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Grip Strength Represents Total Muscular Strength in a Sample of Young University Students from the City of Bogotá, Colombia

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Abstract There is no conclusive evidence determining whether grip strength (GS) correctly represents total muscular strength (MS) in young university students. To determine the correlation between GS and total MS of a sample of university students from the city of Bogotá, Colombia, a descriptive and cross-sectional study was carried out on 191 students from the University Foundation of the Andean area, located in Bogotá, Colombia. GS was measured using a model T.K.K.540 dynamometer. The total MS was evaluated through the assessment of one-repetition maximums (1RM) in five different exercises. The five exercises were assessed in the following order: bench press, squats on the Smith Machine, military press, leg press, and pull down. Following the assessment, the results of the individual tests were summed together and divided by five in order to estimate a variable known as the general strength index. Results were evaluated for correlations between the variables using the Pearson correlation coefficient. The criteria to interpret the strength of association were as follows: small (0.1-0.3), medium (0.3-0.5), large (0.5-1.0). In women, large correlation was present between GS and general strength index (r= 0.894; p=0.001). In men, this correlation was medium (r= 0.492; p=0.001).

Keywords Grip Strength, Muscular Strength, University Students

1. Introduction

Muscular strength has been defined as the ability to exert a force on an external object or resistance [1]. A persons' level of strength depends on both morphological and neural factors, including muscle cross-sectional area and architecture, musculotendinous stiffness, motor unit recruitment, rate coding, motor unit synchronization, and neuromuscular inhibition [2]. In the context of general health, research has shown that low values of MS are associated with premature death from any cause, independent of both body mass index or diastolic blood pressure [3] or even, it is an indicator of recovery in people who have suffered strokes [4]. In the Colombian youth population, it has been determined that better performance on tests evaluating MS are significantly associated with healthy lipid-metabolic profiles and a lower probability of chronic, non-communicable diseases during old age [5]. In the context of sports, greater MS can enhance the force-time characteristics of an individual, which can translate to greater athletic performance, and is strongly correlated with decreased injury rates [6]. For all these reasons, the correct assessment of MS is a very important procedure in terms of public health as well as determining talent in specific sport disciplines.

Traditionally, the most accurate method of evaluating MS has been estimating the one-repetition maximum (1RM) [7]. This concept is defined as the maximum weight that can be moved once during a concentric, dynamic action with correct execution of technique in a certain exercise [8]. The 1RM represents 100% of a person's capacity and the different work zones can be estimated from this value [9]. However, the measurement of 1RM has some limitations and shortcomings that make it impractical for application in some contexts. For example, in order to guarantee an optimal and precise measurement, it requires people to spend a period of at least two weeks familiarizing and adapting to the technique [10]. Another limitation of the 1RM protocol is that it requires isotonic movement, which may be associated with an increased risk of injury [11].

Grip strength, on the other hand, is a practical test that is economical, portable, fast and easy to perform [12]. The GS measurement protocol consists of squeezing a dynamometer for 3 seconds with the greatest force possible while in a standing position with the arms extended. The ease of this protocol's application has made it the most widely used technique in epidemiological studies of MS [13].

Previous research has demonstrated that GS is an accurate indicator of a person's body composition, metabolic risk, functional capacity and quality of life [14,15]. Likewise, higher GS values have been associated with better performance in both individual and group sports [16, 17]. The main controversy regarding the GS measurement technique is that some research has suggested it does not accurately represent the general strength of the people evaluated [18]. The main argument these authors make is that GS only measures strength in the upper extremities, as well as only in specific muscle groups, and, therefore, the values cannot be generalized to other parts of the body [19]. Additionally, GS has been determined to generate a specific isometric contraction, thus its results will never be comparable to those of tests assessing isotonic movements. For this reason, applying tests such as 1RM, which can be applied to different muscle groups, will always be more accurate.

In contrast to this view, one research study conducted on 384 people between the ages of eight and 20 concluded that GS predicts total MS corrected for possible confounders such as age, gender and anthropometrical measurements ($r2 = 0.803$) [20]. Another study determined that a significant correlation exists between GS and 1RM in the bench press exercise in young university students of both sexes, regardless of whether they were physically active or inactive [21].

When reviewing the articles published on this area of knowledge in the Colombian population, it was found that all the studies have focused on determining the GS as a health indicator, but none has focused on establishing whether the GS represents the total MS. For this reason, the results of this research generate new knowledge and its practical applications would be of great help for professionals in sports and physical exercise for health.

Universities commonly apply MS measurement protocols for the purposes of evaluating their athletes and assessing the general health of their students. As very little time is available for these measurements, GS would be a useful test to apply in these contexts, however, it is still not entirely clear whether its results accurately characterize a person's overall MS. Therefore, the aim of this investigation was to determine the correlation between GS and total MS of a sample of university students from the city of Bogotá, Colombia.

2. Materials and Methods

2.1. Participants

A descriptive cross-sectional study was performed during the second semester of 2018 using 191 students from the Fundación Universitaria del Área Andina (145 men and 46 women), which is located in Bogotá, Colombia. For convenience, the sample was selected by means of non-probability sampling. The established inclusion criteria required participants to be active university students between the ages of 18 and 30. Participants who reported any physical disability preventing them from completing MS measurement protocols were excluded. All participants were appropriately informed of the research protocol and signed a consent form. This study was designed following the deontological standards recognized by the Declaration of Helsinki and the Colombian Ministry of Health Resolution 008430 of 1993, which regulates clinical research in humans. This project was approved by the Committee of the "Fundación Universitaria del Área Andina" code CV2018-B89.

2.2. Procedures

2.2.1. Grip strength

GS was measured using a model T.K.K.540 dynamometer. Two alternative attempts with each hand were measured with the wrists in a neutral position and arms fully extended while the participant was standing and looking straight ahead. The dynamometer was individually adjusted to each participant's hand size according to their breadth of grip. The participant was verbally motivated to exert as much force as possible for 3 seconds. The strongest measurement out of three attempts was considered for the statistical analyses. This protocol has previously been validated in a population of young Colombian adults [22].

2.2.2. Total muscular strength

To assess, testing was conducted to determine 1RM in five different exercises using a protocol previously validated in people with no strength training experience [23]. The procedure consisted of an initial familiarization session in which the technique of each exercise, as well as the correct way of breathing during their execution, was taught. During a subsequent session after the participants had mastered each technique, a 5-minute endless band warm-up was performed at 70% of the participant's theoretical maximum heart rate followed by specific preparation for each of the exercises evaluated by performing ten repetitions with a light load. After the warm-up, the definitive assessment of 1RM was started. The initial load and rate of increase were determined on an individual basis depending on the self-perception of each participant. The main objective was to find the weight with which a subject could only perform one repetition in the fewest number of attempts possible. Rest periods of 1 minute were taken between each attempt and a rest period of 2 minutes was taken between each exercise. The exercises were assessed in the following order: bench press, squats on the Smith Machine, military press, leg press, and pull down. Following the assessment, the results of each individual test were summed together and divided by five in order to estimate a variable known as the general strength index. All exercises were performed under the guidance of physical exercise professionals. All the professionals involved participated in a reliability study regarding the application of the tests before the assessments were started. The studies were not commenced until both intratester and intertester reliability were sufficiently high (Pearson correlation coefficient > 0.7.5).

2.2.3. Anthropometric measurements

Anthropometric measurements were performed using segmental bioelectrical impedance analysis with a Tanita IRONMAN BC-1500. The protocol consisted of participants standing on the equipment with both arms extended in front of them for 8 seconds. The evaluations were carried out in the morning with an empty bladder and on a non-conductive surface. Height was measured to the nearest 0.1 cm using a stadiometer (SECA 220®; Seca Ltd., Hamburg, Germany). Using this procedure, each participants' percentage of fat and muscle, as well as body mass index, were determined.

2.3. Statistical Analyses

Prior to the planned statistical analyses, a preliminary analysis was conducted (Kolmogorov-Smirnov) to confirm data distribution normality. GS, MS and anthropometric measurements were reported as the mean ± the standard deviation. An independent samples T test was applied in order to compare the means between the sexes. Correlations between variables were assessed by Pearson's correlation coefficient. Partial correlation was used to adjust for confounders, weight and height. The criteria to interpret the strength of association was as follows: small (0.1-0.3), medium (0.3-0.5), large (0.5-1.0). Statistical significance was established at $P < 0.05$. All analyses were performed using IBM Statistical Analysis SPSS Statistics version 24.0 (Chicago, IL, USA).

3. Results

The general characteristics of the total sample, including all the variables related to body composition and MS tests, are presented in table 1. Compared to women, men demonstrated higher performance in all the tests applied ($P < 0.05$).

Table 1. Characteristics of the sample

Characteristic	Men (n=145)	women (n=46)	P value
Anthropometric measurements			
Age (years)	20.1 (1.3)	20.5 (1.7)	0.460
Body mass (kg)	67.7 (9.8)	56.1 (5.6)	0.001*
Height (m)	173.5 (0.5)	169.1(0.6)	0.001*
Mass body index ($kg·m^{-2}$)	24.2 (5.1)	21.5 (1.7)	0.008*
Fat Mass (%)	16.9 (6.2)	30.9 (4.7)	0.001*
Lean Mass (%)	41.8 (4.1)	28.4 (3.9)	0.001*
Total muscle strength			
Bench press (kg)	58.7 (23.9)	28.5 (9.7)	0.001*
Squats (kg)	79.1 (29.9)	62.1 (32.3)	0.001*
Military Press (kg)	44.3 (22.1)	24.8 (9.7)	0.031*
Leg press (kg)	141.6 (76.2)	111.4 (54.5)	0.021*
Pull down (kg)	72.8 (34.6)	49.6 (25.4)	0.041*
General strength index (kg)	78.8 (36.3)	54.2 (40.2)	0.033*
Grip strength (kg)	40.1 (6.4)	26.9 (6.3)	0.001*

In **Figure 1**, large correlations between GS and each of the tests applied to determine the total MS in women are presented: bench press (r = 0.524; p=0.025), squats on the Smith Machine (r = 0.634; p=0.001), military press (r =0.833; p=0.001), leg press (r = 0.864; p=0.001), and pull down (r = 0.793; p=0.001) and general strength index (r= 0.894; p=0.001). Additionally, the regression formulas adjusted for height and weight are presented.

In **figure 2**, the large and medium correlations between

GS and each of the tests applied to determine the total MS in men are presented: military press (r =0.723; p=0.001), pull down (r = 0.564; p=0.001) and press (r =0.723; p=0.001), squats on the Smith Machine (r =0.433; p=0.001), leg press (r =0.334; p=0.001) and general strength index (r= 0.492; p=0.001).

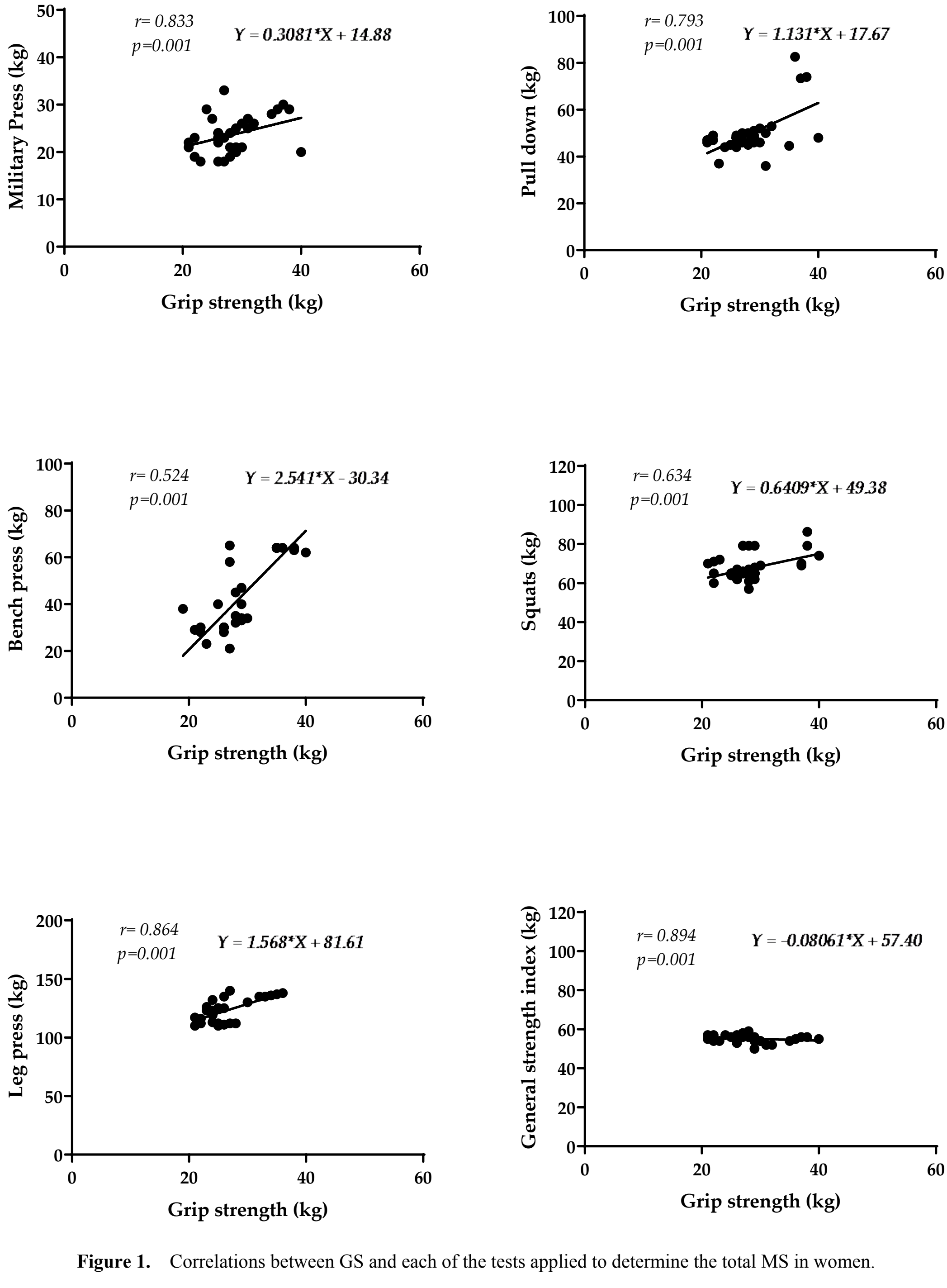

Figure 1. Correlations between GS and each of the tests applied to determine the total MS in women.

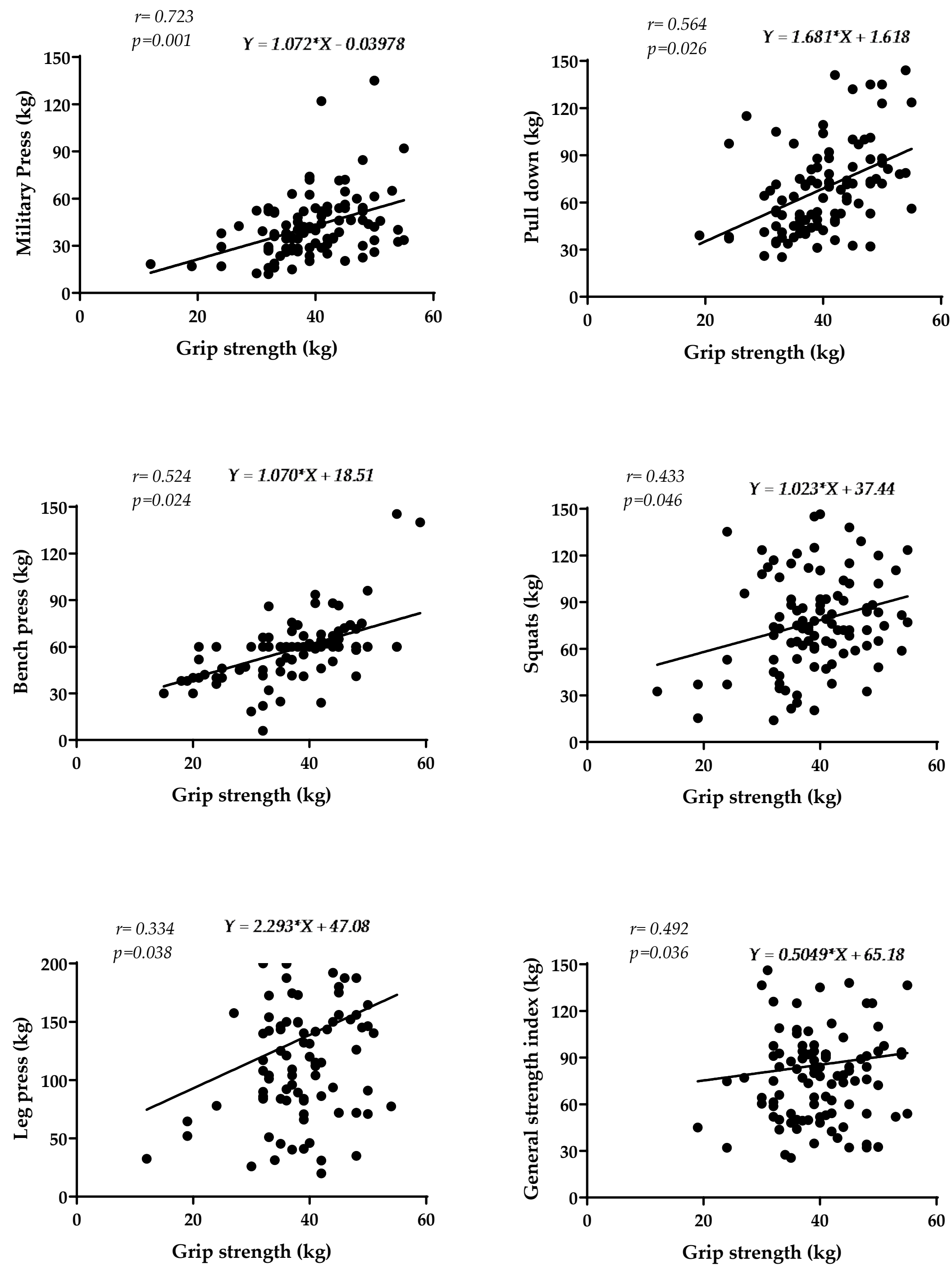

Figure 2. Correlations between GS and each of the tests applied to determine the total MS in men

4. Discussion

The most relevant finding of this research was that in women there is a large correlation between GS and MS, but in men the correlation between these variables is medium.

These results are similar to those found by Trosclair et al., who established that GS was representative of MS, in its different manifestations, in a sample of 54 university students [24]. In their work, relationships were established between GS and maximum strength tests (r = 0.609) as well as resistance strength tests, such as elbow flexion for one minute (r = 0.441). Another study, conducted in 15 young adult subjects, determined that there is a strong relationship between GS and 1RM in the bench press exercise, however this correlation may be modulated by the sex of the subject (for men r = 0.41, for women r = 0.80) [25]. The findings of their research suggest that GS is a reliable and accurate indicator of MS of the upper limbs. In our research, the highest correlations were found between GS and the exercises involving the muscles of the upper body; this finding is justifiable as the muscles involved in the GS evaluation are the biceps and the forearm muscles.

Additionally, a study on 233 children and adolescents determined that GS was consistently associated with several different parameters of physical fitness, regardless of a subjects' age, sex, or sexual maturation, suggesting that GS could serve as a very accurate independent predictor of physical fitness [26]. The associations found in their study were manifested even with tests that evaluated the performance of muscles of the lower extremities, such as vertical jump ($r2 = 0.20$) and a speed test ($r2 = 0.47$). In a similar sense, a study performed on healthy women between 18 and 42 years old found that GS was correlated with upper back strength ($r = 0.501$) and quadriceps strength ($r = 0.536$) [27]. One aspect explaining the findings from these studies is that optimal performance on the GS test is associated with a greater amount of muscle mass throughout the body, thus correlating with a better ability to generate force in any type of test that assesses physical fitness [28].

Other authors have conducted more complex statistical analyses and, using a logistic regression formula, determined that GS is capable of predicting the 1RM value of healthy women in the bicep curl exercise. These results would imply other practical applications of the GS test, such as using it to program work zones when creating a physical exercise program focused on strength training or as an indicator of a person's adaptive responses to the different stimuli applied to it [29].

These results contrast with those found by Rogers et al. who, studying 295 female survivors of breast cancer, established that the GS and 1RM tests can never replace each other, even though a relationship does exist between the two tests [30]. These authors posit that the types of contraction involved in the two tests are completely different, as the 1RM test involves isotonic muscle contraction while the GS test involves isometric muscle contraction. The authors focus on the fact that, at the physiological level, the number of motor units that come into operation and the level of activation of the muscles involved are different. Additionally, at the mechanical level, isometric actions do not involve the elastic component that is required in dynamic actions [31].

On the other hand, a similar investigation performed on 41 American football athletes at the university level determined that the evaluation of GS presents biomechanical aspects and patterns of fiber recruitment so specific that it becomes an imprecise test for characterizing the total MS of athletes [32].In Colombia, there are very few times and spaces in university contexts in which specific tests can be developed to determine the sports talent or metabolic health of a student. Based on the results of our research, it is possible to establish that GS is a valid and practical measure to indirectly determine sports talent or metabolic health since it is associated with total MS. In this sense, universities could include the evaluation of the GS in the entrance tests of new students in order to know their profile.

Another contribution of our research is that a person who started a training process to improve his MS, constantly must develop 1RM protocols to verify the progress in his changes, however, these results indicate that with the measurement of the GS could mean an increase in your MS and the repetitive application of 1RM would not be necessary.

When analyzing the results of all these studies, it becomes evident that the use of GS as an indicator of general MS is an issue requiring further investigation, as the correlations tend to vary according to conditions such as the subjects' level of training, sex or population group. In this sense, the results of this investigation can only be extrapolated to the sample that was evaluated.

5. Conclusions

The conclusion we draw from this research is that GS does represent the total MS in our sample of female university students from the city of Bogotá, Colombia, including when adjusted for possible confounding factors, weight and height. In men, this correlation between these variables is not high enough. The practical implication of these findings is that GS can be a valid, fast and accurate protocol used for assessing health parameters or as an indicator of sports talent in female university students from the city of Bogotá, Colombia. This study presents limitations such as the size of the sample and the way in which the sample was selected, thus preventing these results from being extrapolated to all young university students in the city of Bogotá.

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