

## **Muscle strength and its association with body composition among Saudi Female Physical Education and Sport Sciences Students at Taibah University**

Dr. Mohammad Ali Alahmadi, Associate Professor of Exercise Physiology, Department of Physical Education and Sport Sciences, Taibah University, Madinah, Saudi Arabia

### **Abstract**

To date, muscle strength in Saudi females has received less attention compared to physical activity. Thus, the present study aimed to assess muscle strength among Saudi female Physical Education and Sport Sciences (PESS) students at Taibah University in Madinah and to examine the association between muscle strength and body composition. Forty female university students (aged  $18.7 \pm 0.6$  years) were recruited. Hand grip strength for both hands was measured using a digital hand grip dynamometer. Body composition, including fat-free and fat mass, was determined using a bioelectrical impedance analyzer. The mean ( $\pm$  standard deviation) values of right-hand grip strength, left-hand grip strength, fat-free mass, and fat mass were  $17.5 \pm 5.0$  (kg),  $18.2 \pm 5.6$  (kg),  $26.5 \pm 2.4$  (%), and  $32.3 \pm 7.8$  (%), respectively. Significant associations were observed between right- and left-hand grip strength and fat-free mass ( $r = 0.33$  ( $P = .03$ ) and  $r = 0.45$  ( $P = .00$ ), respectively). However, hand grip strength was not significantly correlated with fat mass. To conclude, our findings indicate that muscle strength should be targeted to enhance health status among Saudi female PESS students at Taibah University in Madinah. This may be accomplished by local health centers, which should offer resistance training programs aimed at enhancing Saudi female students' muscle strength.

**Keywords:** Physical activity - Overweight - Obesity.

## القوة العضلية وارتباطها بالتكوين الجسمي لدى طالبات التربية البدنية وعلوم الرياضة السعوديات بجامعة طيبة

د. محمد بن علي الأحمدى، أستاذ مشارك فسيولوجيا الجهد البدني، قسم التربية البدنية وعلوم الرياضة، كلية التربية، جامعة طيبة، المدينة المنورة، المملكة العربية السعودية

إلى وقتنا الحالي، حظيت القوة العضلية لدى الفتيات السعوديات باهتمام أقل مقارنة بالنشاط البدني. لذا هدفت الدراسة الحالية إلى قياس القوة العضلية لدى طالبات التربية البدنية وعلوم الرياضة السعوديات في جامعة طيبة بالمدينة المنورة ودراسة العلاقة بين القوة العضلية والتكوين الجسمي. شارك في الدراسة أربعين طالبة جامعية (متوسط العمر  $18.7 \pm 0.6$  سنة). وقد تم قياس قوة قبضة اليد لكلتا اليدين باستخدام جهاز قوة القبضة الرقمي. وتم قياس التكوين الجسمي، بما في ذلك الكتلة الغير دهنية والكتلة الدهنية، باستخدام جهاز المقاومة الكهروحيوية. وكانت قيم المتوسطات الحسابية ( $\pm$ ) الانحراف المعياري) لقوة قبضة اليد اليمنى، وقوة قبضة اليد اليسرى، والكتلة الغير دهنية، والكتلة الدهنية  $5.0 \pm 17.5$  (كجم)،  $5.6 \pm 18.2$  (كجم)،  $2.4 \pm 26.5$  (%) و  $7.8 \pm 32.3$  (%).، على التوالي. وتشير النتائج إلى وجود علاقة ارتباطية دالة احصائياً بين قوة قبضة اليد اليمنى واليسرى والكتلة الغير دهنية ( $r = 0.33$ ، مستوى الدلالة =  $0.03$ ) و ( $r = 0.45$ ، مستوى الدلالة =  $0.00$ )، على التوالي. غير أنه لم تكن قوة قبضة اليد مرتبطة احصائياً مع الكتلة الدهنية. ونستنتج من النتائج التي توصلنا إليها إلى أن القوة العضلية يجب أن يتم استهدافها لتحسين الحالة الصحية لدى طالبات التربية البدنية وعلوم الرياضة السعوديات في جامعة طيبة بالمدينة المنورة. ويمكن تحقيق ذلك من خلال المراكز الصحية المحلية، والتي ينبغي أن تقدم برامج تدريبات المقاومة التي تهدف إلى تعزيز قوة عضلات الطالبات السعوديات.

الكلمات المفتاحية: النشاط البدني – زيادة الوزن - السمنة

## Introduction

The population is rapidly aging, and by the year of 2051, the percentage of people aged 65 and up is expected to rise from 16% to 24% of the total population (Lloyd et al., 2014). Moreover, by the time they reach the age of 60, an average individual has already lost from 20% to 30% of their youth maximum muscular strength (Frontera et al., 2000). Muscle mass decreases at a rate of around 1–2% each year and muscle strength decreases at a rate of 1.5% per year in older individuals as a result of the aging process (Cruz-Jentoft et al., 2010; Studenski et al., 2014). However, since the primary cause of muscle loss and strength reduction is sedentary behavior (Rom, Kaisari, Aizenbud, & Reznick, 2012), younger sedentary people are also at risk of deteriorating muscle mass and muscle strength. It has been shown that about one month (28 days) of prolonged inactivity (i.e., bedrest) resulted in 2% of muscle loss in young, healthy adults (Paddon-Jones et al., 2004). In fact, poor muscular strength is regarded as a risk factor for major causes of death in early adulthood, such as cardiovascular disease (Henriksson et al., 2020; Ortega, Silventoinen, Tynelius, & Rasmussen, 2012; Timpka, Petersson, Zhou, & Englund, 2014). Several health consequences have also been reported in relation to muscle loss and poor muscle strength, including disability, morbidity, and mortality (Rantanen et al., 2000; Sayer et al., 2005). In addition, a loss of muscle mass is associated with an increase in fat mass and, as a result, changes in body composition (Holloosy, 2000; Volpi, Nazemi, & Fujita, 2004). Changes in body composition, such as a decreased lean mass and a higher fat percentage, have a negative impact on elderly people's health, increasing their risk of illness and death (Silva Neto, Karnikowski, Tavares, & Lima, 2012; Vilaça et al., 2013; Visser et al., 2002). However, strengthening exercise is widely recognized as a promising intervention for reversing the aging-related weakening of muscle function and degradation of muscle structure (Hurley & Roth, 2000). Further, a sufficient amount of physical activity may also help elderly people maintain a healthy lifestyle by slowing the loss of functional and physical capabilities (Milanović et al., 2013)

Moreover, several studies have demonstrated that poor hand grip strength is associated with several adverse health consequences (Celis-Morales et al., 2018; García-Peña et al., 2013; König et al., 2021; Qian et al., 2020). The hand grip strength test is commonly used to assess muscle strength owing to its efficiency, convenience, and cost-effectiveness (Saint-Maurice, Laurson, Karsai, Kaj, & Csányi, 2015). It is also an important field test that is applied in large populations and is used as an important indicator of health-related quality of life, particularly in older individuals (Jang & Kim, 2020; Musalek & Kirchengast, 2017). Most notably, hand grip strength is commonly used to predict an individual's wellbeing over the course of their life (Cooper et al., 2011) and has become a popular marker of nutritional status (Norman, Stobäus, Gonzalez, Schulzke, & Pirlich, 2011). Although muscle strength is easily measured using hand grip strength tests to determine one of the most important components of health-related physical fitness, hand grip strength in young females in Saudi Arabia has received little attention. To the best of our knowledge, only one study has measured hand grip strength and developed normative values for young female university adults (aged 19–25 years) (Shaheen, Omar, & Ali, 2021), while the rest of the available research was conducted among Saudi children (aged 6–16 years)

(Alahmari et al., 2019; M. T. Omar, Alghadir, & Al Baker, 2015; M. T. A. Omar, Alghadir, Zafar, & Al Baker, 2018), young male adults (Alahmari et al., 2017), and old people (aged 60 years and above) (Bindawas et al., 2019). Recently, a new Physical Education and Sport Sciences (PESS) major for females was introduced at several Saudi universities, including Taibah University in Madinah city, western Saudi Arabia. To the best of our knowledge, no previous study has measured hand grip strength among female university students in the PESS field. Therefore, the present study aimed to assess muscle strength among female Saudi PESS students at Taibah University in Madinah and to examine the association between muscle strength and body composition.

## **Methods**

### **1- Participants and study procedure**

Forty female students (mean  $\pm$  SD, age  $18.7 \pm 0.6$  years (ranging from 18 to 20 years); body mass  $54.7 \pm 10.0$  kg; height  $156.9 \pm 5.5$  cm) participated in this study. The PESS female students were randomly selected from Taibah University in Madinah city, western Saudi Arabia, during the 2018–2019 academic year. All female students were already enrolled in the required Sport Sciences and Physical Activates program, a four-year bachelor's degree program offered by the Department of PESS in the College of Education at Taibah University. The study protocol and procedures conform to the ethical guidelines, and all participants signed an informed consent form.

### **2- Measurements**

#### **2.1 Anthropometry and Body Composition**

Body weight was estimated to the nearest 100 g using a body weight scale (Seca, Germany), and stature was estimated to the nearest 0.1 cm using a stadiometer (Seca, Germany). Body mass index (BMI) was determined from stature and body weight using the following equation:  $BMI = \text{body weight}/\text{stature}^2$ .

The participants' percentage fat and fat-free mass were measured using a bioelectrical impedance analyzer (OMRON, BF511 body composition monitor). In accordance with the manufacturer's instruction manual, the participants wore light clothes and no shoes, and the bioelectric impedance measurement was performed by placing the feet together on the foot electrodes with the weight equally distributed. The participants held their knees and backs in a straightened position, with the arms extended forward and the hands holding the grip electrodes for a few seconds. The percentage fat and fat-free mass readings appeared on the display unit and were recorded.

## 2.2 Hand grip strength

Maximal isometric handgrip strength was measured using a digital hand grip dynamometer (Takei Kiki Kogyo® dynamometer) adjusted to hand size. A single measurement was taken for each hand to obtain the maximal isometric handgrip strength values. Each subject was instructed to maintain maximal isometric contraction for three seconds during each measurement (Kamimura & Ikuta, 2001). The participants performed the contractions with each hand and with both feet on the floor, their shoulders flexed at a 90° angle, and the elbow completely extended. Both hands were assessed, and handgrip strength was obtained from both hands and rounded to the nearest 1 kg. The higher value for each hand was recorded and used for analysis.

## 3-Statistical analysis

The data were analyzed using the statistical software package SPSS, version 21. Descriptive statistics are presented as mean values and standard deviation (SD). The Pearson product moment coefficient of correlation was used to determine the relationship between hand grip strength and body composition. Statistical significance was set at  $p < 0.05$ .

## Results

Forty female PESS students were assessed to determine muscle strength and body composition. Table 1 presents the average and SD values for the participants' characteristics, muscle strength measured by hand grip strength, and body composition measured using a bioelectrical impedance analyzer. Table 2 shows the association between hand grip strength and fat-free and fat mass among Saudi female PESS students. Right- and left-hand grip strengths were significantly correlated with fat-free mass. Moreover, no statistically significant associations were found between hand grip strength and fat mass.

Table 1. Physical characteristics and hand grip strength of Saudi female PESS students

Variable	Mean ( $\pm$ SD)
Age (years)	18.7 $\pm$ 0.6
Weight (kg)	54.7 $\pm$ 10.8
Height (cm)	156.9 $\pm$ 5.5
BMI (kg/m <sup>2</sup> )	22.3 $\pm$ 3.8
Right-hand grip strength(kg)	17.5 $\pm$ 5.0
Left-hand grip strength(kg)	18.2 $\pm$ 5.6
Fat-free mass (%)	26.5 $\pm$ 2.4
Fat mass (%)	32.3 $\pm$ 7.8

Table 2. Correlations between hand grip strength for both hands and body composition among Saudi female PESS students

Variables	Body composition	
	Fat-free mass	Fat mass
Right-hand grip strength	.33 (P= .03*)	.19 (P= .24)
Left-hand grip strength	.45 (P= .00*)	.25 (P= .12)

\*Correlation is significant.

## Discussion

The present study's primary aim was to assess muscle strength in a sample of Saudi female PESS students at Taibah University and to correlate it with body composition. To the best of our knowledge, the present study is the first of its kind to assess muscle strength and body composition among Saudi female PESS students at Taibah University. The average hand grip strength for both the right and left hands of Saudi female PESS students in our study was lower than that reported in a recent descriptive cross-sectional study conducted in Riyadh among Saudi female college students (aged 19–25 years) (Shaheen et al., 2021). In fact, our hand grip strength scores for both hands (17.5 and 18.2 kg) are considerably lower than the muscle strength norms developed by Shaheen et al. (2021), who reported that the mean hand grip strength scores for dominant and non-dominant hands were 24.2 kg and 21.9 kg, respectively, for Saudi female students aged 19 years. The considerably poor hand grip strength observed in our female university students in the present study is even lower than that among older Saudi females (aged 60–64 years) whose right- and left-hand grip strengths were measured at 20.9 kg and 19.3 kg, respectively (Bindawas et al., 2019), and lower than the 25<sup>th</sup> percentile reported in a large study of 125,462 healthy adults (aged 35–70 years) conducted in 21 countries, including Saudi Arabia (Leong et al., 2016). The latter study showed that the average and the median 25<sup>th</sup> and 75<sup>th</sup> percentiles for hand grip strength, measured using a Jamar dynamometer, in Middle Eastern women (aged 35–40) were 26 kg, 22 kg, and 30 kg, respectively (Leong et al., 2016). Moreover, low hand grip strength scores observed in Saudi female PESS students may indicate poor health status. In Saudi Arabia, one study measured hand grip strength using a hand dynamometer in young and middle-aged Saudi females (aged  $30.82 \pm 7.5$  years), showing that muscle strength improved following vitamin D supplementation (Ewid et al., 2019). Overall, the poor hand grip strength values observed in Saudi female university students in Madinah are surprising, and action should be taken to address the problem, including increased muscle strength components in health-related physical fitness through resistance exercise training programs.

Additionally, our findings indicate that fat-free mass is positively correlated with hand grip strength. The significant correlation between hand grip strength and fat-free mass in Saudi female students observed in our study is in line with the findings of an earlier study that evaluated this correlation and demonstrated a positive association between right- and left-hand grip strength and fat-free mass ( $r = 0.63$  and  $r = 0.71$ , respectively) (Charlton et al., 2015). This suggests that fat-free mass is an important positive predictor of hand grip strength and also indicates that higher lean body mass is associated with higher hand grip strength. This may be attributed to a higher proportion of skeletal muscle mass rather than fat mass, which is primarily responsible for body strength, resulting in greater hand grip strength among Saudi female university students. The correlation that is often found between fat-free mass and muscle strength is often independent of fat mass. For example, Hulens et al. (2001) found a positive correlation between hand grip strength and fat mass in lean and obese women; however, when the independent effect of fat-free mass was taken into account, hand grip strength became lower in obese women than in lean women.

In conclusion, our findings indicate that muscle strength should be targeted to enhance health status among Saudi female PESS students at Taibah University in Madinah. Further, even with normal BMI found among Saudi female PESS students, body fat percentage is still alarmingly high, indicating overweight and obesity status and elevated health risk. Moreover, like most people, Saudi female PESS students in Madinah may benefit from additional resistance training programs and opportunities that will help them to increase their muscle strength. This may be facilitated by local health centers, which should offer supervised strengthening exercises aimed at improving female students' muscle strength, and through participation in programs run by local health organizations or universities. The present study is the first to have been conducted among a unique sample of Saudi female PESS students at Taibah University in Madinah and provides a foundation for the assessment of muscle strength and its association with body composition. However, further research with larger samples including both male and female university students is recommended.

**Acknowledgements:** The author would like to thank Ms. Nada Alzaidi, an accredited nutritionist, for providing valuable assistance in the data collection phase of this study

## References

- Alahmari, K. A., Kakaraparthi, V. N., Reddy, R. S., Silvian, P. S., Ahmad, I., & Rengaramanujam, K. (2019). Percentage difference of hand dimensions and their correlation with hand grip and pinch strength among schoolchildren in Saudi Arabia. *Niger J Clin Pract*, 22(10), 1356-1364. doi: 10.4103/njcp.njcp\_121\_19
- Alahmari, K. A., Silvian, S. P., Reddy, R. S., Kakaraparthi, V. N., Ahmad, I., & Alam, M. M. (2017). Hand grip strength determination for healthy males in Saudi Arabia: A study of the relationship with age, body mass index, hand length and forearm circumference using a hand-held dynamometer. *J Int Med Res*, 45(2), 540-548. doi: 10.1177/0300060516688976
- AlBuhairan, F. S., Tamim, H., Al Dubayee, M., AlDhukair, S., Al Shehri, S., Tamimi, W., . . . Al Alwan, I. (2015). Time for an Adolescent Health Surveillance System in Saudi Arabia: Findings From "Jeeluna". *Journal of Adolescent Health*, 57(3), 263-269. doi: <https://doi.org/10.1016/j.jadohealth.2015.06.009>
- Bindawas, S. M., Vennu, V., Al-Orf, S. M., Alshammari, S. A., Al-Amoud, M. M., Calder, P. C., . . . Alhamdan, A. A. (2019). Normative Data for Handgrip Strength in Saudi Older Adults Visiting Primary Health Care Centers. *Medicina*, 55(6). doi: 10.3390/medicina55060251
- Celis-Morales, C. A., Welsh, P., Lyall, D. M., Steell, L., Petermann, F., Anderson, J., . . . Gray, S. R. (2018). Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all cause mortality: prospective cohort study of half a million UK Biobank participants. *BMJ*, 361, k1651. doi: 10.1136/bmj.k1651
- Charlton, K., Batterham, M., Langford, K., Lateo, J., Brock, E., Walton, K., . . . McLean, C. (2015). Lean Body Mass Associated with Upper Body Strength in Healthy Older Adults While Higher Body Fat Limits Lower Extremity Performance and Endurance. *Nutrients*, 7(9), 7126-7142. doi: 10.3390/nu7095327
- Cooper, R., Kuh, D., Cooper, C., Gale, C. R., Lawlor, D. A., Matthews, F., & Hardy, R. (2011). Objective measures of physical capability and subsequent health: a systematic review. *Age Ageing*, 40(1), 14-23. doi: 10.1093/ageing/afq117



- Cruz-Jentoft, A. J., Baeyens, J. P., Bauer, J. M., Boirie, Y., Cederholm, T., Landi, F., . . . Zamboni, M. (2010). Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing*, *39*(4), 412-423. doi: 10.1093/ageing/afq034
- Ewid, M., AlTelbany, M., Billah, S., Saquib, N., Helmy, A., Aljundi, S., . . . Sherif, H. (2019). Muscle strength and quality of life improved after vitamin D supplementation among adult Saudi females. *Clinical Nutrition Experimental*, *26*. doi: 10.1016/j.clnex.2019.04.002
- Frontera, W. R., Hughes, V. A., Fielding, R. A., Fiatarone, M. A., Evans, W. J., & Roubenoff, R. (2000). Aging of skeletal muscle: a 12-yr longitudinal study. *J Appl Physiol (1985)*, *88*(4), 1321-1326. doi: 10.1152/jappl.2000.88.4.1321
- García-Peña, C., García-Fabela, L. C., Gutiérrez-Robledo, L. M., García-González, J. J., Arango-Lopera, V. E., & Pérez-Zepeda, M. U. (2013). Handgrip strength predicts functional decline at discharge in hospitalized male elderly: a hospital cohort study. *PLoS One*, *8*(7), e69849. doi: 10.1371/journal.pone.0069849
- Henriksson, H., Henriksson, P., Tynelius, P., Ekstedt, M., Berglind, D., Labayen, I., . . . Ortega, F. B. (2020). Cardiorespiratory fitness, muscular strength, and obesity in adolescence and later chronic disability due to cardiovascular disease: a cohort study of 1 million men. *European heart journal*, *41*(15), 1503-1510. doi: 10.1093/eurheartj/ehz774
- Holloszy, J. O. (2000). The biology of aging. *Mayo Clin Proc*, *75* Suppl, S3-8; discussion S8-9.
- Hulens, M., Vansant, G., Lysens, R., Claessens, A. L., Muls, E., & Brumagne, S. (2001). Study of differences in peripheral muscle strength of lean versus obese women: an allometric approach. *International Journal of Obesity*, *25*(5), 676-681. doi: 10.1038/sj.ijo.0801560
- Hurley, B. F., & Roth, S. M. (2000). Strength training in the elderly: effects on risk factors for age-related diseases. *Sports Med*, *30*(4), 249-268. doi: 10.2165/00007256-200030040-00002
- Jang, S.-K., & Kim, J.-H. (2020). Association between Hand Grip Strength and Self-Rated Health in Middle- and Old-Aged Korean Citizens. *Korean journal of family medicine*, *41*(1), 53-60. doi: 10.4082/kjfm.18.0200
- Kamimura, T., & Ikuta, Y. (2001). Evaluation of grip strength with a sustained maximal isometric contraction for 6 and 10 seconds. *J Rehabil Med*, *33*(5), 225-229.
- König, M., Buchmann, N., Seeland, U., Spira, D., Steinhagen-Thiessen, E., & Demuth, I. (2021). Low muscle strength and increased arterial stiffness go hand in hand. *Scientific Reports*, *11*(1), 2906. doi: 10.1038/s41598-021-81084-z
- Leong, D. P., Teo, K. K., Rangarajan, S., Kutty, V. R., Lanus, F., Hui, C., . . . Yusuf, S. (2016). Reference ranges of handgrip strength from 125,462 healthy adults in 21 countries: a prospective urban rural epidemiologic (PURE) study. *Journal of cachexia, sarcopenia and muscle*, *7*(5), 535-546. doi: 10.1002/jcsm.12112
- Lloyd, L., Tanner, D., Milne, A., Ray, M., Richards, S., Sullivan, M. P., . . . Phillips, J. (2014). Look after yourself: active ageing, individual responsibility and the decline of social work with older people in the UK. *European Journal of Social Work*, *17*(3), 322-335. doi: 10.1080/13691457.2013.829805
- Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., & James, N. (2013). Age-related decrease in physical activity and functional fitness among elderly men and women. *Clin Interv Aging*, *8*, 549-556. doi: 10.2147/cia.s44112
- Musalek, C., & Kirchengast, S. (2017). Grip Strength as an Indicator of Health-Related Quality of Life in Old Age—A Pilot Study. *Int J Environ Res Public Health*, *14*(12). doi: 10.3390/ijerph14121447
- Norman, K., Stobäus, N., Gonzalez, M. C., Schulzke, J.-D., & Pirlich, M. (2011). Hand grip strength: Outcome predictor and marker of nutritional status. *Clinical Nutrition*, *30*(2), 135-142. doi: https://doi.org/10.1016/j.clnu.2010.09.010
- Omar, M. T., Alghadir, A., & Al Baker, S. (2015). Norms for hand grip strength in children aged 6-12 years in Saudi Arabia. *Dev Neurorehabil*, *18*(1), 59-64. doi: 10.3109/17518423.2014.967878
- Omar, M. T. A., Alghadir, A. H., Zafar, H., & Al Baker, S. (2018). Hand grip strength and dexterity function in children aged 6-12 years: A cross-sectional study. *J Hand Ther*, *31*(1), 93-101. doi: 10.1016/j.jht.2017.02.004
- Ortega, F. B., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2012). Muscular strength in male adolescents and premature death: cohort study of one million participants. *BMJ*, *345*, e7279. doi: 10.1136/bmj.e7279
- Paddon-Jones, D., Sheffield-Moore, M., Urban, R. J., Sanford, A. P., Aarsland, A., Wolfe, R. R., & Ferrando, A. A. (2004). Essential Amino Acid and Carbohydrate Supplementation Ameliorates Muscle Protein Loss in Humans during 28 Days Bedrest. *The Journal of Clinical Endocrinology & Metabolism*, *89*(9), 4351-4358. doi: 10.1210/jc.2003-032159

- Qian, T., Sun, H., Xu, Q., Hou, X., Hu, W., Zhang, G., . . . Yang, G. (2020). Hyperuricemia is independently associated with hypertension in men under 60 years in a general Chinese population. *J Hum Hypertens*. doi: 10.1038/s41371-020-00455-7
- Rantanen, T., Harris, T., Leveille, S. G., Visser, M., Foley, D., Masaki, K., & Guralnik, J. M. (2000). Muscle strength and body mass index as long-term predictors of mortality in initially healthy men. *J Gerontol A Biol Sci Med Sci*, 55(3), M168-173. doi: 10.1093/gerona/55.3.m168
- Rom, O., Kaisari, S., Aizenbud, D., & Reznick, A. Z. (2012). Lifestyle and sarcopenia-etiology, prevention, and treatment. *Rambam Maimonides medical journal*, 3(4), e0024-e0024. doi: 10.5041/rmmj.10091
- Saint-Maurice, P. F., Laurson, K. R., Karsai, I., Kaj, M., & Csányi, T. (2015). Establishing Normative Reference Values for Handgrip Among Hungarian Youth. *Res Q Exerc Sport*, 86 Suppl 1, S29-36. doi: 10.1080/02701367.2015.1042354
- Sayer, A. A., Dennison, E. M., Syddall, H. E., Gilbody, H. J., Phillips, D. I., & Cooper, C. (2005). Type 2 diabetes, muscle strength, and impaired physical function: the tip of the iceberg? *Diabetes Care*, 28(10), 2541-2542. doi: 10.2337/diacare.28.10.2541
- Shaheen, A. A. M., Omar, M. T. A., & Ali, O. I. (2021). Normative values of handgrip and pinch strengths in healthy female college students in Riyadh, Saudi Arabia: a cross-sectional study. *Bulletin of Faculty of Physical Therapy*, 26(1), 1. doi: 10.1186/s43161-021-00019-x
- Silva Neto, L. S., Karnikowski, M. G., Tavares, A. B., & Lima, R. M. (2012). Association between sarcopenia, sarcopenic obesity, muscle strength and quality of life variables in elderly women. *Rev Bras Fisioter*, 16(5), 360-367.
- Studenski, S. A., Peters, K. W., Alley, D. E., Cawthon, P. M., McLean, R. R., Harris, T. B., . . . Vassileva, M. T. (2014). The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. *J Gerontol A Biol Sci Med Sci*, 69(5), 547-558. doi: 10.1093/gerona/glu010
- Timpka, S., Petersson, I. F., Zhou, C., & Englund, M. (2014). Muscle strength in adolescent men and risk of cardiovascular disease events and mortality in middle age: a prospective cohort study. *BMC Med*, 12, 62. doi: 10.1186/1741-7015-12-62
- Vilaça, K. H., Alves, N. M., Carneiro, J. A., Ferriolli, E., Lima, N. K., & Moriguti, J. C. (2013). Body composition, muscle strength and quality of active elderly women according to the distance covered in the 6-minute walk test. *Braz J Phys Ther*, 17(3), 289-296. doi: 10.1590/s1413-35552012005000093
- Visser, M., Kritchevsky, S. B., Goodpaster, B. H., Newman, A. B., Nevitt, M., Stamm, E., & Harris, T. B. (2002). Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79: the health, aging and body composition study. *J Am Geriatr Soc*, 50(5), 897-904. doi: 10.1046/j.1532-5415.2002.50217.x
- Volpi, E., Nazemi, R., & Fujita, S. (2004). Muscle tissue changes with aging. *Current opinion in clinical nutrition and metabolic care*, 7(4), 405-410. doi: 10.1097/01.mco.0000134362.76653.b2