INJURY PREVENTION PROGRAMS BASED ON FLYWHEEL VS. BODY WEIGHT RESISTANCE IN RECREATIONAL ATHLETES

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ABSTRACT

Monajati, A, Larumbe-Zabala, E, Sampson, MG, and Naclerio, F. Injury prevention programs based on flywheel vs. body weight resistance in recreational athletes. *J Strength Cond Res* 35(2S): S188–S196, 2021—This study compares the effect of an isoinertial flywheel technology vs. a traditional gravity-dependent exercise protocol on modifiable factors associated with the incidence of hamstring strain (HAM) and anterior cruciate ligament (ACL) injuries. Furthermore, the effect on repeated sprint ability was also considered. Eighteen recreationally trained volleyball players completed one of the following 6-week protocols: (a) flywheel (FY) included 3 exercises using a YoYo isoinertial-squat machine and 3 exercises with a Versa-Pulley isoinertial device, and (b) gravity-dependent (GT) involved 6 similar exercises with no external resistance (participants' body weight). Both programs consisted in 2 sessions·wk^{-1} performing 2 sets of 8 repetitions with 2 minutes of rest. Outcomes included a 10-second tuck jump assessment (TJA), landing knee valgus score, hamstring and quadriceps concentric and eccentric isokinetic 60°·s^{-1} peak torque, optimal peak torque localization, conventional and functional hamstring-to-quadriceps ratio, and 30-m repeated shuttle sprint ability (RSSA) test. FY improved TJA (−2, interquartile range [IQR] = −3 to −1) and valgus (−1, IQR = −1 to 0) scores, hamstring eccentric (20.37, 95% confidence interval [CI] = 9.27–31.47 N·m) and concentric (17.87, 95% CI = 0.40–35.34 N·m) peak torque, as well as the RSSA (−0.28, 95% CI = −0.45 to −0.10 seconds), whereas GT only improved hamstring eccentric peak torque (21.41, 95% CI = 9.00–33.82 N·m). A 6-week protocol using flywheel technology seems to elicit better positive adaptations to protect athletes from HAM and ACL injuries and to enhance RSSA performance compared to exercising with no external resistance other than athletes' body weight.

KEY WORDS anterior cruciate ligament, hamstring strain, isoinertial technology, eccentric overload, valgus

INTRODUCTION

Hamstring strain (HAM) and anterior cruciate ligament (ACL) injuries are, respectively, the most prevalent (25) and serious (29) noncontact occurring injuries in team sports. Several preventive programs involving jumps, strength, unstable, or a combination of different exercise modes have been proposed to prevent both ACL and HAM injuries (19).

Understanding mechanisms underlying these injuries is crucial for choosing suitable approach to develop effective preventive protocols. Noncontact ACL injuries are likely to happen during deceleration and acceleration motions with excessive quadriceps contraction and reduced hamstrings co-contraction at or near full knee extension (28). The ACL loading is also increased when a valgus load is combined with an internal rotation of knee that increases lateral compression. This compressive load combines with anterior force vector produced by quadriceps contraction, resulting in ACL rupture (15). Furthermore, most of the HAM occurs when hamstrings are actively lengthening beyond their upright length (i.e., hip and knee at 0° flexion) to decelerate the forward movement of the tibia during the terminal swing phase of the sprint cycle (32). Based on the above described mechanisms, Monajati et al. (19) identified 7 modifiable risk factors associated with the incidence of ACL and HAM injuries: (a) knee valgus/varus angle and moment; (b) hip adduction/abduction angle and moment; (c) knee and hip rotation angle; (d) knee and hip flexion angle; (e) hamstring and quadriceps muscle strength; (f) hamstring-to-quadriceps (H–Q) conventional and functional strength ratios; and (g) the angle at which the optimal knee flexor peak torque

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35(2S)/S188–S196

Journal of Strength and Conditioning Research

occurred. Current literature suggests that the most effective preventive protocols involve a combination of different exercise modalities (balance, plyometric, strength, and flexibility), emphasizing active lengthening movement and a correct technique of execution (19).

To increase implementation and compliance by coaches and athletes, a time-efficient and easy-to-follow comprehensive protocol is needed to successfully prevent injuries in team-sport athletes. Currently, most of the proposed prevention protocols, such as FIFA 11^{+} and Harmoknee (4,17), use no external resistances apart from the athletes' body weight. However, there is evidence that using external loads produces further neural adaptation, leads to larger muscle strength gains, and therefore would be more effective in injury prevention (9). Consequently, several alternative methods including the use of non–gravity-dependent technology have been recently proposed (27). The isoinertial technology uses the inertia of a rotatory wheel and consequent stored kinetic energy to offer higher eccentric load compared with traditional weight training (27). Norrbrand et al. (23) demonstrated greater hamstring muscle activity and mechanical stress when performing hamstring exercises using an isoinertial flywheel device compared with the typical weight stack machine. Askling et al. (1) reported a substantial decrease in number of hamstring injuries along with improvement in 30-m sprint and muscle strength after a 10-week resistance training using isoinertial technology. Finally, de Hoyo et al. (5) suggested possible decreases in the incidence and severity of hamstring injuries, together with an increase in sprint performance in soccer players after a 10-week training with an isoinertial device. The aforementioned studies support the notion that in addition to its preventive effect, the isoinertial technology may also enhance performance in athletes.

To the best of the authors' knowledge, no studies have analyzed the effect of an injury prevention protocol, including a range of exercises performed with isoinertial technology (flywheel devices), on modifiable risk factors and performance. The aim of this study therefore was to compare the effect of an isoinertial technology vs. a traditional gravity-dependent exercise protocol on modifiable factors associated with the incidence of ACL and HAM in athletes. In addition, the potential effect on sprint performance was also considered.

Methods

Experimental Approach to the Problem

This study used a 2 parallel group randomized controlled pre-post design where 2 between-participant conditions, flywheel (FY) and gravity-dependent (GT) injury prevention protocols, were tested. Once considered eligible for the study, the participants completed 2 sessions of familiarization and the preintervention assessment. Thereafter, participants were enrolled in either FY or GT and started a 6-week (12 sessions) injury prevention program. Postassessment was completed within 1 week after the end of the intervention period.

Subjects

Twenty recreationally trained volleyball players (10 male and 10 female) met the requirements to participate in this study. Participants were excluded if they had (a) hamstring injuries 6 months before the study; (b) history of knee injury; or (c) participated in any injury prevention program during the past 12 months.

Both groups participated in their normal volleyball training sessions twice a week in addition to the intervention protocols. Before providing written informed consent, all the participants were fully informed of the nature, benefits, and risks of the study. The Research Ethics Committee of the University of Greenwich approved the study. All procedures were in accordance with the Helsinki Declaration. The initial characteristics of the groups are summarized in Table 1.

Procedures

Familiarization. Participants attended the laboratory on 2 different occasions. On the first visit, participants were assessed for body mass and height, and familiarized with all the testing procedures and exercises. In addition, they were instructed on how to use the flywheel devices (YoYo Squat and Versa-Pulley).

During the second visit, participants performed as many repetitions as needed to achieve a correct technique for each exercise and were instructed about the assessment procedures.

Training Protocol. Participants in both groups completed 12 training sessions over 6 weeks (2 sessions per week on alternate days). After a standardized warm-up consisting of progressive dynamic flexibility exercises, all the participants performed 2 sets of 8 repetitions with 2 minutes of active rest (walking or slight movements) for each of the 6 exercises included in both (FY and GT) protocols. All training sessions were completed in less than 25 minutes and monitored by an experienced strength and conditioning coach. Participants continue with their habitual twice-weekly volleyball training sessions. No other physical activities, including endurance or resistance exercises, were performed during the intervention period.

Isoinertial Protocol (FY). Two flywheel devices, YoYo Squat (Inertial Power SRL, Argentina) and Versa-Pulley (Versa-Pulley portable; Versa-Climber, Halesowen, United Kingdom), were used to perform the following 6 exercises: (a) double-leg squat (Figure 1A), (b) single-leg squat (Figure 1B), (c) straight leg deadlift (Figure 1C), (d) leg curl (Figure 1D), (e) lunges (Figure 1E), and (f) hip extension (Figure 1F). See the Supplemental Digital Content 1 for further description (http://links.lww.com/JSCR/A115).

Table 1. Initial group characteristics.*

Variable	Flywheel group ($n = 10$)	Gravity-dependent group ($n = 10$)
Age (y)	22.6 ± 2.33	21.0 ± 1.41
Height (cm)	175.3 ± 7.38	176.9 ± 6.44
Body mass (kg)	69.9 ± 8.26	70.6 ± 7.34
Hamstring peak torque (N·m)	96.6 ± 18.54	101.4 ± 29.46
Quadriceps peak torque (N·m)	154 ± 32.12	157.7 ± 38.47

*Mean (*SD*).

The isoinertial technology is a gravity-independent system that uses the moment of inertia of a rotatory wheel over the concentric phase while braking to resist against the accumulated kinetic energy until stopping the wheel at the end of eccentric phase (27). We instructed participants to apply maximum force during the concentric phase and resist the braking during the eccentric phase (1,5,23). The YoYo Squat device was equipped with a 6.5-kg flywheel with a moment of inertia of 0.13 $\text{kg}\cdot\text{m}^{-2}$, and the Versa-Pulley's moment of inertia was 0.22 $\text{kg}\cdot\text{m}^{-2}$.

Gravity-Dependent Protocol (GT). The following commonly used and extensively described injury prevention exercises were assigned to the GT group: (a) single-leg jump (7), (b) single-leg land (10), (c) jump lunge (7), (d) single-leg deadlift (24), (e) ball leg curl (11), and (f) Nordic curl (7). All the exercises were performed with no additional external resistance (only the body weight).

Measurements and Control of the Intervention Compliance. Assessments were performed in one individual session and following the subsequent order: (a) body mass and height, (b) isokinetic dynamometry, (c) tuck jump, and (d) repeated shuttle sprint ability (RSSA) test. Before the testing session, participants were instructed to refrain from any vigorous activity and avoid caffeine ingestion for at least 48 hours. All tests were performed at the same time of the day for each participant. Identical testing procedures were repeated at the end of the intervention. The postassessment session was performed no later than a week after completing the last workout. Tolerance, collected from any adverse events and compliance with the protocols, was evaluated continuously during the intervention. Only participants who completed the 12 workouts with a training frequency of 2 sessions per week were included in the analysis.

Isokinetic Dynamometry. An isokinetic dynamometer (Humac Norm; CSMI, Stoughton, MA, USA) was used to measure peak torque and angle of peak torque during knee flexion and extension. The isokinetic test was conducted only for the dominant leg (preferred leg to kick a ball). The right leg was the dominant leg for 9 of 10 subjects in the FY and for all the subjects in the GT group.

The isokinetic protocol consisted of quadriceps concentric, hamstring concentric, and hamstring eccentric tests performed at a movement velocity of $60°\cdot\text{s}^{-1}$. This velocity was chosen to enable reliable and safe measurement for the selected sample (3,18). Participants completed a standardized warm-up including jogging, dynamic stretch, and 2 sets of 50 and 80% of their perceived maximum effort. They then performed 3 maximum repetitions for each test with 2 minutes of rest between them. Participants were instructed to sit on the dynamometer with their hips at approximately 80° (8) and with the upper body secured with dual cross-over strap. The knee range of motion was set from 0° to 105° (0° full extension position). Thigh and ankle straps were used to restrict thigh lateral movement and stabilize the lower leg, respectively. The data obtained from the isokinetic tests were used to calculate conventional and functional H–Q ratios. The functional and conventional ratios were respectively determined by dividing either the maximal eccentric or concentric hamstring peak torque by the maximal concentric quadriceps peak torque.

Tuck Jump Assessment. Five minutes after completing the isokinetic test, participants underwent the tuck jump assessment (TJA) test consisting in 10 seconds of continuous maximal-height tuck jumps (6). All tests were videotaped from frontal and sagittal planes. The assessment involves the analysis of 10 quantitative and dichotomous items from both frontal and sagittal view (Table 2). Participants scored zero, one, or 2 (magnitude of score) for each criteria described in Table 2. These criteria are used to assess the risk factors related to the incidence of ACL injury (20). The modified style of the test as described by Fort-Vanmeerhaeghe et al. (6) that showed high intrarater and interrater reliability was performed. A researcher, blinded to training status and groups, analyzed the video recorded for each of the participants and scored them according to the modified TJA criteria. The intrarater reliability of TJA measurements performed by the trained investigator in a preparatory study was excellent, with an intraclass correlation coefficient of >0.960 (95% CIs of 0.966–0.995).

Repeated Shuttle Sprint Ability Test. Fifteen minutes after the TJA, participants performed the modified RSSA assessment. The test involved 6 repetitions of 30-m (4 × 7.5 m with 180°

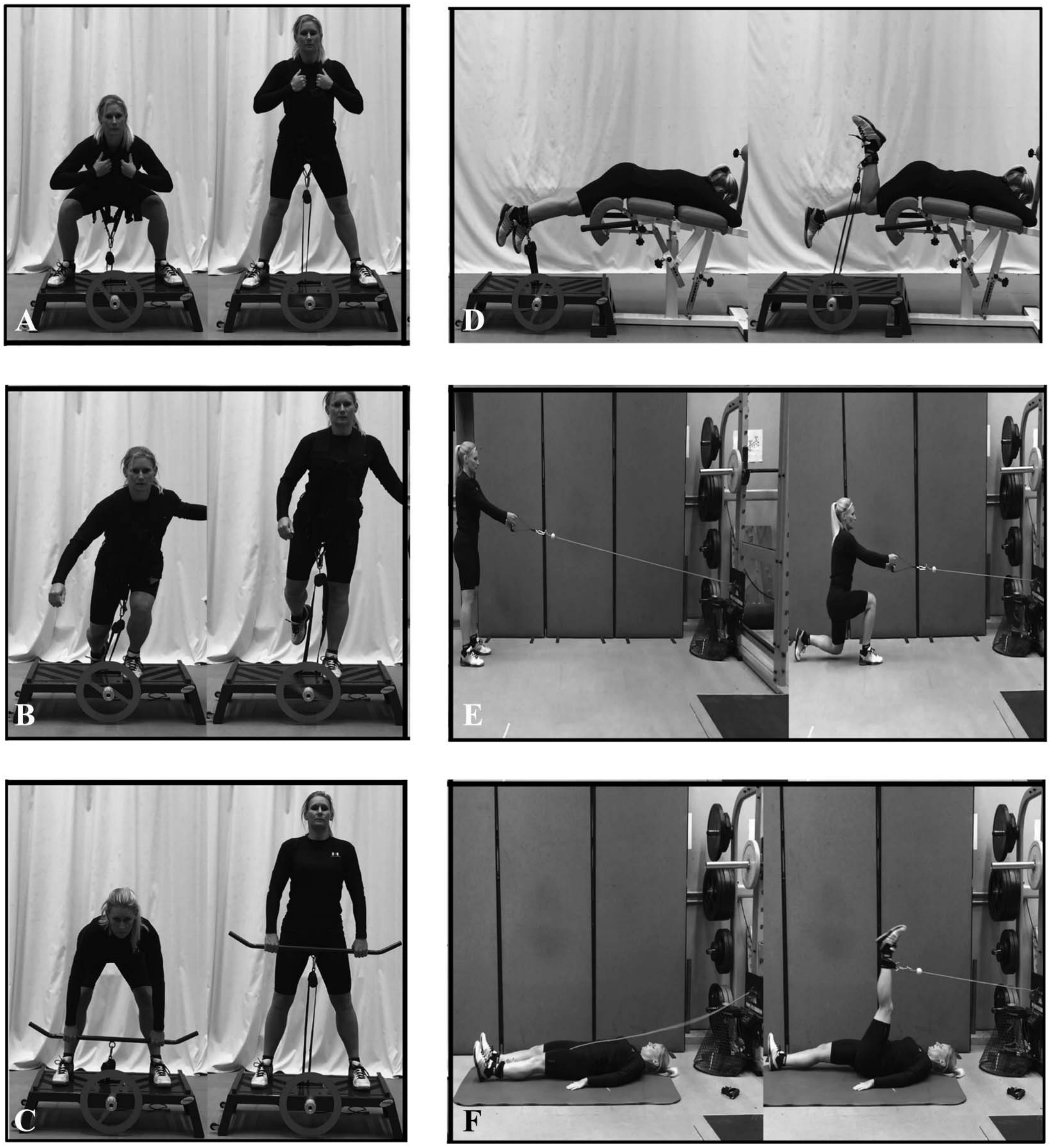

Figure 1. Six exercises performed by the isoinertial group using YoYo Squat (A–C) and Versa-Pulley (D–F). Double-leg squat (A), single-leg squat (B), straight-leg deadlift (C), leg curl (D), lunges (E), and hip extension (F).

turn) shuttle sprint separated by 20 seconds of passive recovery. Timing was recorded using photocell timing gates (Brower Timing Systems; HaB International Ltd., Southam, United Kingdom). Two seconds before each sprint, participants were asked to assume the starting position while the front foot was placed 0.5 m before the timing gate. This test was modified from previous protocols (2,12), and was chosen because it requires rapid acceleration, deceleration, and change of direction with a short recovery to simulate the high-intensity actions during athletic tasks. Strong verbal encouragement was provided through the sprint. Two scores were calculated: (a) best sprint time, and (b) mean sprint time (determined by the average of the 6 shuttle sprints).

Statistical Analyses

A descriptive analysis was performed and subsequently the Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to assess normality. Sample characteristics at baseline were compared between conditions (FY vs. GT) using an independent means Student's *t*-test. Values measured at pre and post intervention and the corresponding determined changes for the continuous data were summarized as mean (*SD*), whereas

TABLE 2. Scoring criteria for each item of the tuck jump assessment.

	Scores		
Criterion	0	1	2
1. Lower-extremity valgus at landing	No valgus	Slight valgus	Obvious valgus: both knees touch
2. Thighs do not reach parallel (peak of jump)	The knees are higher or at the same level as the hips	The middle of the knees are at a lower level than the middle of the hips	The whole knees are under the entire hips
3. Thighs not equal side-to-side during flight	Thighs equal side-to-side	Thighs slightly unequal side-to-side	Thighs completely unequal side-to-side (one knee is over the other)
4. Foot placement not shoulder width apart	Foot placement exactly shoulder width apart	Foot placement mostly shoulder width apart	Both feet fully together and touch at landing
5. Foot placement not parallel (front to back)	Foot (the end of the feet) placement parallel	Foot placement mostly parallel	Foot placement obviously unparalleled (one foot is over half the distance of the other foot/leg)
6. Foot contact timing not equal (asymmetrical landing)	Foot contact timing equal side-to-side	Foot contact timing slightly unequal	Foot contact timing completely unequal
7. Excessive landing contact noise	Subtle noise at landing (landing on the balls of their feet)	Audible noise at landing (heels almost touch the ground at landing)	Loud and pronounced noise at landing (contact of the entire foot and heel on the ground between jumps)
8. Pause between jumps	Reactive and reflex jumps	Small pause between jumps	Large pause between jumps (or double contact between jumps)
9. Technique declines before 10 s	No decline in technique.	Technique declines after 5 s	Technique declines before 5 s
10. Does not land in same footprint (consistent point of landing)	Lands in same footprint	Does not land in same footprint, but inside the shape	Lands outside the shape

ordinal data for the TJA and valgus scores as median (interquartile range). Differences in continuous data change from pretreatment to posttreatment were assessed using one-way analysis of covariance between groups and adjusted for baseline values and sexes. Differences in TJA score and knee valgus were assessed using Wilcoxon's rank-sum test. Confidence intervals of the adjusted differences were calculated and presented. In addition, one-sample Student's *t*-tests were used to test for null effect hypotheses. Eta squared (η^2) and Cohen's *d* values were reported to provide an estimate of standardized effect size (small $\eta^2 = 0.01$, $d = 0.2$; moderate, $\eta^2 = 0.06$, $d = 0.5$; and large $\eta^2 = 0.14$, $d = 0.8$ values were used as reference). Significance level was set to $p < 0.05$. Results are reported as mean (*SD*) unless stated otherwise. Data analyses were performed with the IBM SPSS software package v.20.0 for Windows. A post hoc power analysis of the final sample size was calculated for the differences between treatments in changes from baseline on the main outcomes (TJA score and knee valgus). We assumed a two-independent means comparison model, with 0.05 type I error probability (α) and 0.80 power ($1 - \beta$), to ensure adequacy of the study. Because differences in both outcome variables were assessed using nonparametric statistics, the method described by Ivarsson et al. (13) was used to determine Cohen's *d*. G*Power software was used to perform subsequent power analysis calculations.

RESULTS

Due to reasons not related with the investigation, 2 participants (1 male and 1 female) allocated in GT group abandoned the study. All the remaining athletes in the FY ($n = 10$, 5 males and 5 females) and GT ($n = 8$, 4 males and 4 female) completed all the training sessions and were included in the final analysis. Consequently, the final composition of the 2 groups was balanced (50% women and men) and equivalent at baseline.

Table 3 summarizes the pre and post absolute values, and the calculated adjusted differences from baseline and between treatment conditions.

TABLE 3. Mean (M) and *SD* of pre and post values and corresponding differences adjusted by the pre values and sexes in the analyzed variables for the 2 intervention groups.*†

	Flywheel group ($n = 10$)			Gravity-dependent (body weight) group ($n = 8$)			
Variables	Pre	Post	Adjusted changes (95% CI)	Pre	Post	Adjusted changes (95% CI)	Between-groups ANCOVA or rank-sum test
Hamstring eccentric peak torque (N·m)	127.20 ± 38.62	147.40 ± 46.25	20.37 (9.27 to 31.47)§	131.13 ± 36.13	152.75 ± 50.90	21.41 (9.00 to 33.82)‡	$F(1,14) = 0.018$, $p = 0.895$, $\eta^2 = 0.001$
Hamstring concentric peak torque (N·m)	96.6 ± 18.54	113.8 ± 44.25	17.87 (0.40 to 35.34)‡	104.5 ± 29.46	113 ± 33	7.66 (−11.93 to 27.25)	$F(1,14) = 0.677$, $p = 0.425$, $\eta^2 = 0.046$
Quadriceps concentric peak torque (N·m)	154 ± 32.12	163 ± 32.31	7.16 (−11.38 to 25.71)	165.25 ± 3.847	173 ± 42.55	10.04 (−10.74 to 30.83)	$F(1,14) = 0.048$, $p = 0.829$, $\eta^2 = 0.003$
Hamstring optimum peak torque (N·m)	28 ± 14.15	21.7 ± 8.27	−5.30 (−11.81 to 1.20)	24.63 ± 10.22	27.63 ± 11.75	1.75 (−5.53 to 9.03)	$F(1,14) = 2.380$, $p = 0.145$, $\eta^2 = 0.145$
H–Q conventional ratio	0.63 ± 0.08	0.71 ± 0.28	0.07 (−0.08 to 0.22)	0.63 ± 0.07	0.65 ± 0.07	0.02 (−0.15 to 0.19)	$F(1,14) = 0.261$, $p = 0.617$, $\eta^2 = 0.018$
H–Q functional ratio	0.82 ± 0.19	0.90 ± 0.19	0.08 (−0.02 to 0.19)	0.79 ± 0.12	0.87 ± 0.16	0.07 (−0.05 to 0.19)	$F(1,14) = 0.02$, $p = 0.886$, $\eta^2 = 0.002$
Best RSSA (s)	8.49 ± 0.67	8.24 ± 0.63	−0.23 (−0.40 to −0.53)‡	8.24 ± 0.46	8.25 ± 0.5	−0.02 (−0.21 to 0.18)	$F(1,14) = 2.77$, $p = 0.118$, $\eta^2 = 0.16$
Mean RSSA (s)	8.72 ± 0.68	8.43 ± 0.60	−0.28 (−0.45 to −0.10)‡	8.41 ± 0.50	8.41 ± 0.56	−0.02 (−0.22 to 0.18)	$F(1,14) = 3.94$, $p = 0.067$, $\eta^2 = 0.22$
TJA score, median (IQR)	9 ± 7–11	6.5 ± 5–9	−2 (−3 to −1)§	7 ± 6–9	6.5 ± 5.5–7.5	−1 (−1 to −0.5)	$Z = 2.056$, $p = 0.039$
Knee valgus, median (IQR)	2 ± 1–2	0.5 ± 0–1	−1 (−1 to 0)§	1.5 ± 1–2	1.5 ± 1–2	0 (0 to 0)	$Z = 2.899$, $p = 0.004$

*ANCOVA = analysis of covariance; N·m = Newton meter; RSSA = repeated shuttle sprint ability; TJA = tuck jump assessment; IQR = interquartile range.

†Data are presented as pre and post values, and individual change from baseline to follow-up adjusted for baseline assessment and sex. *p*-values for individual changes were adjusted by Bonferroni method and tested the null hypothesis that adjusted differences equal 0. Descriptive values of TJA and V are median (interquartile range), and the comparison between groups was performed using Wilcoxon rank-sum test.

‡$p < 0.05$.

§$p < 0.01$ compared with zero difference.

Only FY produced positive changes in TJA, valgus, and RSSA scores. Although both groups increased hamstring eccentric peak toque, only FY produced a significant rise of the hamstring concentric peak torque. At postintervention, the FY group showed a significant lower valgus ($p = 0.005$) and TJA ($p = 0.039$) along with a higher mean RSSA performance ($p = 0.067$, $\eta^2 = 0.22$) compared with GT.

We found the effect size for the differences between treatments in TJA score was very large ($d = 1.11$), and the statistical power achieved in our study was 60%. However, the effect size of the differences in knee valgus was determined to be also very large ($d = 1.87$), and the achieved statistical power was 96%.

DISCUSSION

The main finding of this study indicates that the FY protocol enhanced TJA score and improved landing technique by reducing valgus and enhancing RSSA performance. Although both protocols showed no significant changes in the optimal hamstring peak torque angle or both the conventional and functional H–Q ratios, the FY group increases hamstring concentric and eccentric peak torque, meanwhile the GT improved only the hamstring eccentric peak torque.

The TJA is an assessment tool monitoring 10 criteria to identify high-risk mechanisms (i.e., valgus) and screen neuromuscular control during repeated landing. One of the important scoring criteria of the TJA is lower-extremity valgus at landing. In fact, valgus is considered one of the most common risk factors for ACL injury (21). Our results showed significant postintervention improvement in valgus score during TJA for the FY group. Despite the popularity of including mainly bodyweight exercises in the preventive protocols (17), our findings suggest that 6 weeks of GT protocol was not enough to significantly modify the biomechanical factors associated with changes of the valgus and TJA scores. Although the TJA test is not as sensitive as the 3D video analysis, our results agree with those reported by Pollard et al. (26), who found no differences in knee valgus after implementation of a preventive bodyweight-only exercise program throughout a soccer season. Furthermore, Nagano et al. (22) observed no change in knee valgus after 5 weeks of a similar bodyweight-based preventive intervention. Lephart et al. (16) demonstrated that knee valgus at landing remained unchanged after 8 weeks of a preventive program using no external resistance. Finally, Klugman et al. (14) reported that a 10-week in-season–only bodyweight preventive protocol did not change the TJA score above and beyond the control group. The positive effect of the FY training to reduce the valgus score might be due to the higher eccentric overload offered by isoinertial technology compared to exercising with no additional resistance rather than the body weight. During the concentric phase, athletes produce and store kinetic energy in the system by rotating the flywheel through concentric action. The kinetic energy stored at the end of the concentric phase rotates the flywheel back, forcing the trainee to resist decelerating and stopping the wheel through an eccentric action. Unlike the gravity-dependent method, isoinertial technology ensures the accommodated resistance and optimal muscle loading at any particular joint angle through the entire concentric phase. Therefore, the kinetic energy accumulated at the end of the concentric phase is higher than the energy achieved when performing the typical gravity-dependent exercises (i.e., lifting, jumps, etc.) (30). Consequently, the higher overload created during eccentric phase by both isoinertial flywheel systems impose a superior workload on the muscles, increasing the level of muscle activity during the eccentric portion of the movement. The enhanced TJA score and the reduced valgus showed by the FY group suggest that using isoinertial technology would be an alternative to improve neuromuscular control and protect athletes from injuries.

The increased hamstring eccentric and concentric strength measured in both groups could be explained by the inclusion of hamstring-specific exercises such as Nordic curl or leg curl for the GT and FY protocols, respectively. Mjolsnes et al. (18) observed increased hamstring eccentric and isometric strength after a 10-week Nordic curl exercise protocol. Furthermore, 10 weeks of leg curl exercise protocol using a flywheel YoYo Squat device significantly increased hamstring concentric and eccentric muscle strength (5). Our results indicated that a 6-week GT or FY protocol would be enough to improve hamstring eccentric strength. However, despite the increased hamstring strength, H–Q functional and conventional ratio remained unchanged for both training conditions. The observed results can be explained by the inclusion of a variety of exercises requiring the synergic activation of hamstring and quadriceps in the 2 intervention programs. Therefore, improvement in quadriceps strength, although nonsignificant, may have attenuated any expected increase of the H–Q ratios.

The effectiveness of training using isoinertial technology on sprint performance has been reported by previous investigations. de Hoyo et al. (5) demonstrated significant improvement in 20-m sprint and countermovement jump after a 10-week program involving squat and hamstring leg curl using a YoYo Squat device. Furthermore, Askling et al. (1) reported improvement in 30-m sprint performance after a hamstring-specific training using a leg curl isoinertial device. However, to the best of the authors' knowledge, this study is the first investigation to report improvement in RSSA after 6 weeks of training using isoinertial technology. Athletic actions such as sprinting and change of direction require acceleration and deceleration in horizontal plane (5). The importance of specificity to transform power training to sport-specific task has been addressed previously (31). Performing exercises such as lunge using a Versa-Pulley machine, which requires high-intensity acceleration and deceleration in horizontal plane, might be the reason for the observed improvement in the shuttle sprint test. An advantage of isoinertial technology–based training is the possibility to perform sport-specific movements in all 3 dimensions of space, with similar kinematics as in sports events, which does not occur in conventional training (27). In team sports, including a great variety of movements and the integration of a 2 days per week, 20–30-minute training protocol using isoinertial technology with other specific training activities (sprint, drags, weightlifting, etc) will therefore, represent an excellent time-efficient alternative to elicit positive changes for supporting performance and protecting athletes from injuries.

This study is not without limitations. The low sample size included in each experimental group could increase the risk of type 2 error. Nonetheless, the presented effect size analysis reduces the risk of misinterpretation and suggests potential differences between groups that need to be confirmed in future studies. Furthermore, the intervention lasted only 6 weeks. Although this short period is sufficient to achieve changes in markers associated with the risk of injury for both groups (19), it is possible that results between groups could have diverged with a longer implemented intervention protocol. For example, although not significant, the η^2 values >0.14 between groups observed for the best and mean RSSA tests and the hamstring optimal peak torque highlight the potential superior overall effect of the FY protocol. Future investigations need to analysis the effectiveness of flywheel-based training (using isoinertial technology) in conjunction with other resistance training methods (bodyweight, free weight, etc.) on both improving injury risk factors and enhancing performance.

In summary, compared to exercising with gravity-dependent exercise using the resistance offered by bodyweight, a 6-week injury prevention program exercising with isoinertial technology seems to elicit better positive adaptations on some modifiable HAM and ACL injury risk factors as well as to enhance RSSA performance in female and male volleyball players.

PRACTICAL APPLICATIONS

Our findings may have implications for future injury prevention protocols aiming to reduce the risk of HAM and ACL injuries in athletes. It seems that by using a 20-minute program, involving 6 multifaceted exercises performed with isoinertial technology, implemented twice a week during a period of 6 weeks in team-sport athletes not engaged in a regular resistance training program may be effective to enhance lower-body strength and repeated-sprint ability in a relatively short period. The proposed flywheel protocol would also be effective to improve landing technique, reducing the degree of valgus in recreationally trained athletes.

ACKNOWLEDGMENTS

Authors declare no specific funding from grant agencies to support this study, and recognize no conflicts of interest. The authors thank Bruce Hertogs for his support and cooperation with the project and Kelsey Jendrzey from the Clinical Research Institute of Texas Tech University Health Sciences Center for grammar review and editing of the manuscript.

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