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The Effect of A Flywheel Hip Extension Vs A Traditional Hip Extension Exercise on Hamstring Strength

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ABSTRACT

The main aim of this present study was to compare the effect of a flywheel hip extension exercise versus a traditional gravity-dependent exercise on hamstring strength. Twenty U-20 male soccer players volunteered to participate in the study. None had experience with flywheel inertia training, but all had a minimum of 12 months traditional resistance training experience. The participants were randomly assigned to two groups: the flywheel Romanian deadlift and traditional Romanian deadlift groups. Resistance training was performed twice a week for six weeks. Both groups performed four sets of six working repetitions, with the flywheel group performing two extra submaximal pre-repetitions at a low intensity to initiate the rotational force of the flywheel. A significant main effect of time was found for both eccentric strength (p = 0.006) and 3RM (p < 0.001) tests. There was a significant time-by-group interaction for 3RM (p = 0.02) but not for eccentric strength (p = 0.18). Post hoc analyses showed a significant increase in eccentric hamstring strength at the end of the intervention compared to baseline in the flywheel group (13% change, 37 N, p = 0.03, g = 0.51) but not in the traditional group (5% change,14 N, p = 0.282, g = 0.18). Both groups showed significant increases in 3RM Romanian deadlift (flywheel group: 18% change,19 kg, p = < .001, g = 1.07; traditional group: 28 % change, 26 kg, p = < .001, g = 0.99). This study highlights the beneficial use of flywheel training for optimising hamstring strength adaptation. Although both groups showed similar improvements in the 3RM Romanian deadlift, the flywheel group showed superior eccentric strength improvements.

Keywords: flywheel inertia training, eccentric hamstring strength, hip extension exercise, inertia loading.

INTRODUCTION

Hamstring strain injuries (HSI) are the most common type of injury in soccer, accounting for 13% of all injuries in elite players [1], based on a recent systematic review and meta-analysis [2] reporting the incidence of hamstring injury in field-based team sports is 0.81 per 1000 exposure hours. A professional team can expect 5-6 HSIs per season, and these injuries are known to have high recurrence rates [2,3]. HSI rates have increased by 4% annually among professional soccer players [4]. Playing time lost due to an injury can compromise team performance and negatively affect club finances, making HSI prevention a primary objective [5]. Although the cause of HSI is multifaceted, a few intrinsic factors have been linked to an increased injury risk [6]. Previous HSIs and advanced age are the most significant non-modifiable risk factors for previous HSIs [6]. However, not an exhaustive list, modifiable risk factors in soccer players include strength [7] and strength imbalance [8], fatigue [9], poor flexibility [7], shorter bicep femoris long head (BFlh) fascicle length and poor eccentric hamstring strength [10].

Opar et al. [6] and Timmins et al. [10] reported that athletes with weaker limbs, measured when performing a Nordic Hamstring Curl, were more likely to develop an injury. Pre-season eccentric strength below 256 Newtons (N) and post season

279 N increased the risk of HSI by 2.7 and 4.3 times, respectively, in a group of 210 elite Australian footballers [6]. In addition, Timmins et al. [10] reported that for every 10 N increase in eccentric hamstring strength, the chance of injury decreased by 8.9%. A variety of strength training programs, including exercises such as the Nordic hamstring exercise (NHE), have demonstrated favourable adaptations to eccentric hamstring strength and BFlh fascicle length [11,12] as well as reducing the risk of first-time and recurrent HSI [13]. Although NHE has proven effective, it is underused in high-level soccer, with only 13% of UEFA football teams reporting the implementation of research-based programs in a survey conducted in 2021[14]. Therefore, alternative modes of strength training, such as Flywheel Inertial Training (FIT), are becoming increasingly popular [15].

Flywheel devices provide resistance through inertia generated by the rotating flywheels [16]. During the concentric phase, a strap attached to the shaft of the device is unwound owing to the applied force, which initiates the flywheel rotation [17]. When the concentric phase is completed, the strap rewinds, and the user must resist the generated inertia by performing a decelerating eccentric muscle action [17], which leads to brief moments of an eccentric overload. [18–20]. Timmins et al. [21] previously investigated the effects of a flywheel hip extension exercise on BFlh architecture, eccentric hamstring strength, and sprint performance in elite Australian footballers. This study, which included pre- and in-season measurements, was conducted over a period of 39 weeks. Positive increases were reported for the BFlh fascicle length (d = 1.99, p < 0.001), eccentric hamstring strength (d = 1.34, p = 0.026), maximal velocity (3.4% ± 1.4%), and horizontal force production (9.7% ± 2.2%).

A significant amount of research has compared FIT with traditional resistance training, but few studies have targeted hamstring-specific exercises. According to Norrbrand et al. [22], when performing hamstring movements with an isoinertial flywheel device as opposed to a traditional weight stack machine, hamstring muscle activity and mechanical stress were significantly higher (p < 0.05) with the isoinertial flywheel device. A more recent study [23] compared the flywheel Romanian Deadlift and squats with traditional resistance training in well-trained junior basketball players. The equivolumed study compared the effects of both modalities on lower body strength, countermovement jump, t-test, and 5 and 20 m sprint performance. Compared to the equivalent traditional strength training, 8 weeks of flywheel training with 1–2 sessions per week, including up to four sets of eight repetitions performed with maximum concentric intensity, produced superior improvements in the vertical jump, 5 m sprint time, and change in direction ability [23]. To the best of the authors knowledge, this was the first study to compare flywheels with traditional Romanian deadlifts. Numerous studies have compared the flywheel and traditional squats [24–27], lunges [24], and knee extensions [22,28]; however, more research is warranted on hip extension exercises, such as the RDL. Another previous study [29] compared the effects of both straight leg deadlift and hip extension exercises on gravity-dependent exercises in an injury prevention program, with the flywheel group showing positive improvements in both concentric and eccentric peak torques. However, it should be noted that the exercises used in the gravity-dependent group were unloaded body weight exercises, which may not have provided sufficient stimulus to augment positive adaptation.

To the best of the author's knowledge, no studies have directly compared the effects of a flywheel and traditional Romanian deadlift on hamstring strength. Therefore, this study aimed to compare the effect of flywheel hip extension exercise with that of a traditional hip extension exercise protocol on hamstring strength in U-20 soccer players.

METHODS

Experimental Design

The participants were randomly assigned to two groups: flywheel (FW) and traditional (RDL). The NHE exercise was used to determine eccentric hamstring strength and the 3RM Romanian deadlift was used to determine concentric strength. All tests were performed in the resting state, before and after the intervention. Both groups were resistance-trained twice a week for six weeks in conjunction with their regular training, which comprised three soccer sessions each week.

Participants

Twenty-two U-20 soccer players volunteered to participate in this study (Table 1). During the intervention, two participants withdrew from the study because of injuries unrelated to the study (Figure 1). The requirement for inclusion was

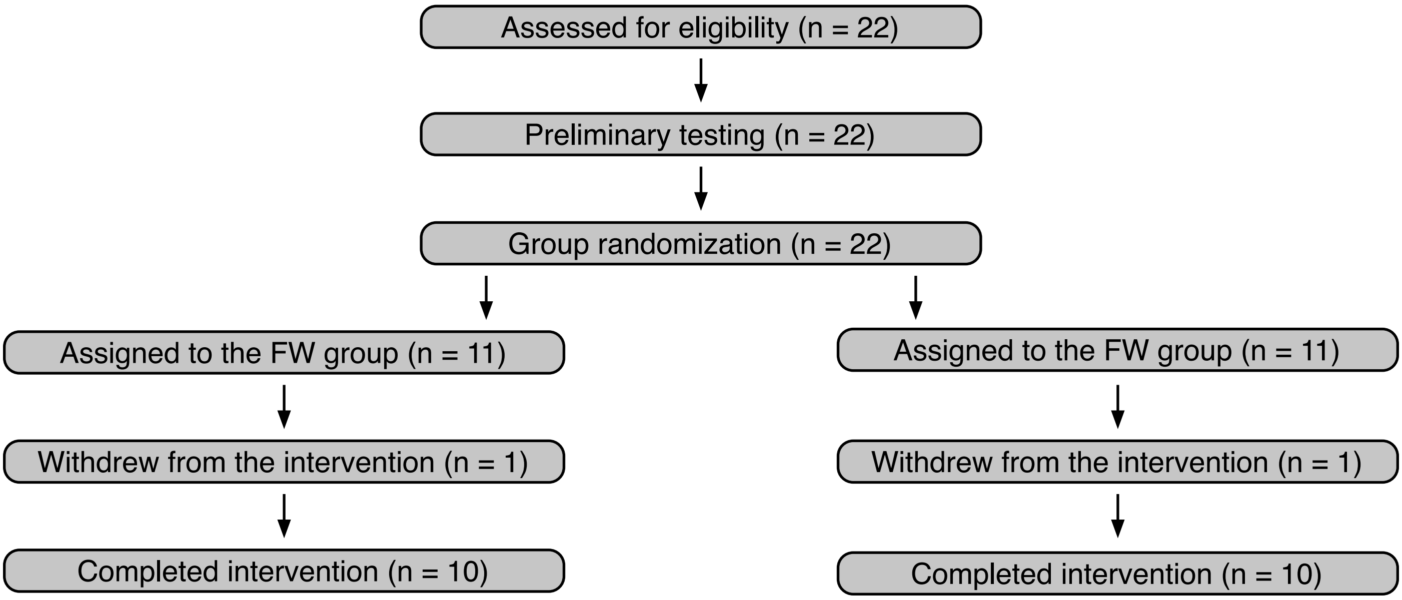

Figure 1. Flow chart of the participant's progress from eligibility assessment to completion of intervention

eligibility to participate in an official match with the team. None of the participants had FIT experience, but all had a minimum of 12 months of traditional resistance training experience. No resistance training was performed 48 h before testing or familiarisation. Participants had to complete each familiarisation and testing session to be included in the study, and they could not have incurred any injuries in the three months before the intervention. Participants were informed of the study objectives and provided informed consent before participation. The participants were free to withdraw from the study at any time. Written informed consent was obtained from all participants. This study adhered to the guidelines of the Declaration of Helsinki (2013) and was approved by the South East Technological University Carlow Ethics Board (Code: C00232530).

Procedures

Testing and Familiarisation

The height (cm) of all the participants was measured using a wall-mounted stadiometer. Body mass (kg) was measured using an electronic scale (Fit Scan BC-545F®; Tanita Corporation, USA). Three familiarisation sessions were conducted to familiarise the participants with the testing and training procedures. Three familiarisation sessions were previously advised to familiarise participants with FIT and minimise the learning effect [30]. Participants were instructed on both the flywheel and traditional Romanian deadlift techniques. On the final familiarisation day, a FIT power assessment was performed. Outcome measures were assessed in one session. The testing session and the last familiarisation session were separated by 48 hours to avoid the effects of muscular fatigue and delayed onset of muscle soreness. An active warm-up of 15 min preceded all the testing and familiarisation sessions. Five minutes of low-intensity jogging was followed by dynamic stretching of the gluteal, hamstring, adductor, quadriceps, and gastrocnemius muscles.

Eccentric Strength

The participants were positioned on a Hamstring Solo® (Hamstring Solo Elite®, Kilkenny, Ireland) device cushioned surface with their ankles fixed beneath the load cells superior to the medial and lateral malleoli. The participant's knee position was recorded using markings on the device and the same knee position was used throughout the trials. When in the correct position, they were instructed to fold their hands across their chest and to fully extend their knees in a controlled manner until they could no longer sustain eccentric hamstring contraction and land on their palms on the floor. Participants were encouraged to maintain a neutral pelvic position and limit excessive lordosis to their best ability. Participants were encouraged to provide maximal effort throughout each repetition. Each participant performed three repetitions with a 60s intra-set recovery. The peak force (N) was recorded for both limbs through wireless data acquisition from the load cells and transmitted via Bluetooth to an iOS device (iPad Mini®, Apple, Cupertino, CA, USA).

3RM

The maximal dynamic strength was assessed

Table 1. Descriptive data of the participants (mean ± SD)

Variable	RDL Group	FW Group	*p*	*d*
Age (yrs.)	18.5 ± 0.7	18.4 ± 0.6	0.53	0.10
Height (cm)	180.6 ± 4.2	179.4 ± 4.1	0.54	0.28
Body Mass (kg)	76.3 ± 5.7	76.6 ± 5.7	0.92	0.05

Abbreviations: d, Cohens d Effect Size.

using the 3RM Romanian deadlift. To ensure the participants' ability to perform the lift safely, adequate time was allowed for technique instruction. Once the appropriate technique was shown, participants were allowed to participate in the testing session. The Romanian deadlift-specific warm-up consisted of five repetitions at 40–60% of their perceived 3RM, and after 3 min of full recovery, they performed three repetitions at 60–80% of their perceived maximum. The load was then continuously increased until the athletes could not perform another trial with the required technique. During testing, lifting straps were used to ensure that the weight was maximal and was not limited by the grip strength of the subjects. Owing to the participants' phase of the season and low training age, the 3RM test was deemed a safe maximum strength test option.

Power Assessment

Previous research [31] has highlighted the effects of varying the inertial load on the power variables during a flywheel RDL. Therefore, an individualised approach is recommended. A power test protocol previously shown [32] to be reliable and specific to a flywheel Romanian deadlift was used to determine the optimal inertial load to produce the maximum ECC power output. The test was performed using a FIT device (K-Box 4®, Exxentric, Stockholm, Sweden) and a data reader and transmitter (K-meter, Exxentric, Stockholm, Sweden). The power assessment consisted of four sets of eight repetitions, with different inertial loads for each set (0.025, 0.050, 0.075, 1.00 kg.m^2). The first and second repetitions of each set were used to build momentum and were excluded from data analysis. The order of inertial load used in each trial was standardised for all participants:0.025 kg.m^2, secondly 0.050 kg.m^2, thirdly 0.075 a kg.m^2 and last was 0.100 kg.m^2, respectively. Peak concentric, eccentric, and the % eccentric overloads were recorded for analysis. The inertial load that provided the largest eccentric power output was the initial inertial load employed by the participants.

Training Intervention

Resistance training was performed twice a week for six weeks. Each session was performed on the same day and at the same time every week. Exercise intensity was increased only if the technical execution was adequate. If a participant did not perform the technical movement correctly, the intensity was reduced, or the participant received individual technical guidance on how to perform the movement correctly. Each session followed the same warm-up sequence used in the familiarisation and testing sessions. Both groups followed the same training program for six weeks apart from the different Romanian deadlift variations used (flywheel Vs. traditional). Both groups performed four sets of six working repetitions, with the flywheel group performing two extra submaximal pre-repetitions at a low intensity to initiate the rotational force of the flywheel. The flywheel group started with whatever inertial load was determined to produce the maximum power in their power assessment, and the gravity-dependent group used 80% of their predicted 1RM. To begin the concentric phase of the lift, participants were instructed to extend their hips with maximum effort. In the flywheel group, once full extension was reached, the participants were instructed to flex the hips and attempt to stop the flywheel using a braking action, whereas the gravity-dependent group was instructed to lower the bar in a slow and controlled manner.

Autoregulation (set-RPE)

An autoregulation method was used to match the intensities between the FW and RDL groups. All the participants were extensively informed about the autoregulation method. Participants were asked to rate their efforts on a modified scale from 1 to 10, with lower numbers indicating easier effort and higher numbers indicating harder effort (set-RPE). RPE has previously been shown to be a valid method for assessing and prescribing resistance training [33]. For both training groups, the load was adjusted to match the set RPE of 8. In the gravity-dependent group, the load was adjusted on the barbell, whereas in the flywheel group, the inertial load was adjusted until the desired RPE was achieved. An RPE of 8 was believed to achieve a sufficient training stimulus while maintaining acceptable movement performance.

Statistical Analysis

Normality was assessed for all variables using the Shapiro-Wilk statistical test. Levene's test of equality tested the assumption that homogeneity of variances was not violated. An independent t-test was used to assess differences between the groups' pre-intervention physical characteristics (Table 1). The effect size was determined using Hedges g and can be interpreted as <0.2, 0.2–0.49, 0.5–0.79, and >0.8, representing small, trivial, moderate, and large effects, respectively [34]. Comparisons for all performance variables were analysed using 2 × 2 (group × time) repeated-measures two-way analysis of variance (ANOVA), where groups represent flywheel and traditional Romanian deadlift, and time represents pre- to post-training data. Where significant main or interaction effects were detected ($p < 0.05$), group-specific Bonferroni post hoc tests were applied. All statistical analyses were performed using JASP® software version 0.9.1 (Amsterdam, Netherlands) for Windows.

Results

There was no significant difference between group pre-intervention for eccentric strength ($p = 0.54$) or 3RM ($p = 0.19$). A significant main effect for time was found for both eccentric strength ($p = 0.006$) and 3RM ($p < 0.001$) tests. There was a significant time by group interaction found for 3RM $F(1) = 5.62$, $p = 0.02$, $\eta^2 = 0.007$, but not for eccentric strength $F(1) = 1.884$, $p = 0.18$, $\eta^2p = 0.006$, indicating that the effect of training intervention on 3RM and eccentric strength differed significantly between the groups. Post hoc analyses showed a significant increase in eccentric hamstring strength at the end of the intervention when compared to baseline for the FW Group (13% change, 37 N, $p = 0.03$, g = 0.51) but not for the RDL group (5% change, 14 N, $p = 0.282$, g = 0.18). At the end of the intervention, both groups had significant increases in 3RM (FW Group: 18% change,19 kg, $p = < .001$, g = 1.07; RDL Group: 28 % change, 26 kg, $p = < .001$, g = 0.99).

DISCUSSION

The aim of this study was to assess the impact of traditional and flywheel hip extension exercise programs on both maximum concentric and eccentric hamstring strength. Our results show that 6 weeks of both traditional and FIT training will significantly improve 3RM strength, whereas FIT will also improve eccentric hamstring strength.

A study by Coratella et al. [35] studied the effects of 10 weeks of flywheel squat training in male soccer

Table 2. Pre- and post-intervention results for the RDL and FW groups. Values are displayed as mean ± SD.

	RDL Group				FW Group			
Variable	**Pre**	**Post**	***d***	**%**	**Pre**	**Post**	***d***	**%**
3 RM (kg)	94 ± 28	120 ± 22	1.0	28	107 ± 18	126 ± 16	1.11	18
ECC (N)	259 ± 78	273 ± 71	0.2	5	278 ± 67	315 ± 71	0.53	13

Abbreviations: 3RM; 3 rep maximum test; ECC, eccentric hamstring test; %, percentage change between pre-and post-intervention; d, Cohens d Effect Size.

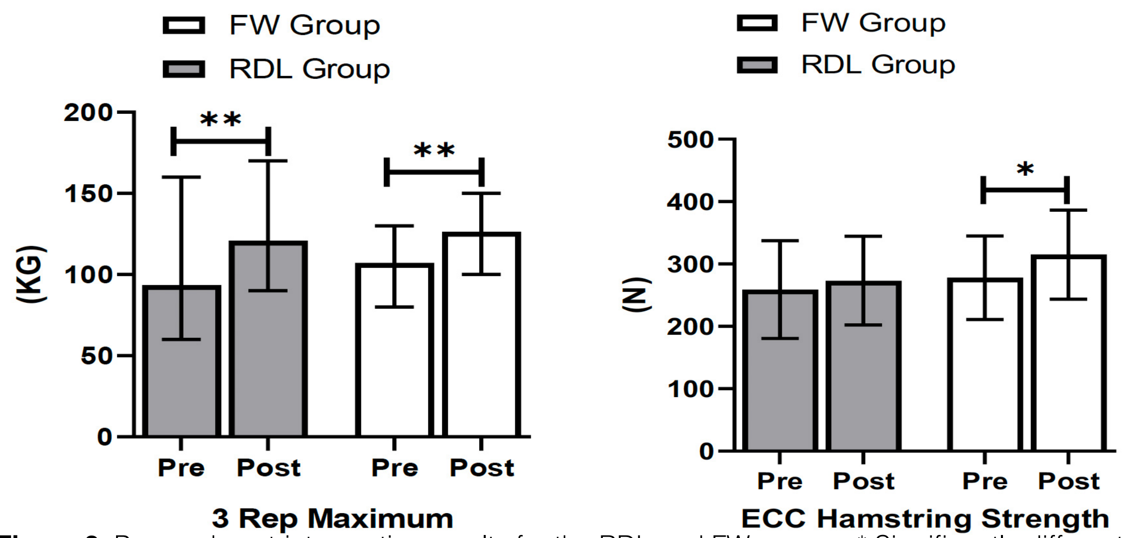

Figure 2. Pre- and post-intervention results for the RDL and FW groups. * Significantly different from pre-intervention value, where * $p < 0.05$, and ** $p < 0.001$.

players and found significant gains in all isokinetic peak torque parameters in the knee extensors and flexors. Furthermore, Pecci [36] reported significant increases in female soccer players in both concentric and eccentric isokinetic peak torque of the knee extensors and flexors after six weeks of flywheel squat training. These studies highlight that flywheel exercises can improve both concentric and eccentric strength in a chosen exercise, which coincides with the findings of the present study that the FW group significantly improved both concentric strength (3RM) and eccentric strength (NHE). Although both previous studies are in line with our own research, it should be noted that the discussed studies [35,36] used isokinetic dynamometry as the outcome measure, and both used a different flywheel exercise (flywheel squat); therefore, a direct comparison may not be applicable.

The bulk of evidence regarding hamstring-specific [37–40] FIT has used the flywheel leg curl exercise. The flywheel leg curl exercise has been shown to preferentially recruits medial hamstring muscles [41], whereas hip dominant exercises have been shown to recruit lateral hamstring muscles [41]. Further research is warranted to investigate the effect of hip-dominant flywheel training intervention on hamstring strength. Only one previous study [21] has investigated the effect of flywheel hip extension exercise on hamstring strength. In comparison to the present study, Timmins et al. [21] reported significant increases in ECC hamstring strength, 57N after 16 weeks and 82N after 39 weeks, while our study showed a 37N increase after 6 weeks. The training age of the participants may have been a factor, as participants in our study had a low training age and would be expected to see large adaptations early, whereas participants in the Timmins et al. study [21] who were described as "semi-professional" may have had a higher training age and perhaps a lower ceiling of adaption, as it has previously been shown that trained adolescents displayed hindered improvements in strength training compared to untrained [42]. The findings of this study may have implications for injury prevention. Timmins et al. [10] reported that for every 10 N increase in eccentric hamstring strength, the chance of injury decreased by 8.9%. Our study's findings of a 37N increase over a 6-week period may be valuable for practitioners who wish to implement injury reduction protocols in the pre-season.

No prior research has examined the effects of a flywheel hip extension exercise against a traditional gravity-dependent exercise on hamstring strength. The findings of the current study suggest that FIT may be a viable option for increasing hamstring strength. The FW group showed a significant increase in 3RM (18% change,19 kg, $p \leq .001$). It could be hypothesised that a concentric specific exercise (traditional barbell Romanian deadlift) would increase the maximum concentric strength only, and an eccentric specific exercise (flywheel Romanian deadlift) would increase the eccentric strength only, suggesting that strength adaptions are contraction-specific; however, this was not the case for the FW group in this current study, which increased both. FIT enables maximal force output throughout the concentric phase of exercise, as well as brief moments of overload in the eccentric phase [43]. It has previously been discussed [23] that the superior impacts on strength-related performance outcomes in FIT are most likely due to the flywheel-specific loading pattern (concentrically maximally loaded or eccentrically overloaded). Both concentric and eccentric contractions may have been adequately loaded in the present study to induce a strength increase. Additionally, an increase in the eccentric phase output can lead to an increase in the concentric phase output [23].

The RDL group showed a significant increase in 3RM (28 % change, 26 kg, $p = < .001$, g = 0.99), which was a larger increase then the FW group, but there was no statistically significant increase in ECC strength for this group, although there was a small percentage change (5%). Previous research has shown that both flywheel and traditional gravity-dependent exercises may induce similar findings regarding maximum strength. An eight-week study by Corratela et al. [35] showed that flywheel strength training performed once per week with up to six sets of eight repetitions of squats provided benefits comparable to those obtained by traditional weight training (80 % of 1 RM). The results of another six-week study by Maroto-Izguierdo et al. [18], FIT (4 × 7 maximal intensity half squats with 0.145 kg·m^2 inertia) generated improvements similar to traditional weight training (4 × 7 leg press with a load corresponding to 7 RM). No significant differences (< 0.05) between strength training modes were identified for maximum strength improvement (12.2% and 7.9% for flywheel and traditional weight training, respectively). Finally, Sagelv et al. [25] examined the effects of flywheel and traditional strength training on lower body strength (1 RM squat) in 38 active male football players. During the six-week intervention (2 sessions per week), both flywheel and traditional strength training progressively increased squat exercise from 3 sets with 6 repetitions (week one) to 4 sets with 4 repetitions (week six). The flywheel group performed exercises with individually adjusted inertia, while the traditional strength training intensity was set at 85% of 1 RM. Although both groups improved significantly ($p < 0.05$), traditional strength training was superior to flywheel training in improving lower body strength (46% Vs. 19%, respectively). This research corresponds with the findings of this current study that both flywheel and traditional training modalities are successful in increasing maximum dynamic strength. The present research proposes the beneficial use of flywheel training in optimising hamstring strength adaptation. Although both groups showed similar improvements in the 3RM Romanian deadlift, the FIT group showed superior eccentric strength improvement.

This study had several limitations. First, the duration of this study was limited to 6 weeks, which may not reflect long-term adaptations to FW or traditional barbell RDL training. Second, the sample size consisted only of male youth soccer athletes, which might limit the generalisability to other populations or different sports backgrounds. Another potential limitation of this study is the lack of a control group. The research design included two intervention groups: FW and RDL, without a control group. Although the decision to exclude a control group was made to focus on comparing the effectiveness of the two training interventions, it limited the ability to determine whether the observed changes in performance characteristics were solely due to the interventions or were influenced by other factors. Other factors, such as athletes' pre-existing training experience and natural progression of physical capabilities over time, may have contributed to the outcomes. Furthermore, the absence of a control group may make it difficult to establish a cause-and-effect relationship between training protocols and performance changes. Future research should explore the long-term effects of FW RDL training over several months or across different training seasons. From a practical standpoint, this study provides valuable insights for coaches, trainers, and athletic therapists working with male soccer athletes. Given the notable improvements in both concentric and eccentric hamstring strength, incorporating FW hip extension exercises such as FW RDL can be a valuable addition to strength and conditioning programs.

In conclusion, this study confirms the benefits of FW RDL training in improving both concentric and eccentric hamstring strength in male soccer players. Although both traditional and FW RDL training led to improvements in the 3RM RDL, the FW RDL approach displayed a greater capacity to enhance eccentric hamstring strength. These findings are consistent with prior research underscoring the versatility of FW training as an effective tool for increasing both concentric and eccentric strength.

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