significant relationship (r = .151, P > 0.05) was observed between HGS and chronological age. It indicates that the muscular strength of female subjects is not significantly increased with age. Similarly, no significant correlation was observed between HGS and SU (r = .094) of female participants. Several factors may be responsible for these outcomes such as nutrition intake, low birth weight, physical inactivity, participation in sports, and other social issues, which are further areas of interest to be investigated.

In the context of HGS, it is also important to acknowledge global standards of HGS for both genders. Previous studies have developed normative data for a specific population. Kyung-Sun & Lee Jaejin Hwang (Lee & Hwang, 2019) reported a comparative evaluation of Asian, European, and United States populations. The studies conducted in these continents with different age groups are reported by the researcher. The average HGS values reported in these studies are used for comparative evaluation with the outcomes of the present study. (See figure 3) The mean grip strength for Americans was higher at 49.23 kg for males, 27.67 kg for females than European have 47.22 kg for males, 28.84 kg for females respectively, while Asian have the lowest mean grip strength with 40.56 kg and 24.85 kg for females. In the present study, the mean HGS (50th percentile) of male participants was 47.40 kg showing similarities to American and European populations for the 18 to 25 years of age group. In the case of female participants, the present study reported that 90 percent of female HGS are below normal HGS in comparison to international standards.

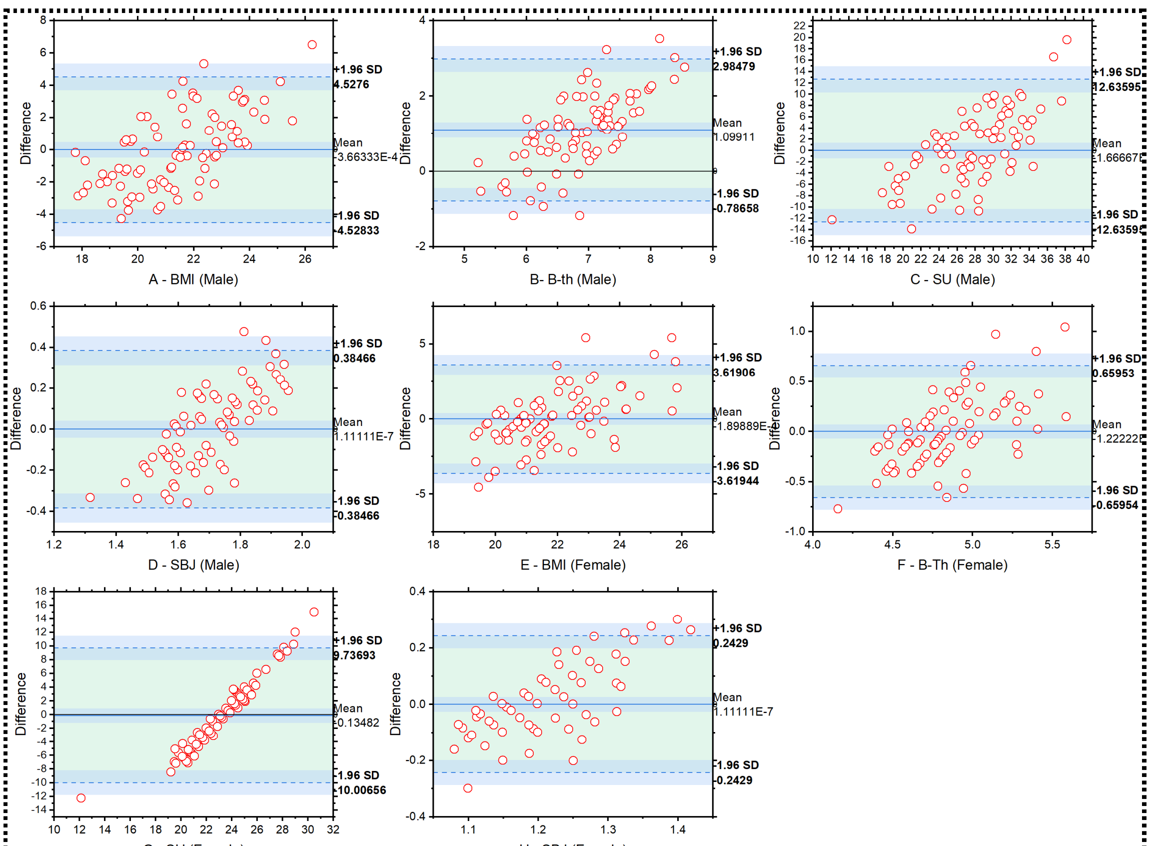

Figure 4 Bland-Altman plots from A to H showing Mean difference with 95% confidence interval (CI) between observed and predicted values of given parameters of both genders.

Conclusions

The study proposed to evaluate the relationship among grip grength, body compostion, muscular strength and cardiovascular endurance. Morever, to develop reference equations to predict fitness parameters in general public settings.

The study's uniqueness is that HGS was a significant predictor of various general health parameters such as, body composition and, muscular strength. The overall muscular strength of upper and lower extremities can be predicted through provided reference equations. While no significant relationship was found between cardiovascular endurance and HGS of both genders. The reference equations calculated implicate its usefulness as a method to predict muscular strength simply. The results apply to anyone interested in testing muscular strength in group settings; or with special populations.

The current study provide researecher, physical education teachers and physicians with important findings regarding the implementation of reference equations to measure over-all muscular strength based on HGS values. The predictive values of the HGS could serve as a useful tool to predict muscular strength that would normally require a more complex assessment. HGS testing requires only a single piece of equipment and minimal effort from subjects who may be unwilling or unable to perform the other more strenuous tests.

Conflict of Interest: The authors declare no conflict of interest.

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