Article

Not peer-reviewed version

Is Strength and Power Comparable for Men and Women in the Bench Press?

Olga López-Torres , Raul Nieto-Acevedo , Amelia Guadalupe-Grau * , Valentin Fernandez

Posted Date: 17 March 2025

doi: 10.20944/preprints202503.1150.v1

Keywords: gender; strength training; mean propulsive velocity

Article

Is Strength and Power Comparable for Men and Women in the Bench Press?

Olga López-Torres [1], Raúl Nieto-Acevedo [2], Amelia Guadalupe-Grau [3]* and Valentín Emilio Fernández Elías [4]

[1] Universidad Europea de Madrid. Department of Sports Sciences. Faculty of Medicine, Health and Sports. Villaviciosa de Odón, Spain
[2] Faculty of Sports Sciences, Universidad Alfonso X el Sabio, 28691, Villanueva de la Cañada, Spain
[3] GENUD Toledo Research Group, Faculty of Sports Sciences, Universidad de Castilla–La Mancha, Toledo, Spain
[4] Research Centre in Sport Sciences, Rey Juan Carlos University, Fuenlabrada, Spain
* Correspondence: amelia.guadalupe@uclm.es; GENUD Toledo Research Group, Universidad de Castilla–La Mancha, Avda. Carlos III S/N, 45071 Toledo, Spain

Abstract: Background: Resistance training (RT) elicits muscle hypertrophy and strength gains in both men and women. However, sex differences in neuromuscular performance, muscle fiber composition, and hormonal environment influence strength and power adaptations. While men generally exhibit greater absolute and relative strength, the extent to which these differences persist across various loads remains unclear. Understanding sex-specific strength and power profiles may optimize training strategies. **Objective:** To compare male and female athletes in strength and power performance during the bench press exercise relative to body mass and fat-free mass (FFM). **Methods:** Twenty-nine physically active individuals (16 men: 21.3 ± 4.1 years, 13 women: 22.6 ± 4.9 years) performed a one-repetition maximum (1RM) test and an incremental velocity-based assessment at 45%, 55%, 65%, 75%, and 85% of 1RM using a Smith machine. Barbell velocity was measured via a linear transducer, with mean propulsive velocity (MPV) recorded for each load. Power-related variables (e.g., peak force [F0], maximal velocity [V0], maximal power [Pmax]) were analyzed. To account for differences in body composition, data were adjusted for body mass and FFM. **Results:** Men exhibited significantly greater strength and power than women at most loads relative to both body mass and FFM ($p < 0.05$). Differences were particularly pronounced when adjusted for FFM, with effect sizes classified as large ($\eta p2 > 0.110$). Sex differences in MPV disappeared at 85% 1RM, suggesting that maximal neuromuscular recruitment reduces sex-related disparities at higher loads. Additionally, men demonstrated significantly greater values in six of the seven power-related variables, with no differences observed in %1RM required for optimal power output. **Conclusions:** These findings confirm that men exhibit higher strength and power than women, even when accounting for body composition differences. However, at high relative loads (>85% 1RM), sex differences in movement velocity diminish, likely due to similar recruitment patterns of fast-twitch muscle fibers. These insights underscore the need for sex-specific RT programming, particularly regarding load selection and velocity-based training applications.

Keywords: gender; strength training; mean propulsive velocity

1. Introduction

Long-term systematic resistance training (RT) has been shown to induce muscle hypertrophy and strength gains in both men and women, although there is significant individual variability [1,2]. Historically, most RT studies have focused on male populations, but recent research has increasingly examined RT in healthy adult women, particularly outside contexts such as menopause or pathologies like fibromyalgia and osteoporosis [3]. The physiological differences between sexes, such as hormonal levels, muscle fiber type, and fuel source utilization, necessitate sex-specific training protocols [4]. For instance, women typically have higher insulin sensitivity and lower testosterone levels, which influence their muscle composition and fat distribution [5]. Additionally, the menstrual cycle significantly impacts women's hormonal status, with estrogen peaks during the follicular phase enhancing muscle strength and mass gains [6,7]. Consequently, the skeletal muscle adaptations to RT in women are often maximized during the follicular phase of the menstrual cycle [8,9]).

Traditionally, one repetition maximum (1-RM), the maximum load that can be lifted once, has been the standard measure for assessing maximal dynamic strength and prescribing training loads [10]. However, 1-RM testing can be problematic due to high variability and daily fluctuations in performance [11]. An alternative approach is Velocity Based Training (VBT), which leverages the high correlation between specific loads and the speed of movement during the concentric phase to estimate the percentage of 1-RM [12]. Maximal concentric velocity is critical for neuromuscular adaptations and hypertrophy [13]. It is well-documented that men exhibit higher absolute and relative strength than women [14]. Since power, defined as the product of force and velocity, is crucial for performance, both strength and speed are essential components [15].

Few studies have standardized VBT protocols to explore sex differences comprehensively [16]. The biological variability within subjects can be significantly reduced by introducing a pause between the concentric and eccentric phases of a movement [17–19]. Therefore, this study aims to describe the differences in maximal concentric velocity during the bench press exercise between sexes using a standardized protocol that includes a controlled pause between the eccentric and concentric phases and accounts for the menstrual cycle phase [20,21] Therefore, the aim of this study was to compare male vs. female athletes in strength and power performance relative to body mass and fat free mass. Our hypothesis was that male would show higher levels of maximum strength and power relative to body mass and fat free mass compared to women.

2. Materials and Methods

2.1. Experimental Approach to the Problem

The present study was a cross-sectional, not controlled, not random study, designed to analyze the sex differences in the bench press exercise performed at maximal concentric velocity. Two different testing sessions were carried out separated by 48-72 hours. In the first session, participants performed a 1RM bench press exercise test using a Smith machine (a barbell that is fixed within steel rails allowing only vertical or near-vertical movement within a steel frame). In the second session, volunteers performed an incremental test against five different loads (45%, 55%, 65%, 75%, and 85% of 1RM) at maximal concentric velocity to analyze the load-velocity profile. Subjects performed three repetitions against each load and the mean propulsive velocity (MPV) of the barbell was measured with a linear velocity transducer (T-Force system, Ergotech) considered as the gold standard.

2.2. Subjects

Twenty-nine participants (n=16 men, mean age ± SD 21.3±4.1y and n=13 women, age ± SD 22.6±4.9y) volunteered to join the study. Participants were recruited from the university student population, with previous resistance exercise experience (2.66 ± 1.83 years) and all of them were familiarized with the bench press exercise technique before the beginning of the study. Volunteers presented no health problems, musculoskeletal injuries or suffered from physical limitations that could compromise the study. Subjects were asked to avoid any strenuous exercise 48 hours before each testing session. They were informed of the study procedures and signed a written informed consent form before initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the Universidad Politécnica de Madrid.

2.3. Procedures

 doi:10.20944/preprints202503.1150.v1

Body composition information was collected the first day of testing using bioimpedance (BIA) measures (Tanita BC 418-MA, Tanita Corp., Tokyo, Japan), followed by a standardized warm-up consisting of 10 minutes aerobic exercise (jogging, rowing, or cycling, by choice), three sets of isometric upper body exercises, and three sets of 10 repetitions of bench press exercise with a 20 Kg bar. The participants were encouraged to perform the last three repetitions of each set of 10 at maximal concentric velocity. After warming up, participants performed an incremental loading bench press maximum strength test (1-RM) in a Smith machine. To execute the bench press, the volunteers were laying on the bench placed under the rack where the bar rested. They could decide the preferred distance to grab the bar while maintaining the elbows bent. Keeping the scapula on the bench, participants were encouraged to fully extend the elbows raising the bar imposing a pause between the concentric and the eccentric phases. The load added to the bar was increased 10 Kg when velocity was over 0.50 m/s, 5 Kg when velocity was between 0.49 and 0.25 m/s, and 2 Kg when velocity was under 0.25 m/s. For each load, participants performed two repetitions except for the 1RM set where they could only perform one. Between sets, subjects rested for 3 minutes. To avoid circadian variations, all sessions were carried out in the morning. In addition, to standardize hormone situation, women performed the first session on their first day of their menstrual bleeding phase. Therefore, all female participants performed the two study sessions during the menstrual bleeding phase (the first and the second-third day). Although there is some evidence that sport performance can be reduced during the bleeding phase of the menstrual cycle [22–24] due to testing limitations and literature inconclusive results [25,26], the easiest and most precise way to standardize the menstrual phase for all female participants was to use the bleeding phase.

On the second day of testing and after warming up similarly as in session one, participants performed the bench press exercise in the Smith machine against five loads (45%, 55%, 65%, 75%, and 85% of the 1RM load obtained in the first session) in incremental order. Subjects imposed a pause between the concentric and the eccentric phases to reduce the biological within-subject variability [27]. After the eccentric phase, participants released the barbell weight on the safety stops for two seconds (controlled with a stopwatch) but still grabbing the barbell. Thereafter, the researcher gave the subject an acoustic signal to start a purely concentric push at the maximum possible velocity. Inter-sets, participants rested for three minutes, individually choosing between, laying or sitting on the bench or standing/walking. Participants performed three repetitions with each load.

2.4. Measurement equipment and data acquisition

Technical characteristics of the device used for measuring the barbell mean propulsive velocity (MPV) of each repetition performed are shown in Table 1. The T-Force device was place vertically under the barbell and connected to a laptop to immediately obtain the data.

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited.

	T-force
Technology	Linear velocity transducer
Support APP on mobile	No
Software version	3.6
Indirect outcome calculation	Velocity; Time
Maximal Sampling frequency	1000Hz
Mechanic parameters	Peak force, mean velocity. Mean power, time to peak power, propulsive phase's duration. estimated load (%1RM), 1RM prediction, number of repetitions, velocity loss (%), velocity alerts. Automatically computed and presented numerically and graphically.
Screen	OLED Screen
Export to Excel	Yes
Bluetooth/WIFI connection	No

 doi:10.20944/preprints202503.1150.v1

External power supply required	Yes
Installation and calibration time before the first execution	2.4 min
Time to obtain the measure after execution	Real time
Number of lost repetitions per each 100 cases	0,8
Price	2600€

2.5. Variables analyzed

The dependent variables analyzed included the medium speed (MV) of the bar measured at the five different %1RM (45%, 55%, 65%, 75% and 85%), as well as seven different variables obtained from the excel sheet proposed by Alcazar et al., [28]. This excel sheet registers the MV measured by an external device (T-force linear encoder, in this concrete study) to posteriorly calculate: Initial force (F0), that measures in Newtons, the maximal applied to the bar, before it stars moving, in isometric contraction; Final velocity (V0), that measures in m/s, the maximal bar displacement before stopping at the end of the concentric phase; Maximal power (Pmax), that measures in watts, the maximal power achieved; Optimal force (Fopt), that measures in Newtons, the optimal force that must be applied to specifically train power; Optimal velocity (Vopt), that measures in m/s, the optimal velocity to be moving the bar to specifically train power; %1RM at Pmax, that measures which % of 1RM should be applied, in Kg, to specifically train power and the Optimal load (Lopt), that measures the optimal load in Kg, that should be lifted to train specifically power.

2.6. Statistical analysis

Descriptive results were presented as mean and standard deviation (SD). Before running the inferential analysis, the data normality assumptions were calculated (Shapiro Wilk test) identifying that all variables were normally distributed, then parametric analyses were considered for. Secondly, in order to compare men and women participants and ANCOVA model was run including all the dependent variables (measures) and the 1RM (Kg) and FFM (Kg) as covariate. Due to the identification of a statistically significant positive correlation between both sexes ($r=0.576$; $p=0.019$ and $r=0.640$; $p=0.018$, for men and women, respectively), two independent ANCOVA models were used for 1RM (Kg) and FFM (kg), respectively, in order to avoid collinearity problems. All the analyses were run using the statistical software IBM SPSS for Windows, version 26.0 (Armonk, NY: IBM.Corp.), and the significant level was set at $p<0.05$.

3. Results

Descriptive characteristics of the participant are presented in Table 2. The mean ± SD values for maximal strength and power obtained in men and women in bench press are shown in Table 3. When the ratio of 1RM/Kg of body weight was introduced as covariable in the analysis, differences between sexes were observed only in the 65% and 75% of the 1RM load ($p=0.022$ and $p=0.046$ respectively). On the contrary, when the covariable used was the ratio 1RM/FFM the significative differences among sexes were seen in all percentages of the 1RM load analyzed but in 85% (p=0,022, p=0,031, p=0,000 and p=0,011 for 45%, 55%, 65% and 75% respectively), with effect size classified as big according to Cohen scale ($\pi p2>0.110$) in both conditions but in 85% of the 1RM when adjusted by Kg of body weight or by FFM ($\pi p2>0.051$, $\pi p2>0.060$, respectively) (see Table 4). In regards the power variables analyzed, significant differences ($p\leq0.05$) between sexes were found in six of the seven variables (exception for the %1RM), with effect size classified as high according to Cohen scale ($\pi p2>0.110$) when the covariable used was the ratio RM/Kg, and very high when the variable used was RM/FFM.

Table 2. Descriptive characteristics of the participants.

	Mean±SD n Total	Mean±SD Males	Mean±SD Females
Age (n= 29)	21.9±4.5	21.3±4.1	22.6±5.0
Height (cm)	171.9±8.9	176.67.2	165.8±7.1
Weight (Kg)	67.8±12.8	75.9±10.1	57.9±7.9
BMI	22.8±2.7	24.3±2.7	21.0±1.3
%Fat_Mass	16.1±4.8	13.3±2.7	19.5±4.6
FFM (Kg)	57.3±11.8	66.1±7.8	46.4±4.4
1RM (Kg)	73.1±26.3	92.0±19.7	49.7±8.1

BMI: Body Mass Index, FFM: Fat Free Mass, 1RM: One repetition maximum.

Table 3. Mean ± Standard deviation values for maximal velocity and power in men and women in bench press.

Variable	Males	Females
45%1RM	0,79 ± 0,06	0,73 ± 0,15
55%1RM	0,66 ± 0,05	0,61 ± 0,12
65%1RM	0,54 ± 0,04	0,47 ± 0,05
75%1RM	0,46 ± 0,05	0,41 ± 0,04
85%1RM	0,34 ± 0,04	0,32 ± 0,05
V0	1,36 ± 0,11	1,20 ± 0,27
F0	1.036,47 ± 185,38	568,18 ± 107,15
Vopt	0,68 ± 0,06	0,60 ± 0,13
Pmax	349,73 ± 64,29	166,66 ± 26,76
%RM	57,18 ± 1,56	58,61 ± 3,42
Opt. Load	52,83 ± 9,44	28,96 ± 5,41

1RM: One repetition maximum, V0: initial velocity, F0: initial force. Vopt: optimal Velocity, Pmax: Maximal Power, Opt. Load: optimal load.

Table 4. ANCOVA results among sexes for the five different loads by two different adjusments.

Variable	Adjusted by Kg of weight			Adjusted by FFM		
	F	**p**	**η2**	F	p	η2
45%1RM	3.309	0.080	0.113	5.906	0.022	0.185
55%1RM	3.529	0.072	0.120	5.190	0.031	0.166
65%1RM	5.971	0.022	0.187	16.118	0.000	0.383
75%1RM	4.394	0.046	0.145	7.449	0.011	0.223
85%1RM	1.390	0.249	0.051	1.664	0.208	0.060

1RM: One repetition maximum, η2 = partial eta squared, ANCOVA = analysis of covariance.

4. Discussion

The aim of the present study was to compare males and females in relative strength and power performances taking into account the body weight and the FFM. The analysis conducted revealed that, for most of the variables studied, men exhibited higher relative strength values than women in both ratios examined (1RM/kg and 1RM/FFM), with differences being more pronounced when using the 1RM/FFM ratio. Additionally, in all power-related variables analyzed, males demonstrated higher values, except for the %RM. The variable "%RM" represents the percentage of 1RM that should be applied, in kilograms, to specifically train power. The lack of significant differences in %RM between sexes suggests that there is an optimal percentage of RM for power training that is consistent and independent of sex. Differences between sexes in power accounted for muscle fiber types, muscle quality, or glycolytic enzymatic activities [29]. A qualitative difference in muscle tissue, such as a higher concentration of glycolytic enzymes and greater proportion of fast type muscle fibers, may

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 March 2025 doi:10.20944/preprints202503.1150.v1

explain the disparity in strength [30] what also might explain that the differences were more pronounced when adjusting by FFM.

This is consistent with Bartolomei et al., [31], who detected significantly greater 1RM in bench press adjusted for FFM in men than in women. As suggested by previous investigations [32], FFM can be considered as one of the most important factors for maximal strength and power performance. Although, no significant sex differences after adjusting for FFM were detected for 1RM in squat exercise [31]. Sex differences are obvious in all muscle groups but are larger for upper-body than lower-body muscle. For this reason, the difference in absolute strength between sexes appears more evident in the upper body compared to the lower body [33].

Moreover, the results of this study revealed significant differences as well between sexes in MPV at most relative loads to 1RM (45%, 55%, 65%, and 75%), whereas these differences were not significant at 85% 1RM. These observations can be explained by physiological and neuromuscular factors inherent to each sex, as well as differences in muscle fiber recruitment strategies under varying load levels. Similar observations were found by others who evaluated bench press, military press, squat and row [34–37]. Similar trends have been reported by Nieto et al., [38] in their metanalyses where show that significant differences between men and women in relative loads disappear with high loads (>85-90% 1RM). Furthermore, Izadi et al., [39] found that women exhibited reduced velocities when handling lighter relative loads compared to men. Conversely, women demonstrated higher velocities when dealing with loads exceeding 85% of their 1RM in contrast to their male counterparts. The significant differences observed at loads from 45% to 75% 1RM align with previous research highlighting men's greater capacity for force and power production due to their higher proportion of type II muscle fibers, higher testosterone levels, and greater muscle cross-sectional area [14,33]. Maximal strength and power are influenced by many neuromuscular factors including muscle morphological characteristics such as muscle thickness, pennation angle, and fascicle length [31], as well as fiber type [33]. These characteristics enable men to generate greater explosive force and velocity during repetitions performed with low to moderate loads. Additionally, the use of the 1RM/FFM ratio as a covariate highlights that the differences are not solely attributable to total body mass but also to FFM composition, which is higher in men. On the other hand, women tend to exhibit greater fatigue resistance at lower loads due to their reduced reliance on type II fibers and greater use of type I fibers, along with a lower accumulation of metabolites during repetitive contractions [40]. However, these advantages are insufficient to match the MPV generated by men at these loads, explaining the observed differences. The absence of significant differences at 85% 1RM may be attributed to the convergence in muscle recruitment strategies as the load increases. At higher loads, both men and women activate a greater percentage of their available muscle fibers, including both fast-twitch type II and slow-twitch type I fibers [31]. This reduces the disparity between sexes, as structural and hormonal differences have a less pronounced impact at these load levels, where neuromuscular factors are primarily limiting. Additionally, recent studies have indicated that women demonstrate superior relative efficiency in handling loads close to their maximum [39]. This adaptation may be related to a greater capacity for sustained effort and reduced strength deficits during prior eccentric contractions, contributing to equalizing velocities with men at this load.

Interestingly, we obtain significant differences in the optimal power in bench press (52,83 ± 9,44% of 1RM for men; 28,96 ± 5,41 of 1RM for women). These results are in line with those obtained by Thomas et al., [41] who found differences between sexes in optimal power output during the squat jump (30-40% of 1RM for men; 30-50% of 1RM for women) and bench throw (30% of 1RM for men; 30-50% of 1RM for women) exercises. Alonso-Aubin et al., 42] also found significant sex-related differences on the bench press exercise for power and time to maximum velocity (40%-60%-70%-80%). Moreover, Bartomei et al., [31] found lower levels of power were detected in females in the upper body (−61.2%). These results could be explained in part by the difference between sexes in anaerobic power, regardless FFM. Similar results have been previously reported by Mayhew et al., [43] and Perez-Gomez et al., [44]. These results differ slightly from those reported by Torrejón et al., [45]. Although they found differences in 1RM between men and women, these differences disappear

 doi:10.20944/preprints202503.1150.v1

when the load is adjusted for body mass. Our results and the results obtain by Torrejón et al., [45] reveals that sex differences are still evident when power per kg of body mass is considered. Consequently, future research should take into account fat free mass to compare strength and power between gender.

Equally, we demonstrated that Pmax, F0 and v0 differed significantly between males and females. The results are in line with Nikolaidis [46], who found that boys had higher values of Pmax, rPmax and v0 than girls, while no differences were found for F0 and v0/F0. Thus, the physiological differences explained previously (i.e., muscle enzyme activities, electromyographic activity, muscle fiber composition, etc.) could explain these differences as well.

5. Practical Implications

These findings highlight the importance of individualizing resistance training programs by considering sex-based differences in force-velocity profiles. For example, in women, training with moderate loads could focus on improving velocity and power, whereas in men, it could aim to optimize maximal fiber recruitment at higher loads.

6. Limitations and Future Research

This study is limited by the relatively small sample size and its exclusive focus on the bench press. Future research could explore these findings in other compound exercises and analyze the impact of accumulated fatigue on propulsive velocity across sexes.

7. Conclusions

In conclusion, the results of the present investigation indicate that significant differences in strength and power relative to body mass and FFM exist between male and female at loads of 45% to 75% 1RM which reflects physiological and neuromuscular disparities. However, these differences disappear at 85% 1RM due to maximal muscle fibers recruitment and similar strategies between sexes. These findings emphasize the need to design sex-specific training strategies to optimize performance according to the sex and load level utilized.

Author Contributions: All authors equally contributed to the execution of the present research. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the Universidad Politécnica de Madrid.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data is presented in this manuscript.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Phillips, S. M. (2000). Short-term training: when do repeated bouts of resistance exercise become training? *Canadian Journal of Applied Physiology, 25*(3), 185-193.
2. Schoenfeld, B. J. (2010). The mechanisms of muscle hypertrophy and their application to resistance training. *Journal of Strength and Conditioning Research, 24*(10), 2857-2872

3. Collins, B. C., Laakkonen, E. K., & Lowe, D. A. (2018). The impact of resistance training on the musculoskeletal system in aging women: a review. *Current Osteoporosis Reports, 16*(1), 38-47
4. Folland, J. P., & Williams, A. G. (2007). Morphological and neurological contributions to increased strength. *Sports Medicine, 37*(2), 145-168.
5. Hansen, M., Jensen, B., & Sjodin, A. (2003). Insulin sensitivity during menstrual cycle. *Diabetes Care, 26*(10), 2777-2782
6. Oxfeldt, M., Dalgaard, L. B., Jørgensen, A. A., & Hansen, M. (2020). Hormonal contraceptive use and muscle adaptations to resistance training: a randomized controlled trial of well-trained women. *Journal of Strength and Conditioning Research, 34*(4), 977-986.
7. Phillips, S. K., Sanderson, A. G., Birch, K., Bruce, S. A., & Woledge, R. C. (1996). Changes in maximal voluntary force of human adductor pollicis muscle during the menstrual cycle. *Journal of Physiology, 496*(2), 551-557.
8. Bambaeichi, E., Reilly, T., Cable, N. T., & Giacomoni, M. (2004). Variability in exercise performance during the menstrual cycle: a series of studies. *European Journal of Applied Physiology, 93*(1-2), 53-60.
9. Elliott, K. J., Cable, N. T., Reilly, T., & Diver, M. J. (2005). Effect of menstrual cycle phase on the concentration of serum amino acids and urinary 3-methylhistidine following prolonged exercise. *Experimental Physiology, 90*(3), 351-356.
10. Knuttgen, H. G., & Kraemer, W. J. (1987). Terminology and measurement in exercise performance. *Journal of Applied Sport Science Research, 1*(1), 1-10.
11. Dohoney, P., Chromiak, J. A., Lemire, D., Abadie, B. R., & Kovacs, C. (2002). Validation of an air displacement plethysmography system for measuring human body composition. *Medicine and Science in Sports and Exercise, 34*(5), 869-873.
12. Jovanović, M., & Flanagan, E. P. (2014). Researched applications of velocity based strength training. *Journal of Australian Strength and Conditioning, 22*(2), 58-69.
13. Haff, G. G., & Nimphius, S. (2012). Training principles for power. *Strength and Conditioning Journal, 34*(6), 2-12
14. Miller, A. E., MacDougall, J. D., Tarnopolsky, M. A., & Sale, D. G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology and Occupational Physiology, 66*(3), 254-262.
15. Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing maximal neuromuscular power: part 1–biological basis of maximal power production. *Sports Medicine, 41*(1), 17-38.
16. Hackett, D. A., Johnson, N. A., & Chow, C. M. (2013). The effect of movement velocity during resistance training on muscle-specific hypertrophy: a systematic review. *European Journal of Applied Physiology, 113*(8), 2101-2118.
17. Aedo-Muñoz, E., & Miarka, B. (2023). Eccentric resistance training: A methodological proposal of eccentric muscle exercise classification based on exercise complexity, training objectives, methods, and intensity. Applied Sciences, 13(13), 7969
18. Franchi, M. V., Reeves, N. D., & Narici, M. V. (2017). Skeletal muscle remodeling in response to eccentric vs. concentric loading: morphological, molecular, and metabolic adaptations. Frontiers in Physiology, 8, 447.
19. Siff, M. C. (2003). Biomechanical foundations of strength and power training. In Zatsiorsky, V. M. (Ed.), *Biomechanics in Sport: Performance Enhancement and Injury Prevention* (pp. 103-139). Wiley-Blackwell.
20. González-Badillo, J. J., & Sánchez-Medina, L. (2010). Movement velocity as a measure of loading intensity in resistance training. *International Journal of Sports Medicine, 31*(5), 347-352.
21. Loturco, I., Ugrinowitsch, C., Roschel, H., Tricoli, V., Silva-Bello, R., & Pereira, L. A. (2015). Transference effect of short-term optimum power training vs. traditional strength training on the sprinting and jumping capacity of elite young soccer players. *Journal of Strength and Conditioning Research, 29*(8), 2008-2016.
22. Greenhall, M.,Taipale, R.S., Ihalainen, J.K. & Hackney, A.C. (2021). Influence of the Menstrual Cycle Phase on Marathon Performance in Recreational Runners. International Journal of Sports Physiology and Performance, human kinetics. 2021, 16, 601-604. https://doi.org/10.1123/ijspp.2020-0238

23. Joo, M. H., Maehata, E., Adachi, T., Ishida, A., Murai, F., & Mesaki, N. (2004). The relationship between exercise-induced oxidative stress and the menstrual cycle. European Journal of Applied Physiology, 93(1-2), 82-86. https://doi.org/10.1007/s00421-004-1168-4
24. Solli, G. S., Sandbakk, S. B., Noordhof, D. A., Ihalainen, J. K., & Sandbakk, Ø. (2020). Changes in Self-Reported Physical Fitness, Performance, and Side Effects Across the Phases of the Menstrual Cycle Among Competitive Endurance Athletes. International Journal of Sports Physiology and Performance, 15(9), 1324-1333. https://doi.org/10.1123/ijspp.2019-0616
25. Kalytka, S., Roda, O., Ierko, I., Panasiuk, O., Kasarda, O., Hrebik, O., Faidevych, V., & Liannoi, M. (2018). Comparative analysis of functional capabilities and special working ability of men and women, specializing in 800 m and 1500 m running. Journal of Physical Education and Sport, 18(4). https://doi.org/10.7752/jpes.2018.04360
26. Middleton, L. E., & Wenger, H. A. (2006). Effects of menstrual phase on performance and recovery in intense intermittent activity. European Journal of Applied Physiology, 96(1), 53-58. https://doi.org/10.1007/s00421-005-0073-936696264.
27. Pallarés JG, Sánchez-Medina L, Pérez CE, De La Cruz-Sánchez E, Mora-Rodriguez R. Imposing a pause between the eccentric and concentric phases increases the reliability of isoinertial strength assessments. J Sports Sci. 2014;32(12):1165-75. doi: 10.1080/02640414.2014.889844. Epub 2014 Feb 28. PMID: 24575723.
28. Alcazar J, Rodriguez-Lopez C, Ara I, Alfaro-Acha A, Mañas-Bote A, Guadalupe-Grau A, García-García FJ, Alegre LM. The Force-Velocity Relationship in Older People: Reliability and Validity of a Systematic Procedure. Int J Sports Med. 2017 Dec;38(14):1097-1104. doi: 10.1055/s-0043-119880. Epub 2017 Nov 10. PMID: 29126339.
29. Serresse, O.; Ama, P.F.; Simoneau, J.A.; Lortie, G.; Bouchard, C.; Boulay, M.R. Anaerobic performances of sedentary and trained subjects. Can. J. Sport Sci. 1989, 14, 46–52.
30. Nindl, B.C.; Mahar, M.T.; Harman, E.A.; Patton, J.F. Lower and upper body anaerobic performance in male and female adolescent athletes. Med. Sci. Sports Exerc. 1995, 27, 235–241. [CrossRef]
31. Bartolomei S, Grillone G, Di Michele R, Cortesi M. A Comparison between Male and Female Athletes in Relative Strength and Power Performances. J Funct Morphol Kinesiol. 2021 Mar 1;6(1).
32. Brechue, W.F.; Abe, T. The role of FFM accumulation and skeletal muscle architecture in powerlifting performance. Eur. J. Appl. Physiol. 2002, 86, 327–336
33. Nuzzo JL. Narrative Review of Sex Differences in Muscle Strength, Endurance, Activation, Size, Fiber Type, and Strength Training Participation Rates, Preferences, Motivations, Injuries, and Neuromuscular Adaptations. J Strength Cond Res. 2023 Feb 1;37(2):494-536. doi: 10.1519/JSC.0000000000004329. Epub 2022 Nov 15.
34. Pareja-Blanco F, Walker S, Häkkinen K. Validity of using velocity to estimate intensity in resistance exercises in men and women. Int J Sports Med. 2020 Dec;41(14):1047–55.
35. Balsalobre-Fernández C, García Ramos A, Jimenez-Reyes P. Load–velocity profiling in the military press exercise: Effects of gender and training. Int J Sports Sci Coach. 2017 Oct 26;13(5):743–750.
36. García-Ramos A, Suzovic D, Pérez-Castilla A. The load-velocity profiles of three upper-body pushing exercises in men and women. Sport Biomech. 2021 Jul;20(6):693–705.
37. Nieto-Acevedo R, Romero-Moraleda B, Montalvo-Pérez A, García-Sánchez C, Marquina-Nieto M, Mon-López D. Sex Differences in the Load–Velocity Profiles of Three Different Row Exercises. Sport 2023, Vol 11, Page 220. 2023 Nov 9;11(11):220.
38. Nieto-Acevedo R, Romero-Moraleda B, Díaz-Lara FJ, Rubia A, González-García J, Mon-López D. A Systematic Review and Meta-Analysis of the Differences in Mean Propulsive Velocity between Men and Women in Different Exercises. Sports (Basel). 2023 Jun 13;11(6):118. doi: 10.3390/sports11060118. PMID: 37368568; PMCID: PMC10303652.
39. Izadi M, Pillitteri G, Thomas E, Battaglia G, Bianco A, Bellafiore M. Sex differences in the determination of prescribed load in ballistic bench press. Front Physiol. 2024 Jan 12;15:1293044.
40. Hunter SK. Sex differences in human fatigability: mechanisms and insight to physiological responses. Acta Physiol (Oxf). 2014 Apr;210(4):768-89. doi: 10.1111/apha.12234. Epub 2014 Feb 25. PMID: 24433272; PMCID: PMC4111134.

doi:10.20944/preprints202503.1150.v1

41. Thomas, K., Brown, L. E., Coburn, J. W., & Lynn, S. K. (2007). Influence of gender on maximal power output and fatigue during dynamic resistance exercise. *Journal of Strength and Conditioning Research*, 21(3), 747-753.
42. Alonso-Aubin DA, Chulvi-Medrano I, Cortell-Tormo JM, Picón-Martínez M, Rial Rebullido T, Faigenbaum AD. Squat and bench press force-velocity profiling in male and female adolescent rugby players. J Strength Cond Res. 2019;Publish Ah:1–7.
43. Mayhew, J.L.; Hancock, K.; Rollison, L.; Ball, T.E.; Bowen, J.C. Contributions of strength and body composition to the gender difference in anaerobic power. J. Sports Med. Phys. Fit. 2001, 41, 33–38.
44. Perez-Gomez, J.; Rodriguez, G.V.; Ara, I.; Olmedillas, H.; Chavarren, J.; González-Henriquez, J.J.; Dorado, C.; Calbet, J.A. Role of muscle mass on sprint performance: Gender differences? Eur. J. Appl. Physiol. 2008, 102, 685–694. [CrossRef]
45. Torrejón, A., Balsalobre-Fernández, C., Haff, G. G., & García-Ramos, A. (2019). The load-velocity profile differs more between men and women than between individuals with different strength levels. *Sports Biomechanics*, 18(3), 245-255.
46. Nikolaidis, P. T. (2012). Age- and sex-related differences in force-velocity characteristics of upper and lower limbs in competitive adolescent swimmers. *Journal of Human Kinetics*, 32, 87-95.