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Grip Strength, Body Composition, and Academic Performance in College Students

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Abstract: Objectives: This study aims to investigate the complex relationship between body composition, physical fitness, and academic performance in college students, focusing on the impact of lifestyle choices related to sleep, diet, and physical activity on their well-being and academic success. Methods: Involving 405 participants, the study explores the associations between handgrip strength (HGS) and physical dimensions (height and weight) with academic performance, as measured by GPA. It seeks to understand how these physical health indicators correlate with cognitive functions in the academic context. Results: Contrary to conventional assumptions that link physical strength with higher cognitive function, our findings reveal an inverse relationship between HGS and GPA. This relationship persists even when controlling for height, weight, and sex, suggesting that factors contributing to academic performance are more complex and multifaceted. Conclusion: The study concludes that there is a counterintuitive relationship between physical strength and academic performance. It underscores the importance of adopting a holistic approach to student health and well-being, which encompasses not only physical but also emotional, psychological, and academic dimensions. Implications: These findings highlight the critical need for educational institutions and policymakers to consider a whole-person approach in their student well-being programs. Such an approach should promote balanced development across all domains to maximize academic success and overall health in college students.

Keywords: Student Success, Hand Grip Strength, GPA, BMI, Whole-Person Education.

Introduction

The prevalence of obesity within the United States is a well-known significant public health concern. Over two-thirds of Americans are overweight corresponding to a Body Mass Index (BMI) of 25 or higher, with nearly half of all adults falling into the obese (BMI of at least 30) or severely obese (BMI of 40 or higher) categories. The rate of adolescent obesity is also alarming, with nearly a third being overweight or obese, with the percentage of obese adolescents increasing by five percent in the last two decades (Sanyaolu et al., 2019). These higher BMI values lead to heightened risks for developing chronic diseases later in life, such as cardiovascular diseases (CVD), diabetes mellitus (DM), cancer, and musculoskeletal disorders (American College of Sports Medicine, 2022).

In students attending college environments, weight gain is a prevalent issue, frequently linked to a combination of factors like staying up late at night resulting in insufficient sleep, easy access to high-calorie food options, and a more sedentary lifestyle. These elements together are significant contributors to the phenomenon commonly known as the "freshman 15," referring to the common weight gain observed in new college students. Despite clear evidence that adopting healthy lifestyle choices—like regular physical activity and balanced diets—can significantly mitigate the risk of adipose weight gain among college students (Anderson et al., 2023), there remains a substantial gap in both awareness and action regarding these risks. As such, many students remain unaware of the potential consequences of their lifestyle choices (Syed et al., 2020; Werner & Betz, 2022).

Consequently, the well-documented link between poor sleep patterns, insufficient exercise, suboptimal eating habits, and elevated BMI among college students becomes increasingly significant. This connection underscores the critical need for increased education on fostering healthy academic communities to bring awareness to healthy and unhealthy habits and lifestyle modifications. Effective education and intervention strategies can play a crucial role in mitigating these risks, thereby promoting overall well-being in the college student population (Anderson et al., 2023; Mishra et al., 2015; Pilcher et al., 2021; Syed et al., 2020).

Effective health education and communication relies on simple methods for measuring personal health and fitness. Most college students do not have access to lab equipment to properly measure percent body fat, so the BMI was created to predict body fat without any invasive procedures. However, BMI is insufficient to predict all spheres of health and fitness, so colleges and college students should seek more simple tools for general fitness assessment. An alternative approach to measuring overall health and level of physical activity is Hand Grip Strength (HGS). This method measures the maximum static force exerted by the hands, and it is routinely employed for a variety of purposes, including assessing hand function, determining disease severity, and evaluating the efficacy of treatments.

Crucially, HGS has been identified as a significant predictor of cardiovascular health and overall well-being, particularly in older adults. This cost-effective tool has gained recognition for its wide-ranging health implications, supported by extensive research. Studies conducted by Hansen et al. (2013), Leong et al. (2015), Rantanen et al. (1992), Shao et al. (2023), and Prasitsiriphon and Pothisiri (2018) have underscored the role of HGS as a vital health marker, underlining its significance beyond mere physical evaluation.

In younger adults, the relationship between BMI and HGS is multifaceted. Firstly, those who engage in physical activities, especially weight training or rock climbing, often exhibit higher HGS values. Conversely, higher HGS values are also observed in students with elevated BMIs, which can be indicative of a higher body fat percentage and potential health risks. This dual association underscores the complexity of using HGS as a health metric for younger adults, revealing its sensitivity to both fitness and adiposity. Thus, it becomes evident that HGS readings must be interpreted within a broader context, taking into account an individual's overall health profile and age (Amo-Setién et al., 2020; Xu et al., 2023; Zaccagni et al., 2020).

There is also a well-documented link between increased physical activity and improved academic performance, including higher GPA scores (Broaddus et al., 2021). Engaging in regular physical activity is associated with numerous psychological benefits, such as improved mood, decreased symptoms of anxiety and depression, and enhanced emotional stability (Churchill et al., 2022; Goldstein et al., 2018; Klaperski & Fuchs, 2021; Leuchter et al., 2022). This intricate web of relationships between physical health, mental well-being, and academic achievement highlights the multifaceted role of physical activity in the lives of young adults.

Our study investigates this area by focusing on college students and examining how HGS relates to academic performance, with a particular emphasis on GPA. This approach addresses a notable gap in existing literature, which has extensively explored the connection between HGS and cognitive function in older adults (Dercon et al., 2021; Jiang et al., 2022; Kim & Kim, 2022; Kim et al., 2021; Lu et al., 2021; McGrath et al., 2020; Yang et al., 2018), but has not sufficiently investigated this dynamic in younger populations. Our objective is to bridge this gap by exploring the interplay between HGS, BMI, physical activity, and academic success among college students. Through this investigation, we aim to provide a comprehensive understanding of the correlations between physical health, academic performance, and overall well-being in this demographic. The findings from this study are expected to be instrumental in developing targeted interventions that support not just the physical health but also the academic success of college students.

Methods

Handgrip Procedures

Handgrip strength and BMI were measured by trained personnel on N = 405 predominantly first-year college students enrolled in required health and fitness classes, (168 males; 41%) and (237 females; 59%) between September 2022 and November 2023. A calibrated Jamar Plus+, digital hand dynamometer was used to measure HGS according to the manufacturer instructions. Subjects were tested in a seated position, with the arm held next to the body, and the elbow flexed at 90 degrees, with the wrist extended between 0 and 30 degrees. Each subject performed 3 maximal effort trials per hand, alternating between right and left hands, with one-minute rest between each trial. Upon completion of the participant's testing, the test average, standard deviation, and coefficient of variation was calculated automatically by the dynamometer and recorded for further analysis.

Dataset Preparation

The HGS dataset from the N = 405 predominantly first-year college students were joined with end-of-semester grade point average (GPA), height in meters (m), and body mass in kilograms (kg). The anthropometric measures were collected as part of the institution's regular health and physical exercise assessment procedures. Using the height and weight data, we computed the BMI for each student. From the HGS values we calculated the Maximum Average Handgrip Strength (MaxAvgHGS), which represents the highest average HGS over three trials. This was determined by comparing the mean HGS values for the left and right hands of each participant. To further refine our analysis, we incorporated the Normalized MaxAvgHGS into our dataset. This normalization was performed using allometric scaling, a method that has been extensively validated in prior studies (Kocher et al., 2019; Neto et al., 2017; Vanderburgh, 1995), where the scaling coefficients b1 and b2 in Equation 0 below were determined using regression in R-4.3.2 (R Core Team, 2023):

(0) $\text{Normalized MaxAvgHGS} = -\ln(\text{MaxAvgHGS}) - b1 \times \ln(\text{body mass}) - b2 \times \ln(\text{height})$

The research presented in this paper forms part of a larger project, which has been approved and is covered under the Institutional Review Board with the reference IRB#: F2018-14. The dataset is available under a CC0 license from figshare (Albaugh et al., 2024).

Results

Investigating the relationship between HGS and academic performance, as gauged by semester GPA, necessitated a thorough consideration of several confounding variables. For instance, both sex and body size are known to influence HGS (Amo-Setién et al., 2020; Xu et al., 2023; Zaccagni et al., 2020) and, in the case of sex as well as healthy and physically active lifestyles, have a documented impact on academic performance (Broaddus et al., 2021). This complexity highlights the need for a nuanced approach in exploring the interplay between physical strength, body composition, and educational outcomes.

HGS and BMI: Controlling for Sex

Our initial analysis explored the connection between maximum average HGS (MaxAvgHGS) and BMI while controlling for Sex. The results revealed a significant and positive relationship between MaxAvgHGS and BMI (β = .608, t = 3.735, $p < .001$). Sex, as anticipated, emerged as a significant predictor of HGS ($p < .001$). The relationships between all variables can be found in Equation 1, which accounted for 49.3% of the variance in MaxAvgHGS (Adjusted R^2 = .493, F = 197.5, $p < .001$):

(1) MaxAvgHGS = 48.233 + .608 × BMI + 33.817 × Sex (male)

HGS in Relation to Body Mass and Height: Dissecting BMI

Next, we separated BMI into its constituent elements—mass (kg) and height (m)—reassessing their relationship with MaxAvgHGS while continuing to control for Sex. Body mass exhibited a significant positive association with MaxAvgHGS (β = .260, t = 4.842, $p < .001$), as did height (β = 57.569, t = 5.314, $p < .001$), see Equation 2. Sex maintained its significance as a predictor in this model, which surpassed the previous one in overall performance, explaining 56% of the variance in MaxAvgHGS (Adjusted R^2 = .560, F = 172.3, $p < .001$):

(2) MaxAvgHGS = −49.065 + .260 × body mass + 57.569 × height + 23.355 × Sex (male)

These results not only underscore the importance of considering various measures of body size but also advocate for splitting BMI into its constituent elements to attain a more comprehensive and nuanced understanding of their relationship with HGS rather than using the standard BMI measurement.

HGS and GPA

One strategy to mitigate the effects of body size variations on Hand Grip Strength (HGS) is the implementation of allometric normalization, a technique well-documented and validated in previous research (Kocher et al., 2019; Neto et al., 2017; Vanderburgh, 1995). To comprehensively assess the relationship between HGS and GPA while addressing the influence of body size, we adopted a dual-model approach.

In the first model, we incorporated body size adjustments directly into the HGS measurements through allometric normalization. This method enabled us to create a normalized HGS variable that accounted for variations in body size, providing a more accurate reflection of an individual's strength capacity. We then performed linear regression of the normalized HGS values with GPA, controlling for Sex.

In the second model, we took a different tack, choosing to juxtapose the raw, non-normalized HGS values with separate quantifications of body mass and height. This approach allowed us to dissect the contributions of these fundamental components of body size, offering a granular perspective on how each aspect uniquely interacts with and influences HGS. We then performed linear regression of the non-normalized HGS values with GPA, controlling for body mass, height, and Sex.

The results of our first model indicated a significant negative association between term GPA and normalized MaxAvgHGS ($\beta = -.260$, $t = -3.391$, $p < .001$), suggesting that higher grip strength correlates with lower academic performance. Sex remained significant ($p < .001$). However, this model, see Equation 3, accounted for only 15.7% of the variance in normalized MaxAvgHGS (Adjusted $R^2 = .157$) but was overall still statistically significant ($F = 38.47$, $p < .001$).

(3) Normalized MaxAvgHGS = 5.759 − .260 × GPA + .902 × Sex (male)

The results of our second model, examining the relationship between BMI components—body mass in kilograms and height in meters (instead of BMI)—alongside term GPA and MaxAvgHGS, once again controlling for Sex, revealed significant positive associations between MaxAvgHGS and both body mass ($\beta = .240$, $t = 4.442$, $p < .001$) and height ($\beta = 63.027$, $t = 5.722$, $p < .001$). Term GPA maintained a significant negative relationship with MaxAvgHGS ($\beta = -2.564$, $t = -2.372$, $p = .018$), again suggesting that higher hand grip strength corresponds to lower GPAs. This model, see Equation 4, explained a much more substantial 56.5% of the variance in MaxAvgHGS (Adjusted $R^2 = .565$) and exhibited an excellent overall fit ($F = 132.1$, $p < .001$).

(4) MaxAvgHGS = −47.763 − 2.564 × GPA + 22.465 × Sex (male) + .240 × body mass + 63.027 × height

Thus, we identified a significant negative relationship between HGS and academic performance, irrespective of the method used to account for body size, and even after adjusting for Sex—a recognized confounding factor for both HGS and GPA. The second, more comprehensive model, which incorporated both mass and height, demonstrated considerably greater explanatory power. However, it only slightly surpassed that of its equivalent predecessor, which did not include the GPA factor (Adjusted $R^2 = .560$).

Discussion

In the context of older adults, low HGS is often associated with declining cognitive function, as highlighted by Jiang et al. (2022), Kim and Kim (2022), and others cited in our introduction. However, our current research emphasizes that this connection may predominantly apply to older populations. Among college-age individuals, the relationship between physical health indicators and academic performance appears more complex. Our study reveals a negative correlation between HGS and GPA for college-age students. This observation indicates that students with higher HGS might prioritize strength training and physical development at the expense of academic pursuits, diverging from the conventional belief that muscle strength and cognitive function, assessed here via GPA, are unconnected in the younger demographic. Regardless, our research identifies a unique relationship between high HGS and lower GPA for college-age students, suggesting that HGS might be an indicator of lifestyle choices rather than cognitive abilities.

Limitations

Some of the limitations of this study include the cross-sectional design and a convenience sample. A portion of the participants were in a weight training class, which may have included college students who had increased levels of strength compared to those who de-emphasize strength training as part of the healthy lifestyle choices one can make. Future studies should employ controlled experimental designs with diverse samples to enhance generalizability and consider measuring and controlling for additional variables, such as exercise and dietary habits.

Conclusion

This study contributes a novel perspective on the relationship between HGS, academic performance, and gender in college students. The negative correlation challenges existing findings, emphasizing the importance of considering lifestyle factors in investigating physical strength and academic success. Practical applications include tailored interventions for individuals that promote a more holistic fitness approach, emphasizing a variety of health behaviors that contribute to improved academic performance and health. Continued investigation is critical to better understanding the complex dynamics between physical health, academic success, and lifestyle choices among college students.

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None.

Availability of data and material

The dataset is available under a CC0 license from figshare (Albaugh et al., 2024).

Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all participants for being included in the study. The research presented is covered under the Institutional Review Board with the reference IRB#: F2018-14.

References

Albaugh, E., Blackburn, J., Bloom, M., Castile, E., Gomes, V., Grooms, K., Jost, S., Kim, C., Lang, A., Mankin, N., Moseley-Broshous, K., Nelson, P., Pittman, K., Repetto-Taylor, R., Salcedo, C., Shoot, I., Skinstad, D., Swartwood, S., Trompler, E., … Winkler, C. (2024). *Grip strength, body composition, and academic performance in college students* (Version 1) [Data set]. figshare. https://doi.org/10.6084/m9.figshare.25138943.v1

American College of Sports Medicine. (2022). Chapter 9: Exercise prescription for individuals with metabolic disease and cardiovascular disease risk factors. In G. Liguori (Ed.), *ACSM's guidelines for exercise testing and prescription, 11th edition*, (pp. 276-306). Wolters Kluwer.

Amo-Setién, F. J., Leal-Costa, C., Abajas-Bustillo, R., González-Lamuño, D., & Redondo-Figuero, C. (2020). Factors associated with grip strength among adolescents: An observational study. *Journal of Hand Therapy*, *33*(1), 96–102. https://doi.org/10.1016/j.jht.2018.10.005

Anderson, J. R., Bloom, M. J., Broshous, W. T., Chen, G. Y. X., Jost, S. R., Lang, A. S. I. D., Neto, L. C. L. D. S., Mankin, N. V., McMahan, E. R., Merheb, J. A., Nelson, P. P., & Valderrama-Araya, E. F. (2023). Can leading a physically active and healthy lifestyle prevent gaining the freshman 15?. *Human Movement*, *24*(3). https://doi.org/10.5114/hm.2023.127976

Broaddus, A. M., Jaquis, B. J., Jones, C. B., Jost, S. R., Lang, A. S. I. D., Li, A., Li, Q., Nelson, P. P., & Spear, E. M. (2021). Fitbits, field-tests, and grades: The effects of a healthy and physically active lifestyle on the academic performance of first year college students. *International Journal of Sport & Exercise Psychology*, *19*(1), 90–101. https://doi.org/10.1080/1612197X.2019.1623062

Churchill, R., Teo, K., Kervin, L., Riadi, I., & Cosco, T. D. (2022). Exercise interventions for stress reduction in older adult populations: A systematic review of randomized controlled trials. *Health Psychology and Behavioral Medicine*, *10*(1), 913–934. https://doi.org/10.1080/21642850.2022.2125874

Dercon, Q., Nicholas, J. M., James, S.-N., Schott, J. M., & Richards, M. (2021). Grip strength from midlife as an indicator of later-life brain health and cognition: Evidence from a British birth cohort. *BMC Geriatrics*, *21*. Article 475. https://doi.org/10.1186/s12877-021-02411-7

Goldstein, E., Topitzes, J., Brown, R. L., & Barrett, B. (2018). Mediational pathways of meditation and exercise on mental health and perceived stress: A randomized controlled trial. *Journal of Health Psychology*, *25*(12), 1816–1830. https://doi.org/10.1177/1359105318772608

Hansen, D., Peeters, S., Zwaenepoel, B., Verleyen, D., Wittebrood, C., Timmerman, N., & Schotte, M. (2013). Exercise assessment and prescription in patients with type 2 diabetes in the private and home care setting: Clinical recommendations from AXXON (Belgian Physical Therapy Association). *Physical Therapy*, *93*(5), 597–610. https://doi.org/10.2522/ptj.20120400

Jiang, R., Westwater, M. L., Noble, S., Rosenblatt, M., Dai, W., Qi, S., Sui, J., Calhoun, V. D., & Scheinost, D. (2022). Associations between grip strength, brain structure, and mental health in >40,000 participants from the UK Biobank. *BMC Medicine*, *20*, Article 286. https://doi.org/10.1186/s12916-022-02490-2

Kim, H., Kim, S. H., Jeong, W., Jang, S. I., Park, E. C., & Kim, Y. (2021). Association between change in handgrip strength and cognitive function in Korean adults: A longitudinal panel study. *BMC Geriatrics*, *21*, Article 671. https://doi.org/10.1186/s12877-021-02610-2

Kim, K., & Kim, H. (2022). Handgrip strength and cognitive function among elderly Koreans: Insights from the Korean Longitudinal Study of Ageing. *International Journal of Environmental Research and Public Health*, *19*(9), 5262. https://doi.org/10.3390/ijerph19095262

Klaperski, S., & Fuchs, R. (2021). Investigation of the stress-buffering effect of physical exercise and fitness on mental and physical health outcomes in insufficiently active men: A randomized controlled trial. *Mental Health and Physical Activity*, *21*, 100408. https://doi.org/10.1016/j.mhpa.2021.100408

Kocher, M. H., Oba, Y., Kimura, I. F., Stickley, C. D., Morgan, C. F., & Hetzler, R. K. (2019). Allometric grip strength norms for American children. *The Journal of Strength & Conditioning Research*, *33*(8), 2251-2261. https://doi.org/10.1519/JSC.0000000000002515

Leong, D. P., Teo, K. K., Rangarajan, S., Lopez-Jaramillo, P., Avezum, A., Jr., Orlandini, A., Seron, P., Ahmed, S. H., Rosengren, A., Kelishadi, R., Rahman, O., Swaminathan, S., Iqbal, R., Gupta, R., Lear, S. A., Oguz, A., Yusoff, K., Zatonska, K., Chifamba, J., …Yusuf, S. (2015). Prognostic value of grip strength: Findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet*, *386*(9990), 266-273. https://doi.org/10.1016/S0140-6736(14)62000-6

Leuchter, R. K., Stuber, M. L., McDonald, A. L., & Croymans, D. M. (2022). Relationship between exercise intensity and stress levels among U.S. medical students. *Medical Education Online*, *27*(1). https://doi.org/10.1080/10872981.2022.2027651

Lu, S., Herold, F., Zhang, Y., Lei, Y., Kramer, A. F., Jiao, C., Yu, Q., Doig, S., Li, J., Yan., Z, Kuang, J., Wang, T., & Zou, L. (2021). Higher handgrip strength is linked to better cognitive performance in Chinese adults with hypertension. *Brain Sciences*, *11*(8), 985. https://doi.org/10.3390/brainsci11080985

McGrath, R., Vincent, B. M., Hackney, K. J., Robinson-Lane, S. G., Downer, B., & Clark, B. C. (2020). The longitudinal associations of handgrip strength and cognitive function in aging Americans. *Journal of the American Medical Directors Association*, *21*(5), 634-639. https://doi.org/10.1016/j.jamda.2019.08.032

Mishra, S., Rout, R. P., & Jayakrishnan, K. (2015). A correlative study to assess the Internet addiction and health status among the students of SOA University Bhubaneswar. *International Journal of Nursing Education*, *7*(4), 82–86. https://doi.org/10.5958/0974-9357.2015.00198.1

Neto, G. A. M., Oliveira, A. J., de Melo Pedreiro, R. C., Pereira-Junior, P. P., Machado, S., Neto, S. M., & Farinatti, P. T. (2017). Normalizing handgrip strength in older adults: An allometric approach. *Archives of Gerontology and Geriatrics*, *70*, 230-234. https://doi.org/10.1016/j.archger.2017.02.007

Pilcher, J. J., Erikson, D. N., & Yochum, C. A. (2021). Fighting the freshman fifteen: Sleep, exercise, and BMI in college students. *American Journal of Health Promotion*, *35*(4), 580–583. https://doi-org.oralroberts.idm.oclc.org/10.1177/0890117120969065

Prasitsiriphon, O., & Pothisiri, W. (2018). Associations of grip strength and change in grip strength with all-cause and cardiovascular mortality in a European older population. *Clinical Medicine Insights: Cardiology*, *12*. https://doi.org/10.1177/1179546818771894

R Core Team. (2023). *R (4.3.2): A language and environment for statistical computing.* R Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org/

Rantanen, T., Parkatti, T. & Heikkinen, E. (1992). Muscle strength according to level of physical exercise and educational background in middle-aged women in Finland. *European Journal of Applied Physiology and Occupational Physiology, 65*, 507–512. https://doi.org/10.1007/BF00602356

Sanyaolu, A., Okorie, C., Qi, X., Locke, J., & Rehman, S. (2019). Childhood and adolescent obesity in the United States: A public health concern. *Global Pediatric Health*, *6*. https://doi.org/10.1177/2333794X19891305

Shao, J., Yao, B., Yu, Z., Xu, J., Wu, J., Ma, Y., Zheng, L., & Sun, Z. (2023). Prevalence of ideal cardiovascular health and its relationship with relative handgrip strength in rural northeast China. *Frontiers in Cardiovascular Medicine*, *10*, 1124757. https://doi.org/10.3389/fcvm.2023.1124757

Syed, N. K., Syed, M. H., Meraya, A. M., Albarraq, A. A., Al-kasim, M. A., Alqahtani, S., Makeen, H. A., Yasmeen, A., Banji, O. J. F., & Elnaem, M. H. (2020). The association of dietary behaviors and practices with overweight and obesity parameters among Saudi university students. *PLoS ONE, 15*(9), Article e0238458. https://doi.org/10.1371/journal.pone.0238458

Vanderburgh, P. M., Mahar, M. T., & Chou, C. H. (1995). Allometric scaling of grip strength by body mass in college-age men and women. *Research Quarterly for Exercise and Sport*, *66*(1), 80-84. https://doi.org/10.1080/02701367.1995.10607658

Werner, E., & Betz, H. H. (2022). Knowledge of physical activity and nutrition recommendations in college students. *Journal of American College Health, 70*(2), 340–346. https://doi.org/10.1080/07448481.2020.1750412

Xu, T., Li, X., Wang, D., Zhang, Y., Zhang, Q., Yan, J., Jiang, J., Liu, W., & Chen, J. (2023). Hand grip strength should be normalized by weight not height for eliminating the influence of individual differences: Findings from a cross-sectional study of 1,511 healthy undergraduates. *Frontiers in Nutrition*, *9*, 1063939. https://doi.org/10.3389/fnut.2022.1063939

Yang, L., Koyanagi, A., Smith, L., Hu, L., Colditz, G. A., Toriola, A. T., López Sánchez, G. F., Vancampfort, D., Hamer, M., Stubbs, B., & Waldhör, T. (2018). Hand grip strength and cognitive function among elderly cancer survivors. *PloS One*, *13*(6), Article e0197909. https://doi.org/10.1371/journal.pone.0197909

Zaccagni, L., Toselli, S., Bramanti, B., Gualdi-Russo, E., Mongillo, J., & Rinaldo, N. (2020). Handgrip strength in young adults: Association with anthropometric variables and laterality. *International Journal of Environmental Research and Public Health*, *17*(12), 4273. https://doi.org/10.3390/ijerph17124273