

# Development and Psychometric Evaluation a Novel Rubber-Ball Hand Strength Measurement Tool for Children Aged 6-12 Years

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## Abstract

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**Background:** The musculoskeletal system plays a crucial role in movement and balance, which are coordinated with the nervous system. Therefore, muscle strength has both physiological and clinical implications. Furthermore, the musculoskeletal system, including muscles, undergoes developmental stages with age. Consequently, significant differences in the musculoskeletal system between children and adults are evident. This affects differences in muscle strength measurements, particularly those related to the tools used, which, in turn, influence anthropometric measurements.

**Methods:** This study used a quasi-experimental design involving 70 child respondents aged 6–12 years to evaluate the extent to which the developed tool produces consistent measurements of left and right hands through bilateral correlation, using a simple hand muscle strength measurement tool that can be effectively used in the pediatric population. Evaluation measurement uses the Intraclass Correlation Coefficient (ICC).

**Result:** The reliability test using the ICC with a two-way mixed model and absolute agreement type showed that measurements at the 7 cm position demonstrated good reliability, with a single-measure ICC of 0.774 and an average-measure ICC of 0.872.2. The measurements at the 8 cm position demonstrated higher reliability, with a single-measure ICC of 0.870 (95% CI: 0.797–0.918), which is considered good, and an average-measure ICC of 0.931 (95% CI: 0.887–0.957), which is considered very good. Furthermore, the Cronbach's Alpha value for the 8 cm measurement (0.933) was also higher than for the 7 cm measurement (0.879).

**Conclusion:** This research concludes that measuring hand muscle strength at the 8 cm position demonstrates greater consistency and reliability than at the 7 cm position, and is therefore recommended for use as a measurement method in research and clinical practice.

**Keywords:** Clinical conditions, hand muscle strength, children's muscle strength, rubber-ball, muscle mass

## BACKGROUND

The musculoskeletal system is one of the essential physiological systems in the human body, responsible for facilitating movement and maintaining postural stability. It is composed of muscular and skeletal structures that work synergistically to support various physical activities, such as body motion, flexion and extension, and balance maintenance. Skeletal muscles, which constitute the primary component of the musculoskeletal system, play a critical role in regulating body posture and movement. Their function largely depends on neuromuscular coordination involving both the central and peripheral nervous systems, which regulate muscle contraction and enable smooth and well-coordinated movements. Throughout life, the musculoskeletal system develops with age, and this can be observed in the size and strength of the muscles that accompany it. In infancy, toddlerhood, childhood, and into adolescence, the development of the size of the extremities of the hands and feet can show significant size development, and this will affect muscle strength (1). Therefore, muscle strength across age ranges will differ and is influenced by anthropometry (2), as well as other factors, such as exercise intensity, which also affect the musculoskeletal system, especially muscles (3). This is the basis for understanding anthropometric development and its relationship to muscle strength. How muscle strength is influenced by the number of fibers, thickness, and size of the smooth muscles that make up the skeleton (4).

In children, muscle development and musculoskeletal function are influenced by factors such as age, nutritional status, and overall physical condition (2). During growth and development, assessment of hand muscle strength serves not only to evaluate the child's health status but also to monitor their physiological development (5). Therefore, measuring hand muscle strength in children is essential for identifying potential musculoskeletal disorders that may emerge as they grow older. Research on hand strength assessment in pediatric populations remains limited, as most existing measurement tools are designed primarily for adults. This underscores the urgent need to develop hand-strength measurement instruments specifically tailored for children, accounting for anatomical differences and the distinct patterns of muscle development in this age group (6).

Several previous studies have developed and evaluated various types of hand muscle strength measurement tools, such as hand dynamometers and pinch gauges, across different age groups and populations. Demonstrated that physical exercise, including fitness training, has a significant impact on improving hand muscle strength (7,8). However, most of these studies have focused on adult or adolescent populations, and there has been limited advancement in creating measurement tools that are both effective and valid for use in children. Therefore, the present study aims to evaluate the extent to which the developed tool can produce consistent measurements of left and right hands through bilateral correlation of a simple hand muscle strength measurement tool that can be used effectively in the pediatric population. The tool is designed using rubber balls with diameters tailored to the anatomical hand size of children, and the study examines whether this instrument can produce valid and reliable measurements of hand muscle strength in children.

The tool's development takes into account the media's size and the materials used. In children, in addition to the hand's diameter, the hand's condition differs from that of adults, with a different skin thickness. This is related to age and skin structure (9,10). Therefore, the use of media such as rubber is a consideration when measuring muscle strength to reduce the risk of injury or pain. The development of this tool used natural rubber (NR) as the main component (11). This was chosen because natural rubber contains more rubber than latex, which only contains 25-40%. Therefore, latex is more likely to cause allergies than NR. Therefore, NR is more comfortable on the skin than latex and is less likely to cause injury when pressed during measurement.

The focus of this study is to develop and evaluate a hand muscle strength-measuring device specifically designed for children, accounting for anatomical differences and variations in muscle strength across age groups (12). This research is expected to contribute to the development of more

practical, clinically useful assessment tools for healthcare professionals to evaluate children's physical development and hand muscle function (10). Previous studies have developed similar devices for adult populations (6,13). Accordingly, this study also aims to provide deeper insight into the influence of factors such as age and body size on hand muscle strength, thereby laying the groundwork for the creation of more refined and effective measurement instruments in the future.

## **METHODS**

### ***Study Design***

This study employed a quasi-experimental design, in which the independent variables were not manipulated randomly; however, the instrument was still tested by administering measurements or interventions to a specific group of subjects. This design was selected to evaluate the extent to which the developed tool can produce bilateral correlation measurements of the right and left hands and its reliability when used with children as the first step. The study was conducted at Ad Dhuha Elementary School in Pangkalpinang City and involved children who met the inclusion criteria of having normal hand muscle strength with no indications of finger muscle impairment within the pediatric age group.

### ***Sample/Participants***

This study involved 70 child respondents aged 6 to 12 years, selected using a purposive sampling method. The inclusion criteria required participants to have normal hand muscle strength and no disorders or abnormalities affecting hand muscle function. The sample size was determined using the formula for calculating differences in mean values as described by Charan & Biswas, which is commonly applied in quantitative studies. Based on this calculation, a total of 70 participants was obtained. The sample consisted of both boys and girls with a nearly equal distribution.

### ***Instruments***

The hand muscle strength measurement process in this study used a simple instrument specifically developed to assess hand strength in children. The device consisted of rubber balls with diameters of 7 cm and 8 cm, each filled with air at a controlled pressure. Measurements were performed by instructing participants to grasp the rubber balls alternately with their right and left hands. When the ball was squeezed, the movement of the fingers compressed the rubber, changing the internal air pressure. This pressure alteration was transmitted to a connected manometer, and the deflection of the manometer needle indicated the force exerted. The displayed pressure values were then used to assess each respondent's hand muscle strength. Measurements were conducted on both the right and left hands using the two different ball sizes to determine whether differences existed between hands or between ball diameters. Throughout the measurement process, trained survey personnel or enumerators supervised the procedure to ensure that all assessments were performed correctly and in accordance with the established protocol.

### ***Data Analysis***

Data analysis in this study was conducted using SPSS version 22 to process the measurements obtained during hand muscle strength assessment. The analytical approach consisted of descriptive and inferential statistics. Descriptive statistics were used to provide an overview of respondent characteristics, including age and gender distributions, as well as the mean hand muscle strength values obtained from measurements with the two instrument sizes (7 cm and 8 cm in diameter). This allowed the researchers to visualize the overall distribution and the data's central tendencies. To examine the relationships among the variables, reliability tests were performed using the Intraclass Correlation Coefficient (ICC) (14,15). Previous diagnostic tool assessments for muscle strength have often been

conducted by comparing two different measuring instruments (16,17). However, in this study, internal comparison was performed by examining the mean values obtained from the left and right hands. This approach was used because the instrument is still in the developmental stage and measures strength values based on units of Psi or Bar.

Univariate analysis was conducted to describe individual variables, including age distribution, sex, and hand muscle strength values measured with both rubber ball sizes in the right and left hands. Although anthropometric factors are known to be associated with hand muscle strength, this study primarily assessed the instrument's reliability (12,18). Inferential statistical tests were used to examine hypotheses about differences in mean muscle strength values obtained from measurements with different ball diameters. All of these analyses were performed to ensure that the measurement tool used in this study is valid, reliable, and appropriate for assessing hand muscle strength in children (19,20).

Further validation of this instrument will require additional testing stages, including comparative analyses using standardized measurement tools. However, such comparisons must take into account the instrument's functional suitability for use in children. In the future, this tool may also be applied to assess hand muscle strength in children with specific clinical conditions, such as cerebral palsy, and others (11).

### **Ethical Consideration**

Ethical approval for the study titled “Development of a Hand Muscle Strength Measurement Tool for Children” was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Pangkalpinang. After thoroughly reviewing the proposed research protocol, the committee concluded that the study was ethically appropriate to proceed. The review indicated that the protocol prepared by the researcher, Ns. Eny Erlinda Widyaastuti, M.Kep, Sp.Kep.MB complied with all applicable ethical standards. Therefore, the study was declared “ethically feasible” and approved for implementation in accordance with established research ethics guidelines. The ethical clearance was issued under certificate number 119/EC/KEPK-PKP/V/2022, confirming that no revisions were required regarding ethical aspects of the study procedures.

## **RESULT AND DISCUSSION**

### **Characteristics of Respondents**

The sample consisted of 37 boys (52.9%) and 33 girls (47.1%). Participants ranged in age from 6 to 12 years, with a mean age of 9.2 years and a standard deviation of 1.32. Table 1 displays the age distribution of the participants.

**Table 1.** Characteristics of Respondents (n=70)

| Characteristics | Category | n  | %    | Mean | SD   | Min-Max |
|-----------------|----------|----|------|------|------|---------|
| Gender          | Male     | 37 | 52,9 | 9,2  | 1,32 | 6-12    |
|                 | Female   | 33 | 47,1 |      |      |         |
| Aged            |          |    |      |      |      |         |

*Note: SD = Standard Deviation; n = frequency;*

Each hand muscle strength measurement tool demonstrated different mean values, which are presented in the following table.

**Table 2.** Mean Measurement Result by Instrument Type in Psi Units

| No | Category              | Mean | SD   | Minimum | Maximum |
|----|-----------------------|------|------|---------|---------|
| 1  | Diameter (7 cm) Right | 2,65 | 1,35 | 0,0     | 6       |
| 2  | Diameter (7 cm) Left  | 2,91 | 3,3  | 0,0     | 25      |
| 3  | Diameter (8 cm) Right | 2,69 | 0,87 | 1,0     | 5       |
| 4  | Diameter (8 cm) Left  | 2,57 | 0,94 | 0,5     | 5       |

*Note: SD = Standard Deviation*

The mean hand muscle strength measurements in children were obtained using instruments with two rubber ball diameters (7 cm and 8 cm) for both the right and left hands. According to the data, the mean hand muscle strength for the left hand using the 7 cm ball (2.91 Psi) exceeded that of the right hand (2.65 Psi). In contrast, with the 8 cm ball, the mean muscle strength for the left hand (2.57 Psi) was lower than that of the right hand (2.69 Psi).

The data also demonstrate considerable variability, as indicated by the relatively large standard deviation (SD) for the left-hand measurement with the 7 cm ball (SD = 3.30). This variability suggests substantial differences in muscle strength among participants. Potential contributing factors include variations in hand size, individual muscle strength, age, gender, and overall physical condition.

Reliability test results for the hand muscle strength measurement tool, using two rubber ball diameters (7 cm and 8 cm) for both hands and measured in Psi units, are presented. The instrument's validity was assessed using the Intraclass Correlation Coefficient (ICC) to determine its accuracy in measuring hand muscle strength.

**Table 3.** Reliability Test Results for Hand Muscle Strength Using the 7 cm Diameter Ball for Left and Right Hands in Psi Units

| Parameter              | Value | 95% CI        | p-value | Interpretasi          |
|------------------------|-------|---------------|---------|-----------------------|
| Cronbach's Alpha       | 0,879 | -             | -       | Good reliability      |
| ICC (Single Measures)  | 0,774 | 0,654 – 0,855 | 0,000   | Good reliability      |
| ICC (Average Measures) | 0,872 | 0,791 – 0,922 | 0,000   | Very good reliability |

Note: p-value = 0,000; Cronbach's Alpha = 0,8

The results of the reliability test using the ICC with a two-way mixed model and absolute agreement type showed a single measure ICC value of 0.774 (95% CI: 0.654–0.855), which is included in the good reliability category. Meanwhile, the average ICC value of 0.872 (95% CI: 0.791–0.922) indicates higher reliability.

**Table 4.** Reliability Test Results for Hand Muscle Strength Using the 8 cm Diameter Ball for Left and Right Hands in Psi Units

| Parameter              | Value | 95% CI        | p-value | Interpretasi          |
|------------------------|-------|---------------|---------|-----------------------|
| Cronbach's Alpha       | 0,933 | -             | -       | Very good reliability |
| ICC (Single Measures)  | 0,870 | 0,797 – 0,918 | 0,000   | Good reliability      |
| ICC (Average Measures) | 0,931 | 0,887 – 0,957 | 0,000   | Very good reliability |

Note: 98%CI; p-value= 0,000

The results of the reliability test using the Intraclass Correlation Coefficient (ICC) with a two-way mixed model and absolute agreement type showed a single-measure ICC of 0.870 (95% CI: 0.797–0.918), which falls within the good reliability category. Meanwhile, the average ICC value of 0.931 (95% CI: 0.887–0.957) indicates very good reliability. The Cronbach's Alpha value of 0.933 also indicates very high internal consistency.

## DISCUSSION

Muscle strength in children differs from that of adults and older individuals due to developmental differences in hand anatomy and physiology (20). The muscle strength measurement tool developed for this study accounted for variations in hand dimensions between children and adults. Accordingly, the rubber balls used for measurement in this age group were designed with diameters of 7 cm and 8 cm.

Measurements obtained with these instruments produced different mean values depending on ball size and body side (12). These results illustrate the influence of anatomical size on muscle performance.

Participants in this study ranged in age from 6 to 11 years, as children within this range are generally able to coordinate movements and follow instructions. At this developmental stage, children can also make informed decisions regarding participation. Therefore, research procedures were designed to prioritize beneficence, safety, and voluntary participation.

The proportion of male and female participants was not a primary focus of this study. However, gender is recognized as a factor associated with muscle strength, as muscle mass, habitual activities, physical activity levels, and nutritional status can influence muscle strength (21). Therefore, the study maintained a balanced number of male and female participants to prevent any imbalance from affecting the research objectives. This investigation serves as an initial step in establishing reference values for hand muscle strength using the newly developed measurement tool. The instrument utilized a rubber ball connected to a manometer to assess hand muscle strength. In addition to generating mean strength values for the pediatric age group, the study compared measurement consistency between the left and right hands.

Several previous studies have examined the validity of hand muscle strength measurement instruments, but these investigations have primarily focused on adults and adolescents (22). Validation in pediatric populations requires instruments tailored to children's anthropometric characteristics. The instrument in this study used 7 cm and 8 cm rubber balls to accommodate typical pediatric hand sizes, particularly palm dimensions. Future research will include further validity testing using standard comparison instruments and measurements on the device. Therefore, the study's limitation is the number of participants being less than 100. Therefore, further research involving more than 100 participants is needed. Furthermore, this study is an initial phase of testing a newly developed device, requiring validity testing by comparing measurements with other devices such as a hand dynamometer, pinc gauge, or Martin Vigorimeter.

## CONCLUSION

Reliability testing using the ICC with a two-way mixed absolute agreement model indicated that the hand muscle strength measurement tool demonstrates good to excellent reliability. At the 7 cm position, the tool exhibited good reliability, with a single-measure ICC of 0.774 and an average-measure ICC of 0.872.

At the 8 cm position, reliability was higher, with a single-measure ICC of 0.870 (95% CI: 0.797–0.918), classified as good, and an average-measure ICC of 0.931 (95% CI: 0.887–0.957), classified as very good. The Cronbach's Alpha for the 8 cm measurement (0.933) surpassed that of the 7 cm measurement (0.879), indicating very high internal consistency. Measurement of hand muscle strength at the 8 cm position is more consistent and reliable than at the 7 cm position, supporting its use as the preferred method in research and clinical settings.

The study identified differences in mean hand muscle strength between the right and left hands, as well as between the two ball diameters, suggesting that individual factors such as hand size and muscle capacity may influence measurements (23,24). Therefore, this tool can effectively assess muscle strength in children and may facilitate monitoring of musculoskeletal development and early detection of muscle strength impairments (25).

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## AUTHOR'S CONTRIBUTION STATEMENT

EEW: Conceptualization, Writing- Original Draft, Review & Editing. DDFY: Conceptualization, Methodology, Manuscript review. ARA: Supervision, Formal analysis, Writing -Original draft, Manuscript review. NZG: Validation, Manuscript review.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest

## DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

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## REFERENCES

1. Gallup AC, Fink B. Handgrip Strength as a Darwinian Fitness Indicator in Men. *Front Psychol* [Internet]. 2018; Volume 9-2018. Available from: <https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2018.00439>.
2. Mager DR, MacDonald K, Duke RL, Avedzi HM, Deehan EC, Yap J, et al. Comparison of Body Composition, Muscle Strength, and Cardiometabolic Profile in Children with Prader-Willi Syndrome and Non-Alcoholic Fatty Liver Disease: A Pilot Study. *Int J Mol Sci*. 2022;23(23):1-17. doi:10.3390/ijms232315115. PMID:36499438
3. Mueangson O, Vongvaivanichakul P, Kamdee K, Jansakun C, Chulrik W, Pongpanitanont P, et al. Malondialdehyde as a Useful Biomarker of Low Hand Grip Strength in Community-Dwelling Stroke Patients. *Int J Environ Res Public Health*. 2020;17(21): 1-16 doi:10.3390/ijerph17217918 PMID:33126675
4. Li G, Lu Y, Shao L, Wu L, Qiao Y, Ding Y, et al. Handgrip strength is associated with risks of new-onset stroke and heart disease: results from 3 prospective cohorts. *BMC Geriatr* [Internet]. 2023;23(1):268. doi:10.1186/s12877-023-03953-8
5. Zaccagni L, Toselli S, Bramanti B, Gualdi-Russo E, Mongillo J, Rinaldo N. Handgrip Strength in Young Adults: Association with Anthropometric Variables and Laterality. *Int J Environ Res Public Health*. 2020;17(12). doi:10.3390/ijerph17124273 PMID:32549283
6. Widyaastuti E, Kartika K. Pengembangan Alat Pengukur Kekuatan Otot Tangan di Lingkungan Poltekkes Kemenkes Pangkalpinang Tahun 2019. *J Kesehat Poltekkes Kemenkes Ri Pangkalpinang*. 2022;10:125–38. doi:10.32922/jkp.v10i2.578
7. Carvalho A, MPT Community Physiotherapy, Shyam Ganvir et al. Assessment of Hand Strengths and Hand Functions in Children Aged 6-12 years: A cross-sectional study. © 2023 *Ijnr*. 2023;8(10):665. doi:10.1729/Journal.36741
8. Zhou M, Zha F, Chen Y, Liu F, Zhou J, Long J, et al. Handgrip Strength-Related Factors Affecting Health Outcomes in Young Adults: Association with Cardiorespiratory Fitness. *Biomed Res Int*. 2021;2021:6645252. doi:10.1155/2021/6645252. PMID:33969122
9. Turan Z, Özyemişçi Taşkiran Ö, Erden Z, Köktürk N, Kaymak Karataş G. Does hand grip strength decrease in chronic obstructive pulmonary disease exacerbation? A cross-sectional study. *Turkish J Med Sci*. 2019;49(3):802–8. doi:10.3906 /sag-1811-22.PMID:31190519

10. Louter F, Knoop V, Demarteau J, Freiburger E, Aubertin-Leheudre M, Maier AB, et al. Instruments for measuring the neuromuscular function domain of vitality capacity in older persons: an umbrella review. *Eur Geriatr Med.* 2024;15(5):1191–13. doi:10.1007/s41999-024-01017-7
11. Mandanka N, Diwan SJ. Intra-Rater and Inter-Rater Reliability of Hand Dynamometer and Pinch Gauge in Children with Spastic Cerebral Palsy. *Indian J Physiother Occup Ther - An Int J.* 2020. doi:10.37506/ijpot.v14i2.2619.
12. Wen J, Wang J, Xu Q, Wei Y, Zhang L, Ou J, et al. Hand anthropometry and its relation to grip/pinch strength in children aged 5 to 13 years. *J Int Med Res [Internet].* 2020;48(12):0300060520970768. doi:doi.org/10.1177/0300060520970768
13. Widyaastuti EE, Chaerani E, Husman, Yudo E. Pengembangan Bola Karet Alat Pengukur Kekuatan Otot Tangan. *J Telenursing.* 2023;5(1):143–52. doi:10.31539/joting.v5i1.4756
14. Zárate-Osuna F, Zapico AG, González-Gross M. Handgrip Strength in Children and Adolescents Aged 3 to 16 Years and Residing in Spain: New Reference Values. *Child (Basel, Switzerland).* 2025;12(4). doi:10.3390/children12040471. PMID:40310105
15. Lee JK, Jung M, Lee HB, Chung HJ, Lee SH. Reliability and Validity of the Martin Vigorimeter for Grip Strength Measurement in Korean Adults. *Clin Orthop Surg [Internet].* 2024 ;16(4):610–9. doi:10.4055/cios23383
16. Karademir F, Uysal Ö, Tüzen Tek Ş, Çakıryılmaz EM, Fırat T. Hand Size Reduces the Reliability of K-Force® Grip Dynamometer. *Hand Ther.* 2026;31(1):22–8. doi:10.1177/17589983251347238. PMID:40519966
17. Neumann S, Kwisda S, Krettek C, Gaulke R. Comparison of the Grip Strength Using the Martin-Vigorimeter and the JAMAR-Dynamometer: Establishment of Normal Values. *In Vivo.* 2017;31(5):917–24. doi:10.21873/invivo.11147. PMID:28882959
18. Sherriff A, Wright CM, Reilly JJ, McColl J, Ness A, Emmett P. Age- and sex-standardised lean and fat indices derived from bioelectrical impedance analysis for ages 7-11 years: functional associations with cardio-respiratory fitness and grip strength. *Br J Nutr.* 2009;101(12):1753–60. doi:10.1017/S0007114508135814.PMID:19025717
19. Fredriksen PM, Mamen A, Hjelle OP, Lindberg M. Handgrip strength in 6-12-year-old children: The Health Oriented Pedagogical Project (HOPP). *Scand J Public Health.* 2018;46(21\_suppl):54–60. doi:10.1177/1403494818769851. PMID:29754575
20. Mahmoud AG, Elhadidy EI, Hamza MS, Mohamed NE. Determining correlations between hand grip strength and anthropometric measurements in preschool children. *J Taibah Univ Med Sci.* 2020;15(1):75–81. doi:10.1016/j.jtumed.2020.01.002. PMID:32110186
21. Sobirani I. Hubungan Kekuatan Otot Lengan dan Kemampuan Memukul Bola Kasti Siswa Kelas IVB SDN Tegalpanggung. *J PGSD Penjaskes.* 2019;5(5):1–8.
22. Magni N, Olds M, McLaine S. Reliability and validity of the K-force grip dynamometer in healthy subjects: do we need to assess it three times? *Hand Ther.* 2023;28(1):33–9. doi:10.1177/17589983231152958. PMID:37904810
23. Ali OI, Sarsak HI, Tarshi MM, Marji M, Aljohani ST, Badawood MN, et al. Assessment of Hand Grip and Pinch Strengths in Children with Autism Spectrum Disorders: A Cross-Sectional Study. *Child (Basel, Switzerland).* 2025;12(3). doi:10.3390/children12030320.PMID:40150602
24. Loaiza-Betancur AF, Chulvi-Medrano I. Is Low-Intensity Isometric Handgrip Exercise an Efficient Alternative in Lifestyle Blood Pressure Management? A Systematic Review. *Sports Health.* 2020;12(5):470–7. doi:10.1177/1941738120943882. PMID:32776866
25. Wang X, Wang H, Yuan X, Cai S, Huang Y, Song Y, et al. Imbalance between muscle strength development and weight gain in children and young adults in China: serial cross-sectional evidence from 1.33 million students from five successive national surveys between 2000 and 2019. *Lancet Reg Heal West Pacific.* 2025;61:101640. doi:10.1016/j.lanwpc.2025.101640. PMID:40747129