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THE RELATIONSHIP BETWEEN TOTAL MUSCLE STRENGTH AND ANTHROPOMETRIC INDICATORS IN BRAZILIAN ARMY MILITARY

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ABSTRACT

The aim of this study was to investigate the relationship between the total muscle strength and anthropometric indicators in militaries of the Brazilian Army. The study included 50 soldiers of the Brazilian Army, aged between 19 and 25 years, body mass 71.2 ± 9.1 kg, height 1.75 ± 0.1 m, the Army Physical Training Center soldiers. Anthropometric measurements were: total body mass (TBM) and height. Body composition measures were lean body mass (LBM), fat body mass (FBM), and percentage of body fat (%BF), measured by dual energy ray Absorptiometry (DEXA). It also calculated the body mass index (kg/m^2). It was considered as total muscle strength the sum of flexion and extension torque peaks of shoulder, trunk and knee, evaluated in digital isokinetic dynamometer Biodex® S4 Pro. The bivariate Pearson correlation coefficients indicated that there is significant correlation between total muscle strength and all measures except the FBM and %BF ($p < 0.05$), and found the strongest correlation with LBM measures, TBM and height explaining (R2) 68.89%, 48.30% and 37.70%, respectively. In sumary, these anthropometric indicators are best correlated with total muscle strength.

Key words: Muscle Strength. Anthropometry. Body Composition. Militaries.

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RESUMO

Relação entre força muscular total e indicadores antropométricos em militares do Exército Brasileiro

O objetivo deste estudo foi verificar a relação entre a força muscular total e indicadores antropométricos em militares do Exército Brasileiro. Participaram do estudo 50 militares do Exército Brasileiro, com idade entre 19 e 25 anos, massa corporal de 71,2 ± 9,1 Kg, estatura 1.75 ± 0.1 m, soldados do Centro de Capacitação Física do Exército. As medidas antropométricas realizadas foram: a massa corporal total (MCT) e a estatura (Est). As medidas de composição corporal foram: massa magra corporal (MMC), massa gorda corporal (MGC), e percentual de gordura corporal (%GC), medidas por absormetria radiológica de dupla energia (DEXA). Também foi calculado o índice de massa corporal (Kg/m2). Foi considerada como força muscular total o somatório dos picos de torque de flexão e extensão de ombro, tronco e joelho, avaliados em dinamômetro digital isocinético Biodex® S4 pro. A correlação linear bivariada de Pearson indicou que existe correlação significativa entre a força muscular total e todas as medidas, com exceção da MGC e %G ($p<0,05$), sendo encontrada a correlação mais forte com as medidas de MMC, MCT e Est, explicando (R2) 68,89%, 48,30%, e 37,70%, respectivamente. Conclui-se que estes indicadores antropométricos são os melhores correlacionados com a força muscular total.

Palavras-chave: Força Muscular. Antropometria. Composição Corporal. Militares.

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INTRODUCTION

Muscular strength is related to physical fitness, health status and to the functional capacity of the individual (Matsudo and collaborators, 2015; Soares and collaborators, 2016; Wind and collaborators, 2010). For the military, the maintenance of adequate levels of muscular strength is fundamental in any operational activity (Brasil, 2015). The evaluation of strength levels is fundamental to serve as a criterion of physical selection and as a parameter of training prescription information in order to achieve the basic standards of military performance in the field of professional intervention (Ministério da Defesa, 2008).

For the measurement of muscle strength, different methods with good and moderate intra and intertest reliability may be used (Bohannon, 1999; Kolber and Cleland, 2005; Massy-Westropp and collaborators, 2004). However, in situations that require evaluation in the field of large personnel and in a short period of time, it may be impracticable to perform complex force tests. One solution is the use of prediction models with variables related to total muscle strength.

The ability to predict muscle strength from models where subjects do not perform maximum force tests is directly related to the quality of the parameters established. The higher the correlation with the physical valence, the more significant the parameter's ability to estimate maximum muscle strength (Oliveira, 2010). As stated by Winwood, Keogh and Harris, (2012), anthropometric markers are significantly associated with muscle strength.

According to our knowledge, no studies were found that correlated anthropometric indicators with total muscle strength in physically active individuals with similar eating habits and routines, who use muscle strength in their work activities.

Thus, to collaborate with the information in the scientific literature, the objective of the present study was to verify the relationship between total muscle strength and anthropometric indicators in Brazilian Army military personnel.

MATERIALS AND METHODS

Subjects

The study was composed of 50 men, soldiers of the Brazilian Army, normotensive, physically active and selected for convenience. Based on an a priori analysis, a n of 44 individuals was calculated, after having adopted a power of 0.80, $\alpha = 0.05$, slope H1 of 0.40 and slope H2 equal to zero, two-tailed. It was found that the sample size was sufficient to provide 80.62% of the statistical power. For the calculation of the sample, the procedures suggested by Beck (2013) were adopted. This a priori analysis of statistical power was performed as to reduce the probability of type II error and to determine the minimum number of participants required for this investigation.

All subjects signed the Termo de Consentimento Livre e Esclarecido (Free and Informed Consent Form), according to resolution 466/12 of the Conselho Nacional de Saúde (National Health Council) of 12/12/2012. The research project was approved by the Comitê de Ética na Pesquisa do Hospital Geral da Força Aérea (Research Ethics Committee of the Air Force General Hospital) (CAAE 42214915.1.0000.5250). The following inclusion criteria were adopted: being a soldier of the Brazilian Army; have at least one year of active service, and as exclusion criteria: present injury or limitation for strength evaluation; have a history of musculoskeletal injuries for less than 6 months; have hypermobility, hypomobility; have a habit of smoking.

Study Design

Three visits (V1, V2, V3) were conducted on non-consecutive days, always at the same time, around 8 o'clock in the morning at the Laboratório de Biomecânica do Instituto de Pesquisa da Capacitação Física do Exército (Biomechanics Laboratory of the Research Institute of Physical Training of the Army - IPCFEx). Prior to the visits, a lecture was held, where all the procedures and objectives of the study were clarified and the volunteers signed the Termo de Consentimento Livre e Esclarecido (Free and Informed Consent Form). The interval between all the visits was of 48h, allowing the necessary recovery so that the individuals

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could carry out all the procedures with the maximum effort.

In V1 they underwent an anthropometric evaluation and body composition of total body mass (TBM), height (HT), body mass index (BMI), body fat percentage (% BFP), body fat mass (BFM) and lean body mass (LBM). At V2 and V3, they performed three isokinetic dynamometric tests, one upper limb test, one lower limb test, and one central body test. They performed one or two tests on V2 and the rest or remaining on V3, chosen in random order. During the study, participants were instructed to abstain from exhaustive exercise as well as avoid caffeine, chocolate, nutritional supplements, and alcohol intake during and after study. They were also instructed to sleep for a minimum of six hours the night before the exercise session, and to maintain their eating habits.

Anthropometric evaluation and body composition

Subjects' height was measured with the participants standing barefoot, and by means of a stadiometer (Sanny® - Brazil) with precision of 1 mm, set on the wall. The total body mass was measured on a digital scale (Filizola® - USA), with an accuracy of 100 grams and a scale ranging from 0 to 150 kg. Immediately after the measurement of these two measures, the body mass index (BMI) or Quetelet index was calculated by means of equation 1 (Garber and collaborators, 2011).

$$\text{BMI} = \text{Total Body Mass (kg)}/\text{Height(m)}^2 \quad (1)$$

For the measurement of lean body mass (LBM) and fat body mass (BFM), the DEXA (Dual Energy Radiological Absorption) of the LUNAR brand, model DPX-IQ (software 4.7e), was used. The percentage of body fat (% BFP) was estimated following the equations of the device itself.

Assessment of total muscle strength

The total muscle strength was calculated by summing the peak torque values of the muscular actions of upper limbs tests, flexion and shoulder extension; In trunk, flexion and extension of trunk and lower limbs, knee flexion and extension. The protocol used was the Biodex S4® system for isokinetic testing, which consists in positioning the individual sitting in the chair of the equipment, stabilized by means of belts (pelvic and diagonal). Preceding the experimental protocols in the isokinetic, an organic heating was carried out for 5 minutes on a stationary bicycle, at a power of 50W, between 80 and 90 revolutions per minute (RPM), followed by a specific heating and familiarization in the dynamometer, composed of 1 series of 10 repetitions at the speed of 180º/sec and 1 series of 10 repetitions at a speed of 120º/sec, with a 60 second interval between each series.

In the flexion and shoulder extension test, the individual was positioned comfortably in the equipment chair, with the back in the backrest which was adjusted until the popliteal fossa touched the anterior part of the seat, with the feet supported in specific support of the equipment, handle with the hand in neutral grip, arm along the body at anatomical zero, alignment of the shoulder joint with the mechanical axis of the isokinetic dynamometer made taking as a reference the center of the glenohumeral joint, with the test initiated by the dominant side. In the flexion and trunk extension test, the individual was positioned lying in the equipment seat, stabilized by means of belts (pelvic and diagonal), alignment of the hip joint with the mechanical axis of the isokinetic dynamometer made taking as reference the anterior-posterior iliac spine. In the flexion and knee extension test, the individual was positioned comfortably in the equipment seat, with the back in the backrest adjusted until the popliteal fossa was supported by the anterior part of the seat, stabilized by means of belts (pelvic and diagonal). The alignment of the knee joint with the mechanical axis of the isokinetic dynamometer was made with reference to the joint line of the knee joint (femorotibial), with the tests initiated by the dominant member.

In all isokinetic tests, three tests were performed, with five maximum repetitions, at 60 °/sec, with a 60-second interval between the tests, concentric/concentric type.

To increase motivation during isokinetic tests, subjects were verbally encouraged to perform each repetition with maximum effort. To minimize the error in dynamometric tests, some strategies were employed: a) some instructions were standardized for the test procedure and

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exercise techniques; B) verbal encouragement was standardized during the testing procedure.

Statistical analyzes

All statistical analyzes were performed using the statistical software SPSS package version 20.0 (SPSS Inc., Chicago, IL). The statistical analysis was performed initially by the Shapiro-Wilk normality test and the Levene homogeneity test. The variables showed normal distribution and homogeneity (p> 0.05). The Pearson coefficient was used to analyze the relationship between total muscle strength and anthropometric measures of TBM and HT and body composition, BMI, LBM, BFM and %BF. The level of significance was set at p ≤ 0.05.

RESULTS

No musculoskeletal changes were observed during or immediately after the tests, so it may be assumed that all volunteers were able to make the maximum effort during the evaluation.

The average age of the volunteers was 20.8 ± 1.8 years old. As shown in Table 1, the average of the basic anthropometric measures, total body mass and height were 71.2 ± 9.1 Kg and 1.75 ± 0.1 m, respectively. The low dispersion of data characterizes the homogeneity among study participants.

Table 1 - Results of total muscular strength and anthropometric indicators.

Variables	Average ± SD	Min-Max	CI	CV (%)
TMS (N.m)	1451,1 ± 202,0	1006,1-1831,8	1393,7-1508,5	13,9
TBM (kg)	71,2 ± 9,1	53,8-103,2	68,6-73,7	12,7
HT (m)	1,75 ± 0,1	162,4-187,5	173,4-177,3	3,8
BMI (Kg/m^2)	23,1 ± 2,5	16,6-31,3	22,4-23,8	10,7
LBM (kg)	55,1 ± 6,0	40,4-69,9	53,4-56,8	10,9
BFM (Kg)	13,5 ± 5,6	5,6-33,7	11,9-15,1	41,4
% BF (%)	19,3 ± 6,1	9,1-33,9	17,5-21,0	31,6

Legends: TMS = total muscle strength; TBM = total body mass; HT = height; BMI = body mass index; LBM = lean body mass; BFM = body fat mass; % BF = fat percentage SD = standard deviation; CI = confidence interval; CV = coefficient of variation.

Table 2 - Correlation between anthropometric indicators and total muscle strength.

Variables	TBM (Kg)	HT (m)	BMI (Kg/m^2)	LBM (Kg)	BFM (Kg)	%F (%)
Total Muscular Strength Dependent						
r	0,695*	0,614*	0,374**	0,830*	0,200	-0,34
p	0,000	0,000	0,007	0,000	0,164	0,812

Legends: TBM = total body mass; HT = height; BMI = body mass index; LBM = lean body mass; BFM = body fat mass; % F = percentage of fat. * *p*≤0,001 **p≤0,05.

DISCUSSION

The scope of the present study was to verify the relationship between total muscle strength and anthropometric indicators in Brazilian Army military personnel. The main finding was the strong correlation between total muscle strength and LBM (r = 0.830).

Many studies use TBM in prediction models or to correct muscle strength (Marsola, Carvalho and Robert-Pires, 2012; Ng, Lo and Cheing, 2014; Wang, Leger and Dumas, 2005). However, according to Pereira and Gomes (2003), the literature indicates that the strongest correlation occurs with LBM.

Era and collaborators (1994), found a strong positive correlation between anthropometric indicators and manual grip muscle strength, elbow flexion, knee extension, trunk flexion and extension, and also found the highest correlations with LBM. A study that correlated the strength of elbow flexion with TBM and indicators of length and perimeter of segments found a moderate correlation between TBM and muscle strength (Green and Gabriel, 2012). Although, in these

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abovementioned studies, muscle strength was measured with isometric test, that is to say, in a static way, these data corroborate the results of this work.

In relation to dynamic force measurements, Martenko and collaborators (2007) found a moderate correlation between the 1RM test in the machine development and LBM (r = 0.557) and TBM (r = 0.529). It was also found values of isokinetic muscle strength of knee extension and flexion that exhibited strong correlations between height (r = 0.710) and LBM (r = 0.750) and correlation tending to moderate with TBM (r = 0,480) (Neder Collaborators, 1999). A strong correlation was found between the LBM and the isokinetic muscle strength of extension (r = 0.881) and knee flexion (r = 0.788) (Farias et al., 2015). Moderate to strong correlations between the anthropometric indicators of LBM, TBM and HT and muscular strength are in accordance with the findings of this study, especially if it is evaluated in the isokinetic test at 60º/sec, concentric protocol.

One possible explanation is that there are two fundamental components for determining muscle strength, motor unit activation and muscle size (Green, Gabriel, 2012). Anthropometric variables are directly related to muscle size (Bamman and collaborators, 2000).

However, it was observed that this correlation of moderate to strong muscle strength with anthropometric indicators is not a consensus in the literature (Mayhew and collaborators, 1991; Westphal and Baptista; Oliveira, 2006).

Kravitz and collaborators (2003) found no association between baseline anthropometric measures, TBM and HT, of weight-bearing athletes and muscle strength, for $p < 0.05$. Winwood, Keogh and Harris (2012) conducted a study with rugby semi-professional athletes, in which they correlated anthropometric measures of TBM, LBM and HT with muscular strength in three muscular actions. Strong correlation was found with LBM and most of the other correlations were weak. In both studies, muscle strength was measured by means of the 1 RM tests in squatting, bench press and deadlifting exercises. The results differed from the findings of the present study, probably due to the different training characteristics between athletes and the military.

Although BMI is a measure that involves TBM variables and height, this study found a weak correlation between this variable and muscle strength. Corroborating our findings, Hasan, Kamal and Hussein (2016) found a highly significant correlation between values of muscular strength and BMI ($p < 0.001$), also of low magnitude. Muscle strength was measured with the same instrument and velocity of this study, in the muscular actions of trunk flexion, knee extension and elbow. The values found in the correlation between BMI and knee and elbow flexion were r = 0.44 and r = 0.30, respectively. Only the correlation with the trunk flexion was different from our findings, and a moderate and negative correlation was reported (r = - 0.54).

In a study with Chinese students, there was also a weak correlation (r = 0.249-0.319) between manual grip strength and body mass index values, divided into groups of normoponderal, overweight and obese individuals (Rafique and collaborators, 2014).

No relationship was found between total muscle strength and body fat variables, results reported in other studies analyzed (Farias and collaborators, 2015; Materko, Neves and Santos, 2007; Winwood, Keogh and Harris, 2012).

It is worth mentioning that, although some studies characterize total muscle strength as the sum of the highest value observed in force tests applied to different muscle groups and actions (Carvalho and collaborators, 1998; Kelly, Eisman and Stuart, 1990, Timpka and collaborators, 2013; Wind and collaborators, 2010), no studies were found that employed this protocol and related to anthropometric indicators. However, even though the data was analyzed as total muscle strength, similar correlations to those of other studies that verified the association between anthropometric indicators and the segmented muscle strength were found (Era and collaborators, 1994; Farias and collaborators, 2015; Green and Gabriel, 2012; Materko, Neves and Santos, 2007; Neder and collaborators, 1999).

The limitations of the present study include its transversal character, considering that a longitudinal study, with force training methods as intervention, could establish cause and effect relationships among the variables analyzed. The sample consisted of soldiers, who are young, male and physically active

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individuals. Caution is needed to extrapolate the results to military personnel of other age groups, gender, and sedentary young people.

However, although there are limitations, the present study is important to have verified, through an appropriate methodological approach and gold standard instruments, the relationships between structural parameters of the body and physical valence total muscle strength, characterized by the sum of muscular actions of flexion and extension of axial and appendicular skeletal muscles. In addition, it is not known, until the moment of this study, that this methodology has been used and in military of the Brazilian Army.

CONCLUSIONS

The main conclusion of this study was the positive and highly significant association between LBM and total muscle strength, as assessed by the sum of the peak torque of isokinetic tests applied to muscles of the upper limbs, trunk and lower limbs. In addition, we found a positive and highly significant correlation between total muscle strength and the TBM and HT basic anthropometric indicators, with a strong and moderate tending magnitude, respectively.

Thus, we conclude that researchers in the area of physical exercise and health and the Brazilian Army can benefit from the results of this study not only to estimate strength from simple morphological characteristics, but also to include anthropometric measures and body composition in prediction models of muscular strength that consider other parameters of dynamometry or to establish values of relative strength. The inclusion priority must follow the following order, LBM, TBM and HT. In principle, the variables BMI, BFM and %BF should not be considered.

Other studies with the inclusion of females, age groups and different populations should be performed in order to verify if the relationships between total muscle strength and anthropometric indicators found in this study will be maintained.

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REFERENCES

1-Bamman, M. M.; and collaborators. Evaluation of the strength-size relationship in vivo using various muscle size indices. Medicine and Science in Sports and Exercise. Vol. 32. Num. 7. 2000. p.1307-1313.

2-Beck, T. W. The importance of a priori sample size estimation in strength and conditioning research. Journal of Strength and Conditioning Research / National Strength & Conditioning Association. Vol. 27. Num. 8. 2013. p.2323-2337.

3-Bohannon, R. W. Intertester reliability of hand-held dynamometry: a concise summary of published research. Perceptual and Motor Skills. Vol. 88. Num. 3. 1999. p. 899-902.

4-Brasil, Ministério da Defesa. Exército Brasileiro. Institui diretrizes para o Treinamento Físico Militar e sua Avaliação. Portaria Num. 032 de 31 de março de 2008. Brasília. 2008.

5-Brasil. Manual de Treinamento Físico Militar EB20-MC-10.350. Brasília. EGCF.2015. p.6-1.

6-Carvalho, A. C. G.; and collaborators. Relationship between muscular strength and flexibility in healthy adults of both genders. Revista Brasileira de Medicina do Esporte. Vol. 4. Num. 1. 1998. p.2-8.

7-Era, P.; and collaborators. Maximal isometric muscle strength and anthropometry in 75-year-old men and women in three Nordic localities. Scandinavian Journal of Medicine & Science in Sports. Vol. 4. Num. 1. 1994. p.26-31.

8-Farias, J. P.; and collaborators. Correlação da Força Muscular com Indicadores Antropométricos, Estágio Maturacional e Testes Neuromotores em Adolescentes. Revista Brasileira de Ciência e Movimento. Vol. 23. Num. 2. 2015. p.81-88.

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9-Garber, C. E.; and collaborators. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Medicine and Science in Sports and Exercise. vol. 43. Num. 7. 2011. p.1334-1359.

10-Green, L. A.; Gabriel, D. A. Anthropometrics and electromyography as predictors for maximal voluntary isometric arm strength. Journal of Sport and Health Science, Special Issue on Sports Injuries: Prevention and Rehabilitation. Vol. 1. Num. 2. 2012. p.107-113.

11-Hasan, N. A. K. A. K.; Kamal, H. M.; Hussein, Z. A. Relation between body mass index percentile and muscle strength and endurance. Egyptian Journal of Medical Human Genetics. 2016.

12-Kelly, P. J.; Eisman, J. A.; Stuart, M. C. 90092793 Somatomedin-C, physical fitness, and bone density. Maturitas. Vol. 12. Num. 4. 1990. p.365.

13-Kolber, M. J.; Cleland, J. A. Strength testing using hand-held dynamometry. Physical Therapy Reviews. Vol. 10. Num. 2. 2005. p.99-112.

14-Kravitz, L.; and collaborators. Prediction of 1 repetition maximum in high-school power lifters. Journal of Strength and Conditioning Research / National Strength & Conditioning Association. Vol. 17. Num. 1. 2003. p.167-172.

15-1Marsola, T. S.; Carvalho, R. S. T.; Robert-Pires, C. M. Relação entre peso levantado em teste de 1RM e peso corporal de homens sedentários no exercício supino reto. Revista Brasileira de Prescrição e Fisiologia do Exercício. Vol. 5. Num. 30. 2012. p. Disponível em: <http://www.rbpfex.com.br/index.php/rbpfex/article/view/387/371>

6-Massy-Westropp, N.; and collaborators. Measuring grip strength in normal adults: reference ranges and a comparison of electronic and hydraulic instruments. The Journal of Hand Surgery. Vol. 29. Núm. 3. 2004. p.514-519.

17-Materko, W.; Neves, C. E. B.; Santos, E. L. Modelo de predição de uma repetição máxima (1RM) baseado nas características antropométricas de homens e mulheres. Revista Brasileira de Medicina do Esporte. Vol. 13. Num. 1. 2007. p.27-32.

18-Matsudo, V. K. R.; and collaborators. Handgrip strength as a predictor of physical fitness in children and adolescents. Revista Brasileira de Cineantropometria & Desempenho Humano. Vol. 17. Num. 1. 2015. p.1-10.

19-Mayhew, J. L.; and collaborators. Relationships of structural dimensions to bench press strength in college males. The Journal of Sports Medicine and Physical Fitness. Vol. 31. Num. 2. 1991. p.135-141.

20-Neder, J. A.; and collaborators. Reference values for concentric knee isokinetic strength and power in nonathletic men and women from 20 to 80 years old. The Journal of Orthopaedic and Sports Physical Therapy. Vol. 29. Num. 2. 1999. p.116-126.

21-Ng, T. K.-W.; Lo, S.-K.; Cheing, G. L.-Y. The association between physical characteristics of the ankle joint and the mobility performance in elderly people with type 2 diabetes mellitus. Archives of Gerontology and Geriatrics. Vol. 59. Num. 2. 2014. p.346-352.

22-Oliveira, L.F.; Menegaldo, L. L. Estimativa da Força Muscular Máxima utilizando Ultrassom. VI Congresso Nacional de Engenharia Mecânica. Campina Grande. 2010.

23-Pereira, M. I. R.; Gomes, P. S. C. Muscular strength and endurance tests: reliability and prediction of one repetition maximum - Review and new evidences. Revista Brasileira de Medicina do Esporte. Vol. 9. Num. 5. 2003. p.325-335.

24-Rafique, M.; and collaborators. Comparing BMI and hand grip strength of Tsinghua University Beijing and University of Sindh Pakistan students. IOSR Journal of Sports and

Revista Brasileira de Obesidade, Nutrição e Emagrecimento
ISSN 1981-9919 ***versão eletrônica***

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Physical Education. Vol. 1. Num. 4. 2014. p.36-44.

25-Soares, V. P.; and collaborators. Correlação entre força muscular e capacidade funcional em hipertensos. Revista Pesquisa em Fisioterapia. Vol. 6. Num. 1. 2016.

26-Timpka, S.; and collaborators. Muscle strength in adolescent men and future musculoskeletal pain: a cohort study with 17 years of follow-up. BMJ open. Vol. 3. Num. 5. 2013.

27-Wang, M.; Leger, A. B.; Dumas, G. A. Prediction of back strength using anthropometric and strength measurements in healthy females. Clinical Biomechanics (Bristol, Avon). Vol. 20. Num. 7. 2005. p.685-692.

28-Westphal, M.; Baptista, R. R.; Oliveira, A. R. Relationship between body mass, lean body mass, cross sectional area and 1 RM in women. Brazilian Journal of Kinanthropometry and Human Performance. Vol. 8. Num. 1. 2006. p.52-57.

29-Wind, A. E.; and collaborators. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? European Journal of Pediatrics. Vol. 169. Num. 3. 2010. p.281-287.

30-Winwood, P. W.; Keogh, J. W. L.; Harris, N. K. Interrelationships between strength, anthropometrics, and strongman performance in novice strongman athletes. Journal of Strength and Conditioning Research / National Strength & Conditioning Association. Vol. 26. Num. 2. 2012. p.513-522.

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