The Solution to the Entrenched Scoring Mistake Physical Educators Have Been Making in Push-Up Test

Oliver Napila Gomez

Usfd Ph Opc; Lourdes College Graduate School

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ABSTRACT

This study investigates the concurrent validity of push-up test scoring strategies (repetition-based, transformed score using the Brzycki equation, and transformed score using the Epley equation). Highlighting the limitation of push-up test scoring based on repetition alone to evaluate dynamic muscle strength from the push-up test, this research utilized Brzycki and Epley equations for score transformation using the initial repetition-based score. This descriptive correlational study aims to evaluate the concurrent validity of the scoring strategies by examining their relationship with the scores in the criterion test, the 1RM seated chest press test. The participants in the study are male university students from Ho Chi Minh City, Vietnam, ranging in age from 18 to 25 years. Results show that the repetition-based score does not significantly correlate with the 1RM seated chest press test, indicating no concurrent validity in measuring upper body strength. When compared with the criterion test, the transformed push-up score using the Brzycki equation still needs a considerable distance from being a valid scoring strategy for assessing muscular strength. Lastly, the Epley-based transformed score obtained a strong positive correlation coefficient, which indicates a good concurrent validity in measuring upper-body muscular strength. Therefore, out of all the three methods of scoring, no evidence repetition-based push-up scoring can accurately measure upper body strength. Transforming push-up scores using the Epley equation not only normalizes data but also provides a valid submaximal upper body muscular strength assessment as far as concurrent validity with the 1RM seated chest press test is concerned. Utilizing Epley's equation with push-up tests provides a practical way to measure upper-body muscular strength for schools, gyms, and sports training contexts. The development of a push-up test protocol that integrates Epley's formula in its scoring procedure is recommended, along with investigating the Brzycki equation further in other contexts and other score transformation strategies.

Keywords: Transformed push-up test, concurrent validity, Epley equation, Brzycki equation, muscular strength assessment

INTRODUCTION

One Repetition Maximum (1RM) is the criterion measure of muscular strength, which is the amount of weight a person can lift with a maximum of one full-range repetition (Jawade, 2021). Undeniably, testing 1RM could be dangerous, and a safer alternative is required to measure muscular strength (Yoo et al., 2022). The role of submaximal tests is crucial as they are versatile and easy to execute (Gouvali & Boudolos, 2005; Kubo et al., 2021), safe and effective options for evaluating muscular strength (DiStasio, 2014; Tan et al., 2015). Hence, the push-up test is a safe and sound way to assess upper-body muscular strength (Sigvaldsen et al., 2023). Additionally, push-up tests can be administered practically with less equipment and to a number of people at once (Fielitz et al., 2016; Garcia-Ramos & Jaric, 2018; Neto et al., 2015), as such in educational contexts like Physical Education classes. Despite this, fitness test administrators have repeatedly disregarded the validity of the test, a concern, particularly in populations with specific conditions, requiring cautious selection and administration of fitness tests (de Oliveira Tavares et al., 2021).

The push-up test is supposed to measure dynamic muscular strength as 1RM, the heaviest weight a person can lift for one repetition. However, push-up test alone cannot predict 1RM and may misevaluate a person's true muscular strength (Mayhew et al., 1991). Over the years, push-up test scores only reflect the maximum repetition the test performer achieves. While maximum repetition may seem reasonable, this scoring practice instills unobtrusive but upsetting evaluative inequalities in the test scoring procedure. Employing the maximum repetition as the score attained by a performer ignores individual differences

This study investigates the concurrent validity of push-up test scoring strategies (repetition-based, transformed score using the Brzycki equation, and transformed score using the Epley equation). It highlights the limitation of using repetition alone to evaluate dynamic muscle strength from the push-up test. To address this limitation, this research utilized the Brzycki and Epley equations to transform the initial repetition-based score.

METHODS

This investigative validation study employed a descriptive-correlation design wherein the researchers examined the accuracy of scoring interventions with a gold standard test measure (Collin et al., 2020; Fox et al., 2020). It requires the collection of the repetition-based scores in the standard push-up test. The repetition-based scores are transformed using the two transformation scoring methods – Brzycki and Epley – which measure the participants' average push-up loads and total body weight. The gold standard criterion measure is the 1RM seated chest press test. Although the steps in the validation study also include reliability testing, the current study is limited to examining the criterion validity coefficients alone.

The push-up is a rater-dependent test (Fielitz et al., 2016) in which a judge determines a successful performance and repetition. Hence, this challenge in assessing push-ups correctly implies limiting samples to only those who can accurately perform the test. In this study, the nature of the tests and the skill requirement to perform the correct standard push-up form reduced the number of untrained participants to 34 male university students from Ho Chi Minh City, Vietnam (aged 18-25 years old). The use of non-probability sampling to select participants who can demonstrate an acceptable push-up form is crucial to the validity and reliability of the push-up scores.

Moreover, the study utilized two instruments to collect repetition-based push-up scores and a gold-standard measure. The submaximal instrument is the revised push-up test norms for college students (Baumgartner et al., 2004) with logical modifications, while the gold-standard criterion test is the 1RM seated chest press (Fawcett & DeBeliso, 2014a).

The standard push-up extends the feet, so the curled toes touch the floor. The test then focuses on the ability to exert force and repeatedly push the upper body's weight against the floor. However, certain aspects of the push-up test needed adjustments because the intensity of push-up performance can easily change when the push-up starting position, the cadence, the type of surface, and the range of motion are adjusted (Dhahbi et al., 2022). In line with a recommendation (LaChance & Hortobagyi, 1994), the study devised a uniform music rhythm of 3-second intervals so that the push-up rhythm does not influence the tests' maximum repetition.

The first step of the test is to use a digital body weighing scale in the standard postures to find the average push-up load. The test administrator observes the participants closely how they complete push-up repetitions and stop counting when they can no longer sustain the correct form or cannot keep up with the prescribed rhythm, determining their repetition-based score.

Moreover, the score transformation methods required numerical factors such as the GRF (Dhahbi et al., 2022) and the number of successful repetitions performed in push-ups for computation. The inverse dynamics method determines joint forces, power, and moment by measuring the GRF using a platform combined with motion analysis of joint positions, examining aspects of mechanics, energetics, and movement control (Faber et al., 2018). Hence, a force platform (or a digital weighing scale) can quantify the load applied to the arms (Dhahbi et al., 2022). In this study, the GRF is called push-up load (PUL), the average load of the straight-arm and bent-elbow push-up positions. With this, the predictive equations adopted for push-ups are as follows:

Brzycki equation $$1RM = PUL/(1.0278-(0.0278\times Performance)) \quad (1)$$

Epley equation $$1RM = PUL + (0.033 \times Performance \times PUL) \quad (2)$$

Considering the safety and context, the researchers are not convinced that the 1RM bench press test is the gold standard measure because it is an open kinetic chain exercise (Amasay et al., 2016; Gottschall et al., 2018; van den Tillaar & Ball, 2019), which has a different context from a closed kinetic chain exercise (de Oliveira et al., 2017; Tucci et al., 2014). On the one hand, the bench press is an open kinetic chain exercise with computable barbel weight and adjustable training intensity (Amasay et al., 2016). However, it should be noted that open kinetic chain exercises have more degree of freedom and varied movements than closed kinetic chain, which fix hands on the ground or handles (Amasay et al., 2016; van den Tillaar & Ball, 2019). The performance of an open kinetic chain bench press requires the exercise performer to balance the barbell using the left and right hands because of torque (Amasay et al., 2016).

On the other hand, research (Fawcett & DeBeliso, 2014a) argued that the seated chest press machine test is a more suitable gold standard test criterion than the standard universal bench press machine, as supported in another research (Simpson, 1994). The authors' argument is sensible because of safety issues and because the seated chest press machine test is a closed kinetic chain exercise that matches the push-up test. Hence, the seated chest press (also called the seated bench press) has been used to estimate 1RM in several studies (Glass, 2008; Marques et al., 2020; Schlumberger et al., 2001).

In context, the 1RM seated chest press was obtained by allowing the participant to push the heaviest possible weight while seated on the machine. First, the participants were required to warm up. Then, they were asked to choose the initial weight they thought they could push while seated. Then, depending on their initial attempt, they either increased or decreased the weight until they could perform at least one maximum repetition, the recorded score.

RESULTS AND DISCUSSION

To facilitate a comprehensive discussion of the results, the findings is divided into three sections. The first section discusses the results of the preliminaries, which explains how the research prepared the initial data sets for the repetition-based scores and the equation transformed scores. Subsequently, the descriptive results of the repetition-based push-up test, transformed scores, and 1RM seated chest press test are discussed in the second section. Lastly, the third section investigates the concurrent validity coefficients of each scoring method.

Results of the Preliminaries. The preliminaries involved the measures required for the actual data analysis. *Table 1* shows how the Brzycki and Epley prediction models transform an individual's maximum strength capacity from the number of repetitions they can perform.

Table 1. Transforming PUL and performance into 1RM push-up score using Brzycki and Epley

Push-up load average (kg) (PUL)	Repetition-based score (Performance)	1RM push-up score using Brzycki equation (1993)	1RM push-up score using Epley equation (1985)
35.0	12	33.72	48.86
40.5	26	38.68	75.25
40.8	10	39.37	54.20
31.0	14	29.77	45.32
47.5	12	45.88	66.31
42.0	16	40.42	64.18
47.3	14	45.58	69.08
45.8	7	44.32	56.32
44.0	8	42.59	55.62
42.0	24	40.20	75.26
55.0	18	53.01	87.67

52.0	11	50.29	70.88
42.5	20	40.79	70.55
34.3	10	33.05	45.55
48.8	10	47.15	64.84
44.8	10	43.26	59.52
44.8	10	43.26	59.52
46.8	5	45.35	54.46
53.0	13	51.21	75.74
41.0	10	39.61	54.53
32.5	10	31.34	43.23
60.3	3	58.54	66.21
39.5	20	37.88	65.57
36.5	12	35.18	50.95
39.0	19	37.42	63.45
47.0	8	45.51	59.41
48.0	10	46.42	63.84
38.8	10	37.42	51.54
42.0	35	39.89	90.51
44.8	36	42.54	97.91
28.5	20	27.17	47.31
51.0	20	49.06	84.66
28.5	10	27.45	37.91
25.5	6	24.64	30.55

Preliminary data include the push-up load average (kg) and the repetition-based score or performance from the revised standard push-up protocol. Then, the study uses prediction models to transform repetition-based push-up scores into more comprehensive muscular strength metrics. In this context, 1RM, is the outcome of the recorded variables (average PUL and performance) calculated based on the two equations. The Brzycki and Epley equations proxy for a participant's maximum load capacity in a single push-up, providing deeper insight into each participant's upper body strength.

Results of the repetition-based push-up test, transformed scores, and 1RM seated chest press test. The descriptive statistics and frequency distribution of the result of the repetition-based, Brzycki- and Epley-based transformed scores, and 1RM seated chest press test are presented in *Table 2*.

Table 2. Frequency Distribution and Descriptive Statistics of Various Strength Scores

Items	**Class Intervals (kg)**	**Frequency**	**Percentage (%)**	**Median / Mean**	**IQR / SD**
Repetition-based scores in push-up test	30.0 - 36.0	2	5.88	**Median: 11.5**	**IQR: 8.750**
	23.0 - 29.0	2	5.88		

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	16.0 - 22.0	7	20.59		
	7.0 - 15.0	20	58.82		
	1.0 - 8.0	3	8.82		
Brzycki-based transformed scores	52.2 - 60.0	2	5.88	**Mean: 40.823**	**SD: 7.674**
	44.3 - 52.1	12	35.29		
	36.3 - 44.2	12	35.29		
	28.5 - 36.2	5	14.71		
	20.6 - 28.4	3	8.82		
Epley-based transformed scores	85.0 - 100.0	3	8.82	**Mean: 61.962**	**SD: 15.015**
	69.8 - 84.9	6	17.65		
	54.4 - 69.7	15	44.12		
	39.2 - 54.3	8	23.53		
	23.9 - 39.1	2	5.88		
1RM Seated Chest Press Test (kg)	65.0 - 75.0	8	23.53	**Mean: 51.176**	**SD: 14.145**
	54.0 - 64.0	7	20.59		
	43.0 - 53.0	11	32.35		
	32.0 - 42.0	4	11.76		
	20.0 - 31.0	4	11.76		

For the results of the repetition-based scores in push-up test, Table 2 reveals that the median (11.5) and interquartile range (IQR) (8.750) are used as descriptive statistics, as they provide insights into the variability of the data and the spread of push-up scores. The high concentration (58.82%) within a narrower range of repetitions suggests that most individuals possess comparable proficiency in pushing-ups within the 7.0 - 15.0 push-up range. The relatively low frequency observed in the upper and lower intervals indicates that the individuals do not possess exceptionally high or poor push-up capabilities.

No similar push-up records were published following the same revised push-up protocol in Vietnam, so there is no reference to compare the current data. This may be the first study in Vietnam to record male push-up performance. In this study, the push-up performance clustered from 7 to 15 repetitions, with a median of 11.5 repetitions.

The rhythm adjustment to the 3-second interval between repetitions contributed to the performance. Notably, the study adjusted the revised version of the standard push-up test (Baumgartner et al., 2002) because rhythm (LaChance & Hortobagyi, 1994) and the push-up starting position, surface type, and range of motion can easily change the intensity of the push-up performance (Dhahbi et al., 2022). In Brazil, a study revealed that three cadences (1/1, 2/1, and 1/2) presented a significant difference compared to the fast-paced cadence, observing that the push-up performers did well when a fast self-pace cadence was used (Valente et al., 2017).

Moreover, in analyzing the push-up score of the 34 male Vietnamese participants in terms of repetition, the relative weight each of them carries (average PUL) is an essential aspect of the overall performance. According to research (Clemons, 2019), absolute strength may be fairly assessed if the repetition-based push-up score is considered along with body mass and vertical push-up distance.

Meanwhile, the result of the transformation made to estimate the 1RM using the Brzycki- and Epley equations are also presented in *Table 2*. The descriptive statistics and frequency distribution of the Brzycki- and Epley-based transformed push-up test reveals that the intermediate intervals (44.3-52.1 and 36.3-44.2) had the highest scores, accounting for 35.29% of the total.

On the one hand, it appears that fewer participants were at the extremes of performance, as the intervals with the fewest scores were at the top (52.2-60.0) and the bottom (20.6-28.4). Participants likely had a Brzycki-based transformed score around the mean value of about 40.823, which shows the central tendency of the transformed scores. The standard deviation of 7.674 measures the variation or dispersion from the mean, suggesting a moderate spread of scores around the mean.

On the other hand, the mean score in the Epley-based transformed scores is 61.962, indicating a wide range of performance. Most scores fall within the 54.4 - 69.7 interval, indicating moderate push-up strength. The frequency of participants decreases as performance levels increase, with only 3.82% in the highest interval. High-performance athletes are represented by the 85.0 - 100 interval, with their performances significantly above average.

Drawing from previous studies, some used the Brzycki equation to estimate 1RM for the back squat (Curtis, 2023; Doeringer et al., 2020) or bench press (Ribeiro Neto et al., 2017). The Epley equation was also used in some studies to estimate 1RM for bench press (Nasarudin et al., 2020; Pérez-Castilla et al., 2021). Nevertheless, this study is the first to innovatively and creatively demonstrate that the two predictive equations apply to push-up performance based on the repetition scores and considering the average PUL.

Lastly, the result of the 1RM Seated Chest Press Test (kg) has a mean score of 51.176 and a standard deviation of 14.145. The most common score interval is 43.0 to 53.0, with 32.35% of participants falling in this range. The highest and lowest score intervals (65.0 to 75.0 and 20.0 to 31.0) have equal participants, suggesting fewer individuals with very high or meager upper body strength. The average upper body strength of the group is just above 50 kg for a one-repetition maximum lift. The distribution of scores and the standard deviation suggest that the group is relatively heterogeneous regarding strength levels due to varying training experience, age, body weight, or other factors.

The seated chest press machine, a close kinetic chain exercise, is preferred to obtain the 1RM measure (Fawcett & DeBeliso, 2014b) in this study. To the researchers' knowledge, this is the first time a study recorded the 1RM seated chest press profile of Vietnamese male participants. Hence, no previous data can serve as a reference for this study. Considering the result in the 1RM seated chest press test (51.18± 14.15) and the total body weight profile (61.74±11.67) of the participants, it can be stated that the male Vietnamese participants pushed 82.9% of their total body weight, on average, in this study.

In the seated chest press, the closed kinetic chain exercise performer experiences stability because the machine handles are stable. As a critical component, trunk stability increases the upper and lower limbs' capability for closed kinetic chain training (Horii & Sasaki, 2023). Hence, exercise participants performed well in seated chest presses because of the machine's stable handles.

Result of the concurrent validity analysis of the push-up scoring methods. The study examines the concurrent validity of the repetition-based push-up scores and the two transformed scores when compared with the 1RM seated chest press test.

Table 3. Analysis of the concurrent validity between the repetition-based score in push-ups and 1RM seated chest press test (n=34)

Push-up Test Scoring Method	Criterion test	Statistical Treatment	Concurrent Validity Coefficient
Repetition-based score	1RM Seated Chest press test	Kendall's tau-b	0.379
Brzycki-based transformed score	1RM Seated Chest press test	Kendall's tau-b	0.416
Epley-based transformed score	1RM Seated Chest press test	Pearson r*	0.781

With 34 participants, the study found a coefficient of τ=0.379 between the two tests. Values below 0.70 may indicate limitations in terms of validity or reliability (Post, 2016), suggesting that the concurrent validity coefficient (τ=0.379) of the repetition-based push-up score is far from being a valid scoring technique for muscular strength in as much as 1RM seated chest press test is concerned.

Table 3 also presents the concurrent validity coefficient of 1RM push-up scores estimated using the relationship coefficient between the Brzycki prediction model and the 1RM seated chest press test. However, the data deviates significantly from a normal distribution, requiring a non-parametric statistical analysis. Kendall's tau-b results (τ=0.416) showed a moderate positive association between the Brzycki-based transformed scores and the 1RM seated chest press test results. Nevertheless, values falling below 0.70 may suggest deficiencies in validity (Post, 2016). In this case, the concurrent validity coefficient (τ=0.416) of the Brzycki-based push-up score indicates that it is still a considerable distance from being a valid scoring method for assessing muscular strength in relation to the 1RM seated chest press test.

Finally, the study further examines the relationship between the Epley-based transformed score and the 1RM seated chest press test. The Shapiro-Wilk test for normality (W) results are 0.958 with a p-value of 0.219, confirming no significant deviation from normality in the dataset, suggesting using a parametric statistical analysis, Pearson r.

With 34 participants, the Pearson correlation coefficient (r) is 0.781, indicating a strong positive relationship between the two measures. While values above 0.70 indicate good concurrent validity (Post, 2016), the strong Pearson's r value and the dataset meeting the normality assumption suggest that the Epley-based transformed score is a valid predictor of the 1RM seated chest press test, indicating good concurrent validity.

Epley's formula has been widely used in numerous studies to evaluate maximum strength in diverse populations, including athletes and clinical groups (Doody et al., 2019; Riaz et al., 2024; Teixeira et al., 2019). Additionally, research indicates that Epley's formula offers a more accurate estimation of 1RM compared to other formulas, establishing it as a preferred choice among researchers and practitioners (Bayonas-Ruiz et al., 2024; Hart et al., 2023). This makes it a valuable tool in strength training, enabling effective assessment and programming across various populations.

Moreover, the results of the concurrent validity of the three scoring methods are presented in Tables 3. The concurrent validity coefficients of the repetition-based, Brzycki, and Epley are τ=0.379, τ=0.416, and r=0.781, respectively. Accordingly, values above 0.70 indicate good concurrent validity (Post, 2016), indicating that only the Epley-based transformed score is a valid predictor of the 1RM seated chest press. Unfortunately, there is no way to compare this result with previous studies considering the uniqueness of the protocol followed by the creative yet precise measurement of the average PUL and the use of the 1RM seated chest press test. What is fortunate is that the protocol was elaborately described so that future researchers can replicate the study subject for confirmation in future studies.

CONCLUSIONS

Therefore, out of all the three methods of scoring, there is evidence that repetition-based push-up scoring cannot accurately measure upper body strength while transforming push-up scores using the Epley equation not only normalizes data but also provides valid submaximal upper body muscular strength assessment as far as concurrent validity with 1RM seated chest press test is concerned. Utilizing Epley's equation with push-up tests provides a practical way to measure upper-body muscular strength for schools, gyms, and sports training contexts. The development of a push-up test protocol that integrates Epley's formula in its scoring procedure is recommended, along with investigating Brzycki equation further in other contexts and other score transformation strategies.

REFERENCES

1. Amasay, T., Mier, C. M., Foley, K. K., & Carswell, T. L. (2016). Gender differences in performance of equivalently loaded push-up and bench-press exercises. The Journal of SPORT, 5(1), 4.

http://digitalcommons.kent.edu/sport/vol5/iss1/4?utm_source=digitalcommons.kent.edu%2Fsport%2Fvol5%2Fiss1%2F4&utm_medium=PDF&utm_campaign=PDFCoverPages

2. Baumgartner, T. A., Hales, D., Chung, H., Oh, S., & Wood, H. M. (2004). Revised push-up test norms for college students. Measurement in Physical Education and Exercise Science, 8(2), 83–87. https://doi.org/10.1207/s15327841mpee0802_3
3. Baumgartner, T. A., Oh, S., Chung, H., & Hales, D. (2002). Objectivity, reliability, and validity for a revised push-up test protocol. Measurement in Physical Education and Exercise Science, 6(4), 225–242. https://doi.org/10.1207/S15327841MPEE0604_2
4. Bayonas-Ruiz, A., Muñoz-Franco, F. M., Sabater-Molina, M., González-Moro, I. M., Gimeno, J. R., & Bonacasa, B. (2024). Concurrent resistance and cardiorespiratory training in patients with hypertrophic cardiomyopathy: A pilot study. Journal of Clinical Medicine, 13(8), 2324. https://doi.org/10.3390/jcm13082324
5. Clemons, J. (2019). Construct validity of two different methods of scoring and performing push-ups. The Journal of Strength & Conditioning Research, 33(11). https://journals.lww.com/nsca-jscr/fulltext/2019/11000/construct_validity_of_two_different_methods_of.12.aspx
6. Collin, L. J., MacLehose, R. F., Ahern, T. P., Nash, R., Getahun, D., Roblin, D., Silverberg, M. J., Goodman, M., & Lash, T. L. (2020). Adaptive validation design: A Bayesian approach to validation substudy design with prospective data collection. Epidemiology, 31(4). https://journals.lww.com/epidem/fulltext/2020/07000/adaptive_validation_design__a_bayesian_approach_to.6.aspx
7. Curtis, N. (2023). Post-activation potentiation for firefighter daily preparedness. In Master of Science in Exercise Science. Concordia University.
8. de Oliveira Tavares, V. D., Vancampfort, D., Hallgren, M., Heissel, A., Chaparro, C. G. A. P., Solmi, M., Tempest, G. D., de Oliveira Neto, L., Galvão-Coelho, N. L., Firth, J., & Schuch, F. B. (2021). Reliability and validity of physical fitness tests in people with mental disorders: A systematic review and meta-analysis. Physiotherapy Research International, 26(3), e1904. https://doi.org/10.1002/pri.1904
9. de Oliveira, V. M., Pitangui, A. C., Nascimento, V. Y., da Silva, H. A., Dos Passos, M. H., & de Araújo, R. C. (2017). Test-retest reliability of the closed kinetic chain upper extremity stability test (CKCUEST) in adolescents: Reliability of CKCUEST in adolescents. International Journal of Sports Physical Therapy, 12(1), 125. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5294939/
10. Dhahbi, W., Chaabene, H., Chaouachi, A., Padulo, J., G Behm, D., Cochrane, J., Burnett, A., & Chamari, K. (2022). Kinetic analysis of push-up exercises: A systematic review with practical recommendations. Sports Biomechanics, 21(1), 1–40. https://doi.org/10.1080/14763141.2018.1512149
11. DiStasio, T. J. (2014). Validation of the Brzycki and Epley equations for the 1 repetition maximum back squat test in division I college football players [Southern Illinois University Carbondale]. https://opensiuc.lib.siu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1744&context=gs_rp
12. Doeringer, J. R., Colas, M., & Khan, I. (2020). Post-exercise cooling modified muscle performance and soreness perception. TRANSLATIONAL SPORTS MEDICINE, 3(3), 278–283. https://doi.org/10.1002/tsm2.141
13. Doody, P., Lord, J. M., Greig, C., & Whittaker, A. C. (2019). Assessing the feasibility and impact of specially adapted exercise interventions, aimed at improving the multi-dimensional health and functional capacity of Frail Geriatric Hospital inpatients: Protocol for a feasibility study. BMJ Open, 9(11), e031159. https://doi.org/10.1136/bmjopen-2019-031159
14. Faber, H., van Soest, A. J., & Kistemaker, D. A. (2018). Inverse dynamics of mechanical multibody systems: An improved algorithm that ensures consistency between kinematics and external forces. PLOS ONE, 13(9), e0204575. https://doi.org/10.1371/journal.pone.0204575
15. Fawcett, M., & DeBeliso, M. (2014a). The validity and reliability of push-ups as a measure of upper body strength for 11–12-year-old females. Journal of Fitness Research, 3(1), 4–11. https://research.usc.edu.au/esploro/outputs/99448948402621
16. Fawcett, M., & DeBeliso, M. (2014b). The validity and reliability of push-ups as a measure of upper body strength for 11–12-year-old females. Journal of Fitness Research, 3(1), 4–11.
17. Fielitz, L., Coelho, J., Horne, T., & Brechue, W. (2016). Inter-rater reliability and intra-rater reliability of assessing the 2-minute push-up test. Military Medicine, 181(2), 167–172. https://doi.org/10.7205/MILMED-D-14-00533

18. Fox, M. P., Lash, T. L., & Bodnar, L. M. (2020). Common misconceptions about validation studies. International Journal of Epidemiology, 49(4), 1392–1396. https://doi.org/10.1093/ije/dyaa090
19. Garcia-Ramos, A., & Jaric, S. (2018). Two-point method: A quick and fatigue-free procedure for assessment of muscle mechanical capacities and the 1 repetition maximum. Strength & Conditioning Journal, 40(2). https://journals.lww.com/nsca-scj/fulltext/2018/04000/two_point_method__a_quick_and_fatigue_free.5.aspx
20. Glass, S. C. (2008). Effect of a learning trial on self-selected resistance training load. The Journal of Strength & Conditioning Research, 22(3). https://journals.lww.com/nsca-jscr/fulltext/2008/05000/effect_of_a_learning_trial_on_self_selected.50.aspx
21. Gottschall, J. S., Hastings, B., & Becker, Z. (2018). Muscle activity patterns do not differ between push-up and bench press exercises. Journal of Applied Biomechanics, 34(6), 442–447. https://doi.org/10.1123/jab.2017-0063
22. Gouvali, M. K., & Boudolos, K. (2005). Dynamic and electromyographical analysis in variants of push-up exercise. The Journal of Strength & Conditioning Research, 19(1). https://journals.lww.com/nsca-jscr/fulltext/2005/02000/dynamic_and_electromyographical_analysis_in.25.aspx
23. Hart, A. S., Erskine, R. M., & Clark, D. R. (2023). The use of physical characteristics to explain variation in ball-carrying capability in elite rugby union: A narrative review. The Journal of Strength and Conditioning Research. https://doi.org/10.1519/jsc.0000000000004468
24. Horii, O., & Sasaki, M. (2023). Influences of trunk stability on exercise performance of closed kinetic chain of upper and lower limbs. Journal of Physical Therapy Science, 35(5), 379–383. https://doi.org/10.1589/jpts.35.379
25. Jawade, S. S. (2021). Prediction of the one repetition maximum to design strength training protocol. Journal of Clinical & Diagnostic Research, 15(3). https://doi.org/10.7860/JCDR/2021/46131.14648
26. Kubo, K., Ikebukuro, T., & Yata, H. (2021). Effects of 4, 8, and 12 repetition maximum resistance training protocols on muscle volume and strength. The Journal of Strength & Conditioning Research, 35(4). https://journals.lww.com/nsca-jscr/fulltext/2021/04000/effects_of_4,_8,_and_12_repetition_maximum.1.aspx
27. LaChance, P. F., & Hortobagyi, T. (1994). Influence of cadence on muscular performance during push-up and pull-up exercise. The Journal of Strength & Conditioning Research, 8(2). https://journals.lww.com/nsca-jscr/fulltext/1994/05000/influence_of_cadence_on_muscular_performance.3.aspx
28. Marques, D. L., Neiva, H. P., Marinho, D. A., & Marques, M. C. (2020). Novel resistance training approach to monitoring the volume in older adults: The Role of movement velocity. International Journal of Environmental Research and Public Health, 17(20). https://doi.org/10.3390/ijerph17207557
29. Mayhew, J. L., Ball, T. E., Arnold, M. D., & Bowen, J. C. (1991). Push-ups as a measure of upper body strength. The Journal of Strength & Conditioning Research, 5(1). https://journals.lww.com/nsca-jscr/fulltext/1991/02000/push_ups_as_a_measure_of_upper_body_strength.4.aspx
30. Nasarudin, A. N., Sidek, F. F., & Shaari, I. H. (2020). Prediction of quadriceps one repetition maximum (1RM) among novice lifters using 1RM equations. Healthscope: The Official Research Book of Faculty of Health Sciences, UiTM, 3(1), 17–21. https://www.healthscopefsk.com/index.php/research/article/view/164
31. Neto, J. C., Cedin, L., Dato, C. C., Bertucci, D. R., de Andrade Perez, S. E., & Baldissera, V. (2015). A single session of testing for one repetition maximum (1RM) with eight exercises is trustworthy. J Exerc Physiol Online, 18(3), 74–80. https://www.asep.org/asep/asep/JEPonlineJUNE2015_Neto.pdf
32. Pérez-Castilla, A., Suzovic, D., Domanovic, A., Fernandes, J. F. T., & García-Ramos, A. (2021). Validity of different velocity-based methods and repetitions-to-failure equations for predicting the 1 repetition maximum during 2 upper-body pulling exercises. The Journal of Strength & Conditioning Research, 35(7). https://journals.lww.com/nsca-jscr/fulltext/2021/07000/validity_of_different_velocity_based_methods_and.4.aspx
33. Post, M. W. (2016). What to do with "moderate" reliability and validity coefficients? Archives of Physical Medicine and Rehabilitation, 97(7), 1051–1052. https://doi.org/10.1016/j.apmr.2016.04.001
34. Riaz, H., Maqsood, M., Afridi, A., Ehsan, S., & Jan, S. A. (2024). Effects of High-Intensity Resistance Versus Aerobic Training in PCOS Women at Risk for Psychological Trauma. 48(1), 11–20. https://doi.org/10.1097/jwh.0000000000000295

35. Ribeiro Neto, F., Guanais, P., Dornelas, E., Coutinho, A. C. B., & Costa, R. R. G. (2017). Validity of one-repetition maximum predictive equations in men with spinal cord injury. Spinal Cord, 55(10), 950–956. https://doi.org/10.1038/sc.2017.49
36. Schlumberger, A., Stec, J., & Schmidtbleicher, D. (2001). Single-vs. multiple-set strength training in women. The Journal of Strength & Conditioning Research, 15(3). https://journals.lww.com/nsca-jscr/fulltext/2001/08000/single_vs__multiple_set_strength_training_in_women.4.aspx
37. Sigvaldsen, E., Loturco, I., Larsen, F., Bruusgaard, J., Kalhovde, J. M., & Haugen, T. (2023). Validity and reliability of upper body push and pull tests to determine one-repetition maximum. Plos One, 18(7), e0288649. https://doi.org/10.1371/journal.pone.0288649
38. Simpson, S. R. (1994). Comparison of one repetition maximums between free weight and universal machine exercises. California State University, Long Beach.
39. Tan, S., Wang, J., & Liu, S. (2015). Establishment of the prediction equations of 1RM skeletal muscle strength in 60- to 75-year-old Chinese men and women. Journal of Aging and Physical Activity, 23(4), 640–646. https://doi.org/10.1123/japa.2014-0103
40. Teixeira, J., Monteiro, L., Silvestre, R., Beckert, J., & Massuça, L. M. (2019). Age-related influence on physical fitness and individual on-duty task performance of portuguese male non-elite police officers. Biology of Sport, 36(2), 163–170. https://doi.org/10.5114/biolsport.2019.83506
41. Tucci, H. T., Martins, J., Sposito, G. de C., Camarini, P. M. F., & de Oliveira, A. S. (2014). Closed Kinetic Chain Upper Extremity Stability test (CKCUES test): A reliability study in persons with and without shoulder impingement syndrome. BMC Musculoskeletal Disorders, 15(1), 1. https://doi.org/10.1186/1471-2474-15-1
42. Valente, A., Nascimento, J., Machado, F., Gonçalves, M. M., & Marson, R. (2017). The acute effect of cadence on the maximum number of repetitions in the push-up test. Journal of Science and Medicine in Sport, 20, S121. https://doi.org/10.1016/j.jsams.2017.09.435
43. van den Tillaar, R., & Ball, N. (2019). Validity and Reliability of Kinematics Measured with PUSH Band vs. Linear Encoder in Bench Press and Push-Ups. Sports, 7(9). https://doi.org/10.3390/sports7090207
44. Yoo, J., Kim, J., Hwang, B., Shim, G., & Kim, J. (2022). Estimation of 1-repetition maximum using a hydraulic bench press machine based on user’s lifting speed and load weight. Sensors, 22(2). https://doi.org/10.3390/s22020698