the Journal of Strength and Conditioning Research™

Analysis of Concentric and Eccentric Power in Flywheel Exercises Depending on the Subjects' Strength Level and Body Mass

Pablo Asencio,[1] Adrián García-Valverde,[2] Carlos Albaladejo-García,[1] Marco Beato,[3] Francisco J. Moreno,[1] and Rafael Sabido[1]

[1]Sports Research Centre, Department of Sport Sciences, Miguel Hernández University, Elche, Spain; [2]Faculty of Health Sciences, University Isabel I of Castilla, Burgos, Spain; and [3]School of Health and Sport Science, University of Suffolk, Ipswich, United Kingdom

Abstract

Asencio, P, García-Valverde, A, Albaladejo-García, C, Beato, M, Moreno-Hernández, FJ, and Sabido, R. Analysis of concentric and eccentric power in flywheel exercises depending on the subjects' strength level and body mass. *J Strength Cond Res* XX(X): 000–000, 2024—The objective of this study is to describe how flywheel exercise mechanical outputs are affected by the athletes' body mass (BM) and strength level and by the exercise type. Forty-six recreational athletes came to a laboratory 3 times. On the first day, descriptive data, squat (1 repetition maximum: 1RM) and flywheel familiarization were performed. After a second day of familiarization, subjects performed a randomized flywheel exercise-testing protocol of squat and split squat exercises. The variables used for data analysis were peak concentric power and peak eccentric power, eccentric/concentric ratio, and their relationship with 1RM/BM. Subjects were assigned to a stronger or weaker group according to their 1RM/BM ratio. Group differences were found in absolute values of eccentric overload (EOL) ($p < 0.01$; effect size [ES] = 0.51) and EOL/BM ($p < 0.01$; ES = 0.46) only in the split squat. Absolute power values in the concentric phase showed differences between inertial load ($p < 0.01$; ES = 0.41). The stronger group did not present significant differences between inertial loads during squat ($p < 0.01$; ES = 0.46), but they showed different ratios with light inertias in comparison with the weaker group ($p < 0.01$; ES = 0.46). There were significant differences between groups with light inertias in split squat (nondominant) and squat exercises ($p < 0.05$; ES = 0.29) in the eccentric and concentric phases ($p < 0.116$; ES = 0.20). Squat and split squat exercises present different profiles depending on the training level. In conclusion, it is recommended that practitioners perform a test to understand the inertial load–power profile (concentric, eccentric, and their ratio) for each exercise and also consider the user's strength level for selection of the inertial load and for the exercise to use in training.

Key Words: flywheel squat, flywheel split squat, eccentric overload, inertial loads

Introduction

Strength and power play a crucial role in athletic preparation for success in many sports (14). As power is the product of velocity and force (7), athletes' strength level is a determinant variable for increasing power outputs (1,6). In this way, several studies found an improvement in performance with power training in sports such as soccer (12) or basketball (34). Therefore, it seems that a relationship exists between high lower limb power output and sport-specific ability (1,4,25). From a training perspective, one criterion to identify the right training intensity is to evaluate the load that allows subjects to achieve peak power in a specific exercise (7,14,17). It is important to remember that peak power can vary depending on some variables such as the athlete's strength level (35), training experience (7,16), or type of exercise (8).

Flywheel resistance training uses a rotating mass that stores and releases kinetic energy during exercise. This training has been shown to improve strength (26), power (21), change of direction (10), countermovement jump (10), and sprinting ability (10) in different populations and to generate morphological adaptations (e.g., hypertrophy) (26). To maximize the training effect of flywheel resistance technology, practitioners use an inertial load that allows them to reach the desired mechanical outputs (e.g., power) (21). Training intensity with flywheels is usually monitored based on the power output, which is the product of inertial load (i.e., the combination of discs used) and rotational velocity. Flywheel resistance exercise can be divided into concentric and eccentric phases. It is common to report mechanical output data for both phases and their ratio (eccentric/concentric ratio), which assesses the presence of an eccentric overload (EOL) (10). Flywheel resistance training produce an EOL when a specific mechanical output (e.g., mechanical power) is greater during the eccentric phase than during the concentric phase (18,23). Previous research showed an inverse relationship between load and power outputs and a positive relationship between load and EOL (22,29,32). Therefore, practitioners can modify the intensity by changing the flywheel inertial load to provide changes in the mechanical outputs of interest (e.g., concentric power and eccentric power) (2).

Because of the importance of concentric and eccentric mechanical output maximization during training, previous authors (2,21) suggested practitioners should determine inertia–power and inertial velocity profiles of their athletes to select the most suitable inertial load for each user (38); however, the inertia–power profile is the most commonly used approach because of the

Address correspondence to Pablo Asencio, pasencio@umh.es.

Journal of Strength and Conditioning Research 00(00)/1–7

difficulty in assessing velocity in the applied scenarios (e.g., lack of time or technology) (21). The use of an inertia–power profile to individualize peak power output is supported by previous authors (9), who used this approach to maximize the benefits of squat exercises. However, even with the latest research around flywheel resistance training monitoring (21), we do not have exhaustive evidence for optimization of mechanical outputs during training when the athlete's characteristics and exercises are manipulated. Practitioners need to know more regarding the impact that athletes' characteristics such as body mass (BM) and strength level have on power outputs (e.g., the importance of familiarization) (2,3).

An important variable to determine the inertia–power profile is the type of movement used during the test. Unilateral movements, such as the split squat, are a way to improve sport performance (44,40) and provide training variations (44,36). In certain contexts, their use has shown greater benefits versus bilateral movements (40). In the field of flywheel resistance training, 3 studies on the effects of unilateral and bilateral training (14,15,27) show similar improvements in jump or change of direction with both types of training but with slightly greater benefits for unilateral versus bilateral training. Although program duration and total volume were similar in the 3 studies (6–8 weeks; 2 sessions per week with 4 or 6 sets), training intensities were different. Two of the studies chose low inertial loads to obtain greater power peaks during the movements (14,15), whereas the third used higher inertial loads to maximize EOL (27).

Because of the limited evidence currently available around the influence of BM, strength level and different exercises on power, EOL, and velocity, this research is warranted. The objective of this study is to describe how mechanical outputs are affected by the athletes' BM, strength level, and the exercise performed. We hypothesized the athletes' BM and strength level will allow greater absolute mechanical outputs to be achieved, and these outputs will be exercise dependent.

Methods

Experimental Approach to the Problem

Differences in flywheel resistance exercise variables between stronger and weaker athletes in squat and split squat exercises were investigated. After a familiarization procedure and testing, the subjects enrolled were classified according to their strength level. After a standardized warm-up protocol, they performed a randomized and counterbalanced exercise protocol (experimental conditions) where flywheel resistance exercises were performed with different inertial loads and exercises (see Figure 1).

Subjects

Forty-six recreational athletes (between 21–41 years old) took part in this study. Subjects had at least 1 year of experience in resistance training but no experience with flywheel resistance devices. Subjects were assessed for their 1 repetition maximum (1RM) and BM, both expressed in kilograms, and were subsequently assigned to 1 of 2 groups according on the training level based on their 1RM/BM ratio (13). The cutoff level for each group was performed following James et al.'s (16) criteria to classify the subjects according to their strength level in the back squat exercise: $<$1.5RM/BM for the weaker group; $>$1.5RM/BM for the stronger group.

A stronger group (n = 28; 27.42 ± 5.00 years; 1.74 ± 0.06 m; 72.53 ± 7.96 kg; 1RM = 129.50 ± 16.94; 1RM/BM = 1.79 ± 0.15) and a weaker group (n = 18; 26.10 ± 5.23 years; 1.77 ± 0.08 m; 78.22 ± 15.34 kg; 1RM = 115.16 ± 28.46 kg; 1RM/BM = 1.24 ± 0.13) were identified. Subjects provided written informed consent in accordance with the Declaration of Helsinki, and the experimental protocols were approved by the Ethics Committee of the Miguel Hernández University (Code: ADH.DES.RSS.PAV.23).

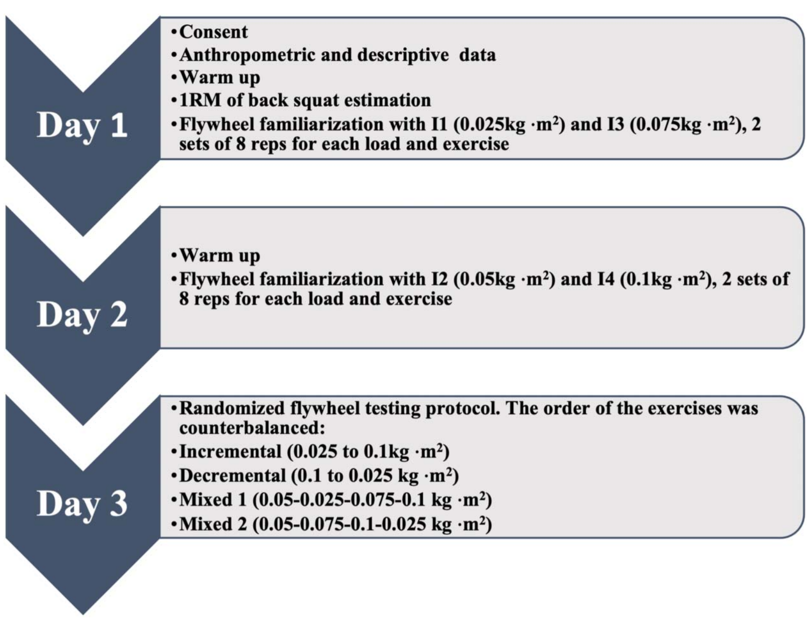

Figure 1. Scheme of the procedure.

Procedures

Subjects came to the laboratory on 3 separate occasions (72 hours of recovery between sessions). On the first day, descriptive (e.g., age, training level) and anthropometric data were recorded for each subject. After that, the 1RM back squat and flywheel familiarization protocols were completed (33). On the second day, another flywheel familiarization protocol took place. On the last day, a randomized flywheel exercise protocol was performed. The variables used for data analysis were peak concentric power (PP_{conc}), peak eccentric power (PP_{ecc}), and EOL. Their relationship with the 1RM/BM ratio was calculated for squat and split squat exercises. Test reliability for these tasks was published in previous studies (32). The values for ICC ranged from 0.79 to 0.93 and from 7.5% to 13.2 for CV.

Testing. On the first day, subjects completed a 1RM back squat exercise recorded using a linear encoder (T-Force System, Ergotech, Murcia, Spain) with a software application to calculate the relevant kinetic and kinematic parameters. For the 1RM estimation, subjects performed a protocol previously described by Loturco et al. (19). Briefly, this consisted of squatting with a shoulder-width stance and the barbell rested on the upper back, approximately at the level of the scapular acromion, with the knees and hips fully extended. Each subject descended until their thighs were parallel to the ground and then ascended to the upright position. Subjects started with a load representing 50% of their BM and thereafter the load was gradually increased until the mean propulsive velocity was $<0.5\ m \cdot s^{-1}$. Using this submaximal load, subjects performed 3 repetitions whereby concentric phases were performed as fast as possible, with an attached linear position transducer, it was possible to automatically estimate the 1RM of the athletes. The rest interval between sets was 4 minutes. The 1RM was estimated through movement velocity, as previously described (19). The coefficient of variation of the test was 9.7%, and the intraclass correlation coefficient was 0.82.

Flywheel Resistance Exercise Protocol. During the last testing day, subjects completed the trial with a randomized load protocol (incremental, decremental, mixed 1, and mixed 2), performing 1 maximum set of 8 repetitions with the addition of 2 initial repetitions needed to initiate the flywheel movement (32). The inertial loads used during the squat and split squat exercises were 0.025 (I1), 0.05 (I2), 0.075 (I3), and 0.1 $kg \cdot m^{-2}$ (I4). After each set, according to Sabido et al. (31,33), the subjects rested for 2 (for I1 and I2) or 3 (for I3 and I4) minutes. During each repetition, both the concentric power and eccentric power were recorded using an encoder and subsequently analyzed (SmartCoach Power Encoder, Europe AB, Stockholm, Sweden).

Statistical Analysis

Statistical analyses were performed using the R-Studio program (4.0.2 version). A reliable estimate of 95% was determined for the confidence interval (CI) (1–7,8–15,17–31,33–40). The data were shown as the average of the mean of 8 repetitions for each set (33). Values were compared among the different inertial loads, exercises and training level through a 3-factor ANOVA test. If necessary, the Bonferroni post hoc test was carried out for pairwise comparisons. The level of statistical significance was set at $p < 0.05$. To assess the magnitude of the changes, a Cohen effect size (ES) calculation was performed, interpreted as trivial (<0.2), small (0.2–0.5), moderate (0.5–0.8), and large (>0.8) (30).

Results

Our results show there were differences between inertial loads for absolute EOL inertial loads [see Figure 2; F (3, 468) = 9.76; $p < 0.01$; ES = 0.51; 95% CI (18.9–24.5)]. Similar results were found for EOL/BM between inertial loads during the split squat exercise [see Figure 3; F (3, 468) = 8.68; $p < 0.01$; ES = 0.46; 95% CI (0.28–0.32)], although this pattern is not repeated exactly the same in the squat exercise [Figure 3; F (2, 468) = 1.28; $p = 0.280$; ES = 0.20; 95% CI (0.27–0.33)]. In addition, for the absolute power values in the concentric phase, there were differences between inertias [see Figure 4; F (3, 468) = 6.62; $p < 0.01$; ES = 0.41; 95% CI (806–852)], but no differences were found in the eccentric phase [see Figure 5; F (3, 468) = 1.68; $p < 0.171$; ES = 0.20; 95% CI (962–1,001)].

The stronger group did not present significant differences between inertial loads during the squat exercise [see Figure 2; F (3, 468) = 8.68; $p < 0.01$; ES = 0.46; 95% CI (16.44–23.74)]. We found that both the stronger and the weaker groups were

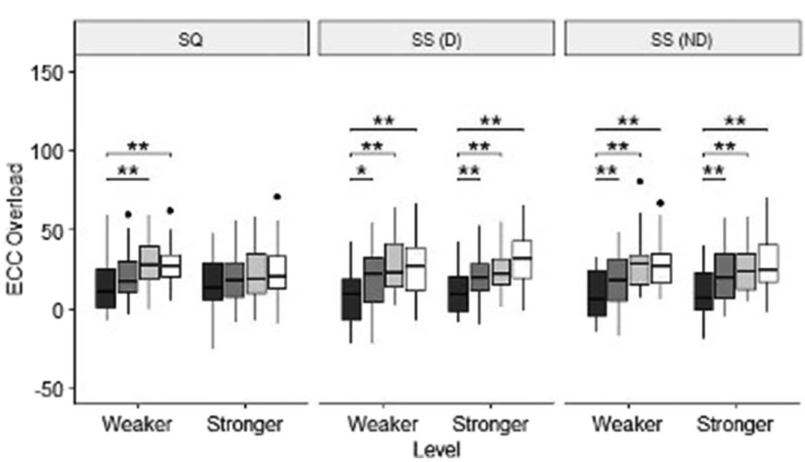

Figure 2. Inter-group comparison of inertias and eccentric overload values for squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises (*$p < 0.05$; **$p < 0.01$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

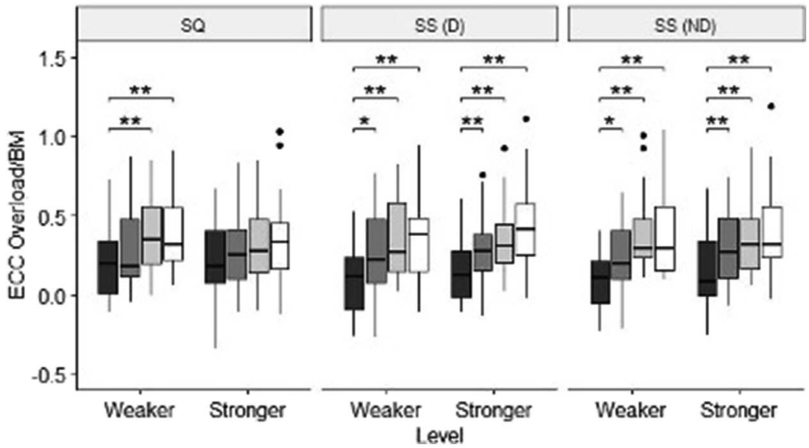

Figure 3. Inter-group comparison of inertias and eccentric overload/body mass (EOL/BM) ratio for squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises (*$p < 0.05$; **$p < 0.01$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

influenced by inertial loads in both exercises for the concentric phase related to BM. However, stronger subjects showed higher concentric ratios in I1 and I2 in comparison with the weaker group [see Figure 6; $F(3, 468) = 7.50$; $p < 0.01$; ES = 0.46; 95% CI (11.63–12.44)]. In the eccentric phase, moreover, there were significative differences between the stronger and weaker groups in I2 in the split squat (nondominant) and in I1 and I2 in the squat exercises [see Figure 7; $F(3, 468) = 4.58$; $p < 0.05$; ES = 0.29; 95% CI (12.88–13.52)].

No meaningful interactions between inertial loads, exercise, and training level were found [$F(6, 468) = 0.11$; $p = 0.99$; 95% CI (20.12–13.35)].

Discussion

The present study aimed to assess how mechanical outputs were affected by the subjects' BM, strength level, and type of exercise performed. The main findings of this research are (1) in relation to EOL, the differences between squat and split squat exercises do not appear to be influenced by BM (2); absolute power variables show differences in the concentric phase between inertial loads and there were also differences between exercises in the eccentric phase (3); stronger subjects can achieve higher EOL values independent of the inertial loads used during a squat exercise (4); weaker subjects can achieve greater EOL values with higher inertial loads; and (5) lighter inertial loads produce greater power outputs independent of the subjects' strength level (weaker and stronger group).

Flywheel resistance training can be very beneficial for improving hypertrophy, jump, power, and strength performance (10,26). However, there is a lack of evidence regarding how best to monitor and individualize training load variables with this technology. For instance, it is unclear how the variation in inertial loads can affect EOL with different exercises (21). Our results show EOL values increase as inertial load increases in bilateral squat (with significant changes only in the weaker group) and unilateral split squat exercises. Our findings are in

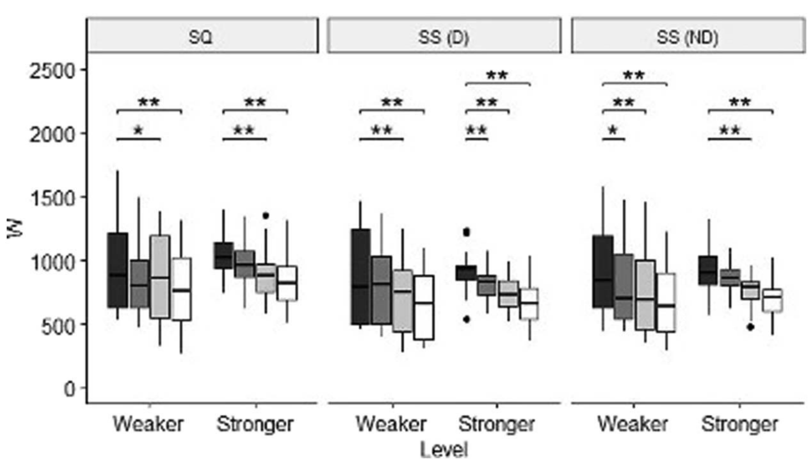

Figure 4. Inter-group comparison of inertias and concentric power values for squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises (*$p < 0.05$; **$p < 0.01$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

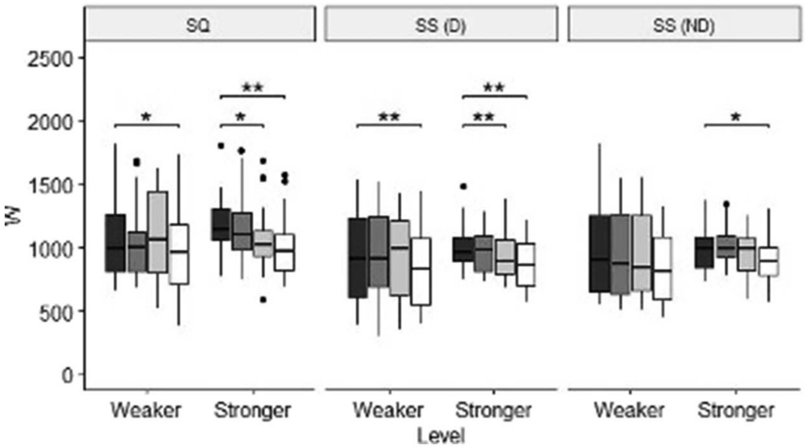

Figure 5. Inter-group comparison of inertias and eccentric power values for squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises (*$p < 0.05$; **$p < 0.01$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

line with previous research showing EOL increases when the load is greater. These results were seen in several exercises, such as the squat (22,32), Romanian deadlift (28), and leg curl (29). However, there are also studies that found different results: for instance, in 2023, Muñoz-López et al. (24) found a trend for increases EOL with lower inertial loads; they also found higher EOL with low inertial loads (0.025 kg·m^{-2}) compared with high inertial loads (0.125 kg·m^{-2}). These results suggest that execution of the half squat compared with the quarter squat could explain the difference in the relationship between EOL and load (32). Nevertheless, our study and the previous one by McErlain-Naylor and Beato (22), found different results even though they used a half squat exercise. It is possible some differences exist in the literature because authors used subjects with different strength levels, but these are not frequently reported. For instance, the characteristics of the subjects enrolled in the study by Muñoz-Lopez et al. (23) could be similar to our stronger group. Therefore, future research investigating power–inertia relationships should also report the subject's strength level to facilitate comparison among studies.

Regarding PP_{conc} and PP_{ecc}, lower inertial loads showed greater power values for both exercises (i.e., squat and split squat with the dominant and nondominant legs). These findings agree with previous studies that tested squat (23,32), Romanian deadlift (28), leg extension (20), and leg curl exercises (29). However, no difference between inertial loads in PP_{conc} was reported in other studies (11,22). McErlain-Naylor and Beato (22) found a similar pattern to our study for velocity and PP variables in the weaker group. However, the patterns for PP_{conc} and PP_{ecc} are very different in the stronger group with respect to the McErlain-Naylor and Beato study. The different number of repetitions during test situations in this study (8 repetitions) compared with the McErlain-Naylor and Beato (22) study (6 repetitions) was proposed as a possible explanation for the difference in the PP pattern. However, in addition to the results from analysis with 8 repetitions, we also realized the same analysis with only the best 3

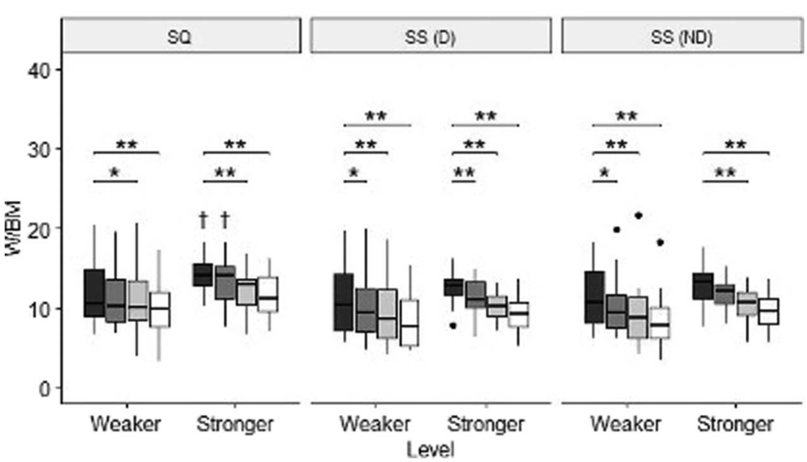

Figure 6. Inter-group comparison of inertias and concentric/body mass (BM) ratio in squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises: *$p <. 05$; **$p < 0.01$; †meaningful differences between groups ($p < 0.05$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

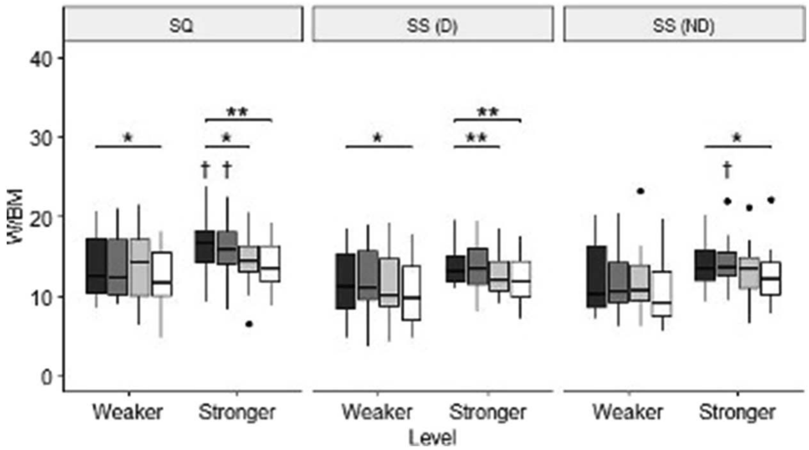

Figure 7. Inter-group comparison of inertias and eccentric/body mass (BM) ratio in squat (SQ), split squat (SS), dominant (D), and non-dominant (ND) exercises: *$p < 0.05$; **$p < 0.01$; †meaningful differences between groups ($p < 0.05$). The different inertia values (1–4) are reported in different colors (black, dark grey, light grey and white), respectively.

repetitions, and no changes were obtained for any variable with respect to the analysis with 8 repetitions. Possibly the strength level of the subjects (not referenced in the McErlain and Beato study) was similar to our weaker group, where the differences in PP_{ecc} are lower between inertial loads. On the other hand, de Keijzer et al. (11) tested 2 unilateral open-chain movements, namely, knee flexion and hip extension, and their results differed from our study. In the knee flexion exercise, they did not find any change in PP_{con} or PP_{ecc} using 3 different inertial loads but increases were observed with higher inertial loads for the unilateral hip extension exercise. However, the values in study are higher compared with similar studies with the same movement such as Suarez-Arrones et al. (37), or, analyzed unilateral open-chain movement Martínez-Aranda et al. (20). It is important to indicate the position and action of arms during movement (e.g., perpendicular position during Keijzer et al.'s study or in Suarez-Arrones et al., where arms were located in the flywheel device). Another factor to consider is the possibility to stabilize the action with core activation or the opposite leg (difference between leg curl and hip extension in Keijzer et al.'s study, in contrast to Martínez-Aranda et al.'s study) can be key variables to explain the different profiles obtained by Keijzer et al. with respect to the majority of studies.

As previously stated, the 3 variables analyzed (EOL, PP_{con}, and PP_{ecc}) showed a similar pattern in the squat and split squat exercises. Eccentric overload tends to increase with the inertial loads, whereas PP_{con} and PP_{ecc} tend to decrease with the inertial loads. However, 2 exceptions must be mentioned: the first is the stronger group did not report any significant difference in EOL using any load during the squat exercise; the second is that PP_{ecc} in the split squat with the nondominant limb did not show differences between inertial loads. Therefore, practitioners who want to use unilateral movement in their training protocol should perform long familiarization periods with the nondominant leg, as previously recommended (32).

To the authors' knowledge, this is the first study to report the effects of training level on flywheel squat and split squat variables. Our results show the stronger group has no differences between different inertial loads in squat exercise EOL values. Thus, stronger subjects could train with any load to obtain an EOL, whereas weaker subjects should preferentially train with higher inertial loads (0.075 or 0.100 $kg \cdot m^{-2}$) to obtain greater squat exercise EOL values. On the other hand, both weaker and stronger groups obtain the best EOL values for the split squat using higher inertial loads. Regarding PP_{con}, both groups obtained greater outputs with lower inertial loads (0.025 or 0.050 $kg \cdot m^{-2}$), so practitioners should preferentially use these inertial loads to maximize PP_{con} during training protocols. Nevertheless, when the target of the protocol is to maximize PP_{ecc}, a different profile can be observed on the basis of the subjects' training level. The weaker group obtained similar outputs using different inertial loads, which could be because of the difficulty for subjects to break the action during the eccentric phase (38). A comparison between 2 groups with different force production can be observed in Piqueras et al.'s (29) study, where men and women were analyzed during a leg curl exercise; however, in contrast to our results, similar profiles were obtained for both groups. De Keijer et al. (11) proposed the relevance of subject experience to obtain a good profile of EOL during different inertial loads. In our study, subjects with similar previous experience can show different EOL profiles according to their relative strength (1RM squat/BM). Thus, it is the authors' opinion that relative strength is a key variable for programming flywheel resistance training because the strength level can influence velocity improvement (16).

The present study has some limitations. First, no female subjects were included, so we cannot be sure whether these results could be applied to female populations. Future research should be carried out with other populations (elderly, young athletes, etc.) to verify the results of this study. Lastly, this study compared different exercises and inertial loads on mechanical power outputs but did not evaluate the benefits of the manipulation of training parameters on chronic adaptations. Future studies need to verify whether higher inertial loads are more suitable than lower inertial loads to generate neuromuscular and morphological adaptations, and whether unilateral exercises are more effective than bilateral exercises.

Practical Applications

The findings reported in this study can be useful for strength and conditioning coaches to optimize flywheel training protocols. The differences between squat and split squat exercises in EOL do not appear to be influenced by BM. Squat and split squat exercises present a different profile depending on the training level. The absolute power variables have shown differences in the concentric phase between inertial loads and also differences between exercises in the eccentric phase. Lighter inertial loads produce greater power output independent of the group (weaker and stronger subjects). In conclusion, it is recommended that practitioner perform a test to understand the inertial load–power profile (concentric, eccentric and their ratio) for each exercise and also consider the user's strength level for selection of the inertial load and for the exercise to use in training.

Acknowledgments

The authors are grateful to all the subjects in the present study. This research was made possible by financial support from Grant PID2019-109632R8-100. Pablo Asencio's contribution was supported by the Spanish Ministry of Science and Innovation (Grant PRE2020-091858).

References

1. Baker D. A series of studies on the training of high-intensity muscle power in rugby league football players. *J Strength Cond Res* 15: 198–209, 2001.
2. Beato M, dello Iacono A. Implementing flywheel (isoinertial) exercise in strength training: Current evidence, practical recommendations, and future directions. *Front Physiol* 11: 569, 2020.
3. Beato M, Maroto-Izquierdo S, Turner AN, Bishop C. Implementing strength training strategies for injury prevention in soccer: Scientific rationale and methodological recommendations. *Int J Sports Physiol Perform* 16: 456–461, 2021.
4. Bevan HR, Bunce PJ, Owen NJ, et al. Optimal loading for the development of peak power output in professional rugby players. *J Strength Cond Res* 24: 43–47, 2010.
5. Brien J, Browne D, Earls D, Lodge C. The effects of varying inertial loadings on power variables in the flywheel Romanian deadlift exercise. *Biol Sport* 39: 499–503, 2022.
6. Bompa TO, Haff GG. Periodization. *Theor Methodology Training* 5: 48–53, 2009.
7. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power: Part 2—training considerations for improving maximal power production. *Sports Med* 41: 125–146, 2011.
8. Cronin JB, Hansen KT. Strength and power predictors of sports speed. *J Strength Cond Res* 19: 349–357, 2005.
9. de Hoyo M, Sañudo B, Carrasco L, et al. Effects of 10-week eccentric overload training on kinetic parameters during change of direction in football players. *J Sports Sci* 34: 1380–1387, 2016.
10. de Keijzer KL, Gonzalez JR, Beato M. The effect of flywheel training on strength and physical capacities in sporting and healthy populations: An umbrella review. *PLoS One* 17: e0264375, 2022.
11. de Keijzer KL, McErlain-Naylor SA, Beato M. The effect of flywheel inertia on peak power and its inter-session reliability during two unilateral hamstring exercises: Leg curl and hip extension. *Front Sports Active Living* 4: 898649, 2022.
12. Faude O, Roth R, Di Giovine D, Zahner L, Donath L. Combined strength and power training in high-level amateur football during the competitive season: A randomised-controlled trial. *J Sports Sci* 31: 1460–1467, 2013.
13. McGuigan M: Administration, Scoring, and Interpretation of Selected Tests, in Haff GG, Triplett TN. Essentials of Strength Training and Conditioning. (4a ed.). Champaign, Illinois: Human Kinetics, 2021.
14. Gonzalo-Skok O, Tous-Fajardo J, Valero-Campo C, et al. Eccentric-overload training in team-sport functional performance: Constant bilateral vertical versus variable unilateral multidirectional movements. *Int J Sports Physiol Perform* 12: 951–958, 2017.
15. Hernández-Davó JL, Monteagudo P, Sabido R. Comparison of six weeks eccentric overload training between bilateral and unilateral squat in basketball players. *Eur J Hum Mov*. 40: 111–121, 2018.
16. James LP, Gregory Haff GG, Kelly VG, Connick MJ, Hoffman BW, Beckman EM. The impact of strength level on adaptations to combined weightlifting, plyometric, and ballistic training. *Scand J Med Sci Sports* 28: 1494–1505, 2018.
17. Kawamori N, Haff GG. The optimal training load for the development of muscular power. *J Strength Cond Res* 18: 675–684, 2004.
18. Kowalchuk K, Butcher S. Eccentric overload flywheel training in older adults. *J Functional Morphology Kinesiology* 4: 61, 2019.
19. Loturco I, Pereira LA, Cal Abad CC, et al. Using bar velocity to predict the maximum dynamic strength in the half-squat exercise. *Int J Sports Physiol Perform* 11: 697–700, 2016.
20. Martinez-Aranda LM, Fernandez-Gonzalo R. Effects of inertial setting on power, force, work, and eccentric overload during flywheel resistance exercise in women and men. *J Strength Cond Res* 31: 1653–1661, 2017.
21. Maroto-Izquierdo S, Raya-González J, Hernández-Davó JL, Beato M. Load quantification and testing using flywheel devices in sports. *Front Physiol* 12: 739399, 2021.
22. McErlain-Naylor SA, Beato M. Concentric and eccentric inertia–velocity and inertia–power relationships in the flywheel squat. *J Sports Sci* 39: 1136–1143, 2021.
23. Muñoz-López A, Nakamura FY, Beato M. Eccentric overload differences between loads and training variables on flywheel training. *Biol Sport* 40: 1151–1158, 2023.
24. Muñoz-López A, Pozzo M, Floria P. Real-time mechanical responses to overload and fatigue using a flywheel training device. *J Biomech* 121: 110429, 2021.
25. Nimphius S, Mcguigan MR, Newton RU. Relationship between strength, power, speed, and change of direction performance of female softball players. *J Strength Cond Res* 24: 885–895, 2010.
26. Norrbrand L, Pozzo M, Tesch PA. Flywheel resistance training calls for greater eccentric muscle activation than weight training. *Eur J Appl Physiol* 110: 997–1005, 2010.
27. Núñez FJ, Santalla A, Carrasquila I, Asian JA, Reina JI, Suarez-Arrones LJ. The effects of unilateral and bilateral eccentric overload training on hypertrophy, muscle power and COD performance, and its determinants, in team sport players. *PLoS One* 13: e0193841, 2018.
28. O'Brien J, Browne D, Earls D, Lodge C. The efficacy of flywheel inertia training to enhance hamstring strength. *J Functional Morphology Kinesiology* 7: 14, 2022.
29. Piqueras-Sanchiz F, Sabido R, Raya-González J, et al. Effects of different inertial load settings on power output using a flywheel leg curl exercise and its inter-session reliability. *J Hum Kinet* 74: 215–226, 2020.
30. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res* 18: 918–920, 2004.
31. Sabido R, Hernández-Davó JL, Capdepon L, Tous-Fajardo J. How are mechanical, physiological, and perceptual variables affected by the rest interval between sets during a flywheel resistance session? *Front Physiol* 11: 663, 2020.
32. Sabido R, Hernández-Davó JL, Pereyra-Gerber GT. Influence of different inertial loads on basic training variables during the flywheel squat exercise. *Int J Sports Physiol Perform* 13: 482–489, 2018.
33. Sabido R, Hernández-Davó JL, García-Valverde A, Marco P, Asencio P. Influence of the strap rewind height during a conical pulley exercise. *J Hum Kinet* 74: 109–118, 2020.
34. Santos EJ, Janeira MA. Effects of complex training on explosive strength in adolescent male basketball players. *J Strength Cond Res* 22: 903–909, 2008.
35. Slimani M, Nikolaidis PT. Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: A systematic review. *J Sports Med Phys Fitness* 59: 141–163, 2019.
36. Stone MH, Stone M, Sands WA. *Principles and Practice of Resistance Training*. Champaign, IL: J Human Kinetics, 2007.
37. Suarez-Arrones L, Nunez FJ, Lara-Lopez P, Di Salvo V, Mendez-Villanueva A. Inertial flywheel knee-and hip-dominant hamstring strength exercises in professional soccer players: Muscle use and velocity-based (mechanical) eccentric overload. *PLoS One* 15: e0239977, 2020.
38. Tous-Fajardo J, Maldonado RA, Quintana JM, Pozzo M, Tesch PA. The flywheel leg-curl machine: Offering eccentric overload for hamstring development. *Int J Sports Physiol Perform* 1: 293–298, 2006.
39. Zhang W, Chen X, Xu K, et al. Effect of unilateral training and bilateral training on physical performance: A meta-analysis. *Front Physiol* 14: 1128250, 2023.
40. Zatsiorsky VM, Kraemer WJ. *Science and Practice of Strength Training*. Champaign, IL: Human Kinetics, 2006.