The Flywheel Paradigm in Team-Sports: A Soccer Approach

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Javier Raya-González
University Isabel I

Daniel Castillo
University Isabel I

Marco Beato
University of Suffolk

The Flywheel Paradigm in Team Sports: A Soccer Approach

Javier Raya-González,[1] Daniel Castillo,[1] and Marco Beato[2]
[1]Faculty of Health Sciences, Universidad Isabel I, Burgos, Spain; and [2]School of Health and Sports Science, University of Suffolk, Ipswich, United Kingdom

ABSTRACT

Strength training is a key strategy to improve performance and injury prevention in team sports. Accordingly, several methods have been used, although because of the benefits reported after training based on eccentric contractions, the use of flywheel (FW) devices has extended within the periodization of strength training of team sports. However, nowadays, there is no clear consensus about the parameters used to optimize the training effects. This article examines the research behind these claims and attempts to draw evidence-based conclusions as to the practical implications for a precise use of FW with team-sport players, attending to their specific demands and objectives.

INTRODUCTION

In most team sports (e.g., soccer, basketball, rugby, handball, or volleyball), players are required to perform a great amount of high-intensity actions (HIA) such as jumps, accelerations, linear sprint, and change-of-direction (COD) (11,77,86), to achieve a great on-field competitive performance (1,2,12). In this sense, the most determinant actions in team sports are preceded by at least one powerful action, for example, straight line sprint before a goal in soccer (30), jumping higher than an opponent to block a shot in basketball (63), or withstand contact and blows during a handball throw (64), which underline the importance of these actions during match-play. Players require high levels of physical conditioning to exhibit HIA, technical and tactical skills throughout a game (85). Regarding this, higher relationships between power outcomes (i.e., application of the maximum force able to be applied in short periods) and HIA in team sports were observed (84). Therefore, it seems that the ability to generate maximal power is related to a player's athletic performance (22), and thus, an appropriate strategy aimed at maximizing on-field performance in team sports is considered crucial (16).

Several resistance training programs have been conducted to improve the HIA performance in team-sport players, although most of them have focused on and are limited by applying loads during the concentric (CON) phase of the movement (i.e., the muscle tension rises to overcome the resistance and then remains stable as the muscle shortens) (83). However, the advantages of training under an eccentric (ECC) regimen (i.e., the muscle lengthens as the resistance becomes greater than the force the muscle is producing) (60) have led to the development of new devices (i.e., YO-YO Technology and Versapulley) which allow a greater application of load during the ECC phase while reproducing the stretch-shortening cycle (SSC) (i.e., CON + ECC phases). In addition, training with these devices after a series of indications (e.g., to delay the braking action to the last third of the ECC phase) favors the presence of greater load during the ECC phase than the CON one, which is named eccentric-overload (6).

The aforementioned devices are based on the flywheel (FW) paradigm, which is characterized by producing unlimited resistance during the entire range of motion (60). During the CON phase, the force applied allow for the unwinding of the cord/strap connected to the shaft within the device, which starts to rotate and store energy. Once the CON action is completed, the cord/strap rewinds and the participant must resist the pull of the device by braking, generating an ECC action (5). Because of its specific characteristics, training through these devices leads to the increase of muscle mass (60,87) as well as improvements in various sports actions such as jumping (38,62), linear sprint (57,82), and COD (50,56). In addition, using these devices has shown positive effects in the prevention of sports injuries (4,50). However, no official guidelines exist about FW training at the moment. Therefore, this review aims to increase the knowledge

Address correspondence to Daniel Castillo, danicasti5@gmail.com.

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strength; eccentric-overload; in-season; performance; injury prevention

about FW training to optimize its use for practitioners in team-sport athletes' performance, specifically for those involved in soccer practice.

FLYWHEEL PARADIGM AND SPORTING ACTIONS

VERTICAL JUMP PERFORMANCE

Traditionally, plyometric training has been considered as an effective strategy to improve vertical jump ability in athletes (81,91) because of the high eccentric load produced and the involvement of high-speed SSC, which is performed in any sport-specific task (76). Since FW paradigm is based on the repetition SSC increasing the ECC load due to an inertia (61,62), substantial improvements in team-sport players' vertical jump ability, measured through the countermovement jump (CMJ), have been reported. In this sense, several studies have used the half-squat FW exercise (38,40,62), proposing a training load of 4–6 sets of 6–10 reps at maximal velocity for a duration of 6–24 weeks, reporting improvements in CMJ of 3.26–10% in team-sport athletes. Other exercises (i.e., leg press and lateral half-squat) or the combination of 2 exercises in the same training program (i.e., half-squat + lunge or half-squat + leg curl) have been used to improve the CMJ performance in team-sport athletes, ranging from 4.53 to 9.80% (50,57,62,69). On the other hand, previous studies have not observed improvements in the vertical jump ability after the application of resistance training programs based on the FW paradigm (38,72,78,89). These studies were characterized by using multiexercise programs, focused on different movement vectors (i.e., vertical, horizontal, and diagonal), and consequently, with lower training volume in relation to the vertical vector, while in those previous studies in which the CMJ performance was improved, vertical exercises were predominantly used. Therefore, and despite being a novel methodology, we must not forget the classical training principles (i.e., principle of specificity) (39), which should be applied to the training programs based on the FW paradigm.

LINEAR SPRINT

Throughout the literature, several distances have been used to assess the linear-sprint performance in team athletes (19,50,82). In this sense, shorter distances (e.g., 5–10 m) are associated with a higher incidence of acceleration ability, while longer distances (e.g., 30–40 m) are needed to assess maximum speed, mainly in adult athletes (17,41). Several studies have included experimental protocols based on FW paradigm for the improvement of the linear sprint; however, these studies presented inconsistent findings (3,20,37,48,49,56,61,73,77,82,89). Regarding this, some authors have observed improvements in both short and long sprint distances (4,38,57,78,82), while other authors failed to improve the performance of athletes in linear sprint through these training programs, mainly over short distances (21,49,50,62,74,89). These results seem to be conditioned by 3 fundamental aspects. At first, it is believed that the performance in sprint tests depends largely on genetic factors, obtaining only relatively small improvements thanks to the training effect (73). Second, the individual adaptation potential of each athlete clearly influences the effects of a training program, making it more difficult to achieve improvements with highly trained professional athletes (54). Third, it is known that sprint performance is the product of stride speed and stride length, in addition to numerous anthropometric components that influence this product (73). Therefore, a key component for the improvement of sprint performance through the FW paradigm may be the application of individualized training programs.

CHANGES OF DIRECTION

COD maneuver is characterized by a high braking action followed by an immediate requirement of high propulsive forces to accelerate (52), similar to the movement pattern required during FW tasks' execution in the transition from ECC to CON phase (88). Therefore, and in accordance with the mentioned principle of specificity (42), it is expected that significant improvements were obtained in COD ability after strength training based on the FW paradigm. In this sense, the literature collects positive effects of this methodology in different COD tests and distances, as well as assessing both sports performance (21,38,57,69,89) and kinetics parameters (51). Attending to only-one COD maneuver tests (i.e., L-run with different turning angles and distances), Gonzalo-Skok et al. (38) showed substantial improvements in COD 45° 2-m performance in both legs after the application of 2 FW training program configurations (i.e., vertical movement vs. multidirectional movements), while only the group who participated with the second configuration improved the COD 45° 10 m performance. Similarly, Nuñez and Sáez de Villarreal (62) observed improvements in COD 90° 10-m performance in both legs after a unilateral program but only in the dominant leg with the bilateral program. Finally, Raya-González et al. (69) only increased the COD 90° 20-m performance in the left leg after a 6-week training program based on the lateral squat. On the other hand, improvements between 5 and 12% were observed in those studies which assessed the COD ability through multiple COD maneuver tests (i.e., T test, 0- to 30-m nonlinear sprint test and V-cut test) (21,57,78,89). Most of the aforementioned studies applied 2 sessions/week, mainly for 6 weeks, while in those in which only one weekly session was held, the experimental period was extended from 8 to 11 weeks (Table 1).

FLYWHEEL AND INJURY PREVENTION

Team sports such as handball, basketball, soccer, or Australian football are characterized by the unpredicted repetition of HIA over the course of the games, which involve an inherent risk of injury for athletes (79). Since injuries are one of the major problems that

Table 1 Summary of research investigating flywheel (FW) training program effects on power performances and injury prevention in team sports				
Study	Subject cohort	Training program	Weekly frequency	Duration
Askling et al. (4)	15 men, 24 ± 2.6 y, professional soccer players	FW leg curl (4 × 8 all-out reps.)	1–2 sessions	10 wk
Coratella et al. (22)	40 men, 23 ± 4 y, semiprofessional soccer players	FW squat (4–6 × 8 all-out reps.)	1 session	8 wk
Gonzalo-Skok et al. (39)	24 men, 20.5 ± 2 y, semiprofessional and amateur team-sport players	FW half-squat (6 × 6–10 all-out reps.)	2 sessions	8 wk
Gonzalo-Skok et al. (39)	24 men, 20.5 ± 2 y, semiprofessional and amateur team-sport players	Multi-exercise program (1 × 6–10 all-out reps.)	2 sessions	8 wk
Gual et al. (41)	27 men and women, 22.5 ± 3.8 y, volleyball and basketball players	FW half-squat (4 × 8 all-out reps.)	1 session	24 wk
de Hoyo et al. (51)	17 men, 17 ± 0.1 y, professional soccer players	FW leg curl and FW half-squat (4–6 × 6 all-out reps.)	1–2 sessions	12 wk
de Hoyo et al. (51)	18 men, 18 ± 1 y, professional soccer players	FW leg curl and FW half-squat (4–6 × 6 all-out reps.)	1–2 sessions	10 wk
Maroto-Izquierdo et al. (58)	15 men, 19.8 ± 1 y, professional handball players	FW leg press (4 × 7 all-out reps.)	2–3 sessions	6 wk
Núñez and Sáez de Villarreal (63)	14 men, 22.8 ± 2.9 y, team-sport players	FW half-squat (4 × 7 all-out reps.)	2 sessions	6 wk
Núñez and Sáez de Villarreal (63)	13 men, 22.6 ± 2.7 y, team-sport players	FW lateral half-squat (4 × 7 all-out reps.)	2 sessions	6 wk
Raya-González et al. (70)	8 men, 14.7 ± 0.3 y, professional soccer players	FW lateral half-squat (4 × 8 all-out reps.)	2 sessions	6 wk
Romero et al. (73)	12 men, 17.3 ± 1.2 y, professional soccer players	Multiexercise program (2–3 × 6–8 all-out reps.)	1 session	15 wk
Sabido et al. (75)	11 men, 23.9 ± 3.8 y, professional handball players	FW half-squat (4 × 8 all-out reps.) and FW lunge (2 × 8 all-out reps.)	1 session	7 wk
Sánchez-Sánchez et al. (79)	5 men, 23.7 ± 5.5 y, semiprofessional futsal players	Multiexercise program (4 × 6–8 all-out reps.)	1 session	8 wk
Suárez-Arrones et al. (83)	14 men, 17.5 ± 0.8 y, professional soccer players	Multiexercise program (1–2 × 6-8-16 all-out reps.)	2 sessions	27 wk
Tous-Fajardo et al. (90)	12 men, 17.0 ± 0.5 y, professional soccer players	Multiexercise program (2 × 6-6-10 all-out reps.)	1 session	11 wk
				(continued)

Table 1 (continued)

Study	Effects on sprint performance	Effects on COD performance	Effects on jump ability performance	Effects on injury prevention
Askling et al. (4)	0–30 m = −2.38% ($p < 0.05$)	—	—	Lower occurrence of hamstring injuries (3 versus 10)
Coratella et al. (22)	No significant improvements in 0–10 m and 0–30 m	T test = 7% ($p < 0.05$)	CMJ = 10% ($p < 0.05$)	—
Gonzalo-Skok et al. (39)	Substantial improvements in: 0–5 m; 0–10 m; 0–20 m and 0–25 m	Substantial improvements in: COD 45° 20 m in both legs	Substantial improvements in: CMJ in both legs	—
Gonzalo-Skok et al. (39)	Substantial improvements in: 0–5 m; 0–10 m; 0–20 m and 0–25 m	Substantial improvements in: COD 45° 10 m and COD 45° 20 m in both legs	Substantial improvements in CMJ only in the left leg	—
Gual et al. (41)	—	—	CMJ = 3.26% ($p < 0.05$)	—
de Hoyo et al. (51)	—	Substantial improvement of kinetic parameters during COD	—	—
de Hoyo et al. (51)	10–20 m = −3.08% (almost certainly) Possibly improvements in 0–10 m and 0–20 m	—	CMJ = 7.28% (very likely)	Severity = −67.80% (very likely) Possibly improvements in incidence
Maroto-Izquierdo et al. (58)	0–20 m = −10.81% ($p < 0.001$)	T test = −6.52% ($p < 0.001$)	CMJ = 9.80% ($p < 0.001$)	—
Núñez and Sáez de Villarreal (63)	Unclear improvements in 0–10 m	COD 90° dominant leg = −3.19% (very likely)	CMJ = 5.40% (likely)	—
Núñez and Sáez de Villarreal (63)	Possibly improvements in 0–10 m	COD 90° 10 m dominant leg = −5.51% (very likely) COD 90° 10 m non-dominant leg = −3.53% (very likely)	CMJ = 4.53% (likely)	—
Raya-González et al. (70)	No substantial improvements in 0–20 m and 0–30 m	COD 90° left leg = −6.33% (very likely)	CMJ = 5.33% (likely)	—

Table 1 (continued)

Romero et al. (73)	—	—	No significant improvements in CMJ ($p < 0.05$)	—
Sabido et al. (75)	Possibly improvements in 0–20 m	—	—	—
Sánchez-Sánchez et al. (79)	0–30 m linear = −2.78% ($p < 0.05$)	0–30 m nonlinear = −12.73% ($p < 0.01$)	No substantial improvements in CMJ	—
Suárez-Arrones et al. (83)	Substantial improvements in: 0–10 m; 0–30 m; and 0–40 m	—	—	—
Tous-Fajardo et al. (90)	Unclear improvements in 0–10 m and 0–30 m	V-cut test = −5.50% (almost certainly)	Possibly improvements in CMJ	—

COD = change of direction; CMJ = countermovement jump.

team-sport athletes have to face throughout their careers (29) because of its negative impact on team performance (43) and economy (28), great efforts have focused on reducing the injury incidence (68). In this regard, strength training has shown significant benefits in terms of reducing likelihood of injury (55), either preparing muscles and tendons to resist strains produced by HIA (20), reducing muscular asymmetries (37), modifying the angle of peak torque toward longer muscle lengths (10), or allowing a player to activate the required muscles suddenly and with adequate force-level ahead of unpredictable situations (25). Because these effects are magnified thanks to the application of ECC loads (61) and the muscle's injury risk is influenced by its capacity to generate or absorb force during the ECC phase (32), it seems beneficial to include strength sessions additionally to standard on field training sessions across the team athletes' periodization to improve ECC power, and consequently to reduce the injury risk. Regarding this, FW devices are considered a valid alternative to traditional strength training programs to generate load during the ECC movement phase (61), allowing high-velocity executions as well as reproduction of specific sporting movement patterns. Thus, previous studies have analyzed the effects of strength training programs based on the FW paradigm in team-sport athletes' injury incidence. For example, de Hoyo et al. (50) applied a FW training program based on the half-squat and leg curl exercises in U-19 elite male soccer players and substantially reduced the severity of injuries (from 5.9 ± 8.2 to 1.9 ± 1.8 absence days), despite no differences in injury incidence being observed (effect size = 0.18; possibly). On the other hand, Askling et al. (4) showed a significant lower number of hamstring injuries (3 versus 10) after the application of a 10-week eccentric-strength training program amongst professional soccer players. These results observed in the aforementioned studies revealed the beneficial effects of training programs based on the FW paradigm on injury rate and severity.

CONSIDERATIONS FOR FLYWHEEL PARADIGM TRAINING PRESCRIPTION: A SOCCER PRACTICAL APPROACH

Soccer is a team sport that requires high levels of physical conditioning to allow players to exhibit their technical and tactical skills throughout a game (45). Players are exposed to greater physical and physiological demands during the soccer-specific context, both during training sessions and matches (18). In line with this, higher strength and power levels, and more concretely greater capacity to produce a maximal amount of power in a minimum amount of period (85), are related with successful soccer players (3,93). So, power training has great interest (22,24) because of its association with the likelihood to achieve sport success. Regarding this, ECC-oriented power training seems to be an interesting alternative for soccer players (82) since most of the performance determining actions in this sport (i.e., COD, landings and jumps) require them to perform ECC muscle contractions at high velocity (70). In addition, different studies have concluded that strength gains are magnified when combining CON and ECC movement phases in the same exercise compared with the use of isolated CON or ECC actions (46,47), so incorporating training sessions based on the FW paradigm into a soccer team's schedule could be an interesting strategy to improve their performance while reducing the injury risk.

Despite the results obtained with soccer players (i.e., improvements in vertical jump, linear sprint, and change of direction abilities), this methodology must be used with caution, periodizing training load and recovery periods adequately, due to ECC actions generated by FW devices could imply acute reductions in maximal isometric voluntary contraction values (14) as well as greater levels of fatigue and muscle damage (13), mainly when players start working with these devices (31). Regarding this, it is necessary to be aware that soccer schedules are often chaotic in nature and constantly changing, due to several factors which may include television rights and progression through knock-out tournaments (92). These handicaps characterize soccer as a sport with a highly dense competitive period, where multiple matches can be played per week (26), significantly hindering training periodization, and even minimizing the number of weekly training sessions, which are mainly aimed at posteffort recovery and activation for the competition. In addition, differences between teams, starters and nonstarters, and matches per week influence the amount of time available to train and thus further complicates the organization of training. These aspects must be considered when locating strength training using FW devices in soccer periodization.

In response to the specific demands and objectives of soccer, as well as the characteristics of this sport, the following methodology is proposed for training with FW devices, based on some key variables (i.e., type of programs, exercises, density, volume, intensity, recovery, familiarization, weekly frequency, and blocks' duration) (Table 2).

MULTIEXERCISE PROGRAMS

Given the nature of soccer movement directions (i.e., horizontal, vertical, and rotational), it seems necessary to combine exercises that emphasize the application of force in each of these directions, being also a time-efficient protocol. This is also justified by the fact that the force-vector application may play an important role in developing different and specific functional adaptations (38). In addition, considering that the rotational movements demand high loads to players (53), other types of exercises (i.e., compensatory [exercises that involve muscle groups not included in the main exercises of the workout, with the aim of achieving a harmonious and multilateral development of the player reducing deficits and asymmetries] and complementary [monoarticular or analytical exercises whose objective is to strengthen the specific muscles to obtain different benefits]) should be added to attenuate the decompensatory effects generated by these aggressive loads, as well as by the soccer practice.

SEQUENCES

Soccer is dominated by acyclic actions defined as situations of an intermittent nature, which include periods of high intensity that are interspersed with others of low intensity (77), so it seems necessary to use a configuration for strength training programs based on the FW paradigm that allows to alternate between different acyclic actions to comply with the specificity principle (80). In this sense, an interesting option is the sequence of exercises, which also allows for the greater time efficiency and stimulus variability (23,27). Some authors indicated (79) that sequences in strength training programs could be performed following to different configurations (79). On one hand, sequences which develop one area mainly (e.g., hamstrings), and on the other hand sequences which develop several areas (e.g., hamstrings, quadriceps and core muscles). Sequences could include primary (i.e., FW exercises) and secondary (i.e., compensatory and complementary) exercises, and the proportion of each type depend on the main goal (e.g., prevention or performance), and it is related to the recovery needs (22). Finally, previous studies have postulated the need to include several elements (e.g., instability, concurrent vibratory stimuli, and unexpected and antiphase movements) to find an optimal degree of fluctuations between exercise progressions to optimize the FW training program effects (38,48).

UNILATERAL EXECUTION

Most HIA in soccer occur unilaterally (7,36) being unlikely to be performed in equal amounts using both limbs (8). In this sense, previous studies have analyzed the comparative effects of

Table 2 Key variables to develop the flywheel (FW) methodology in soccer players		
Blocks' duration	6–8 wk	
Weekly frequency	1 session/week during in-season; 2 sessions/week during preseason	
Volume	Sets Repetitions	1–3 sets/sequence 6–8 repetitions/set
Intensity	Inertial loads Movement velocity	Light-high for performance; high for injury prevention Maximal intended velocity
Recovery	2 min between sets; 3 min between sequences	
Density	1:1 injury prevention; 2:1 performance (focused on several muscle groups); 1:1 and 1:2 performance (focused on one muscle group)	
Familiarization	At least 2 sessions, recommended 3 sessions	
Exercises	Multiexercise program Sequences Unilateral execution	

strength training programs executed bilaterally or unilaterally, involving mainly FW exercises or plyometric protocols (35,62). The aforementioned studies are conclusive and have showed an increase effect on sporting actions (i.e., jumping, sprinting, and COD ability) when training programs are prescribed based on unilateral executions. Despite this, some authors (67) have observed that changes in young soccer players' performance are specific to the modality of strength training (i.e., bilateral versus unilateral). Thus, although a greater proportion of FW training programs must be composed of unilateral exercises, it could be interesting to combine unilateral and bilateral exercises during preparatory periods (38). On the other hand, some authors have postulated (44) that the differentiation between limbs' force-production generate the appearance of interlimb asymmetries in soccer players, confirming that asymmetry is a by-product of playing soccer. Regarding this, thresholds of >10% are to be accepted as cutoffs where reduced performance (9) and increased risk of injury are present (71), so one of the main objectives of the training is the reduction of interlimb asymmetries. In this sense, Gonzalo-Skok et al. (37) observed that only the unilateral strength training program had positive effects in the reduction of asymmetries, so its use is also justified in this regard.

REDUCED REPETITIONS

Owing to the chaotic nature of current elite soccer schedules, the FW-based strength training programs will be performed mainly before regular on-field training, although, ideally, they would be performed as different sessions with a longer recovery time. In this sense, an interesting option is to perform a reduced number of repetitions per series in relation to the maximum number of possible repetitions, to avoid a negative impact on subsequent training, either by reducing performance or increasing the risk of suffering an injury due to fatigue. In addition, this training load configuration seems to generate improvements of a neural nature, prioritizing structural improvements. Several authors such as González-Badillo et al. (33) and Pareja-Blanco et al. (66) have shown that performing half of the maximal repetitions reached by the athlete instead of reaching muscular/volitional failure or getting close to it produces lower impairments of neuromuscular performance and faster recovery as well as reduced hormonal responses and muscle damage. Specifically, several authors (75) studied from which repetition number there were significant ECC-power losses with respect to the best repetition in the half-squat executed in a FW device, obtaining ranges between 5 and 10 repetitions in the studied inertial loads (i.e., 0.025, 0.050, 0.075 and 0.100 $kg \cdot m^{-2}$). Therefore, 6–8 repetitions per series, programming 1–3 series for each sequence, seem to be adequate to optimize performance of soccer players.

MAXIMAL INTENDED VELOCITY

Given that most soccer actions are performed at maximum intensity and an aim of strength training is to allow the players to be able to generate as much power as possible in the shortest time (85), it seems clear that during FW programs, each repetition must be performed with the maximal intended velocity. Despite this and under the influence of weightlifting as the most relevant strength-based sport, many studies have analyzed the improvements on strength training exercises executed at low velocity, or without indicating lift velocity to move a certain load, although few previous studies have analyzed differences in lifting with maximal intended velocity in comparison with an intentional half-maximal velocity. In this sense, González-Badillo et al. (34) showed that performing every repetition at the maximum possible velocity compared with intentionally slower velocity resulted in considerably greater gains in strength and velocity developed against any given load. Specifically, and based on what has been previously mentioned, most of the studies based on the FW paradigm specify that the exercises were executed at maximal velocity, with the objective of achieving a specific execution to the gestures of the sport itself.

FAMILIARIZATION/PROGRESSION

Despite the multiple reported benefits related to strength training through FW devices, it seems essential to consider 2 aspects in the implementation of this type of program, with the aim of optimizing its possibilities: progression and familiarization, which are closely related. Regarding this, it is essential to follow the principle of progression to mitigate the negative effects derived from the FW (shown above), since using an individualized progression will affect the muscles involved in a controlled manner. In addition, several authors have shown that the repeated bout effect takes place in these types of exercises, which indicates that in the case of training sessions where intense ECC actions are performed, significant muscle damage will occur, although the muscles are able to adapt, and therefore, that same session will generate less muscle damage the following occasions (59). Attending to the familiarization process, there are several previous studies that have shown that the power values generated by FW devices failed to stabilize until at least the third familiarization session with such devices (58,75,90). In addition, one of the most affected variables by the inexperience of the participants was the production of ECC-power and, consequently, the ECC-overload generated. For all these reasons, it seems essential to perform a progression of individualized training for each player along with a wide familiarization with the FW devices to be used.

INERTIAL LOADS AND STRATEGIES TO IMPROVE ECC-OVERLOAD

As traditional exercises, the differences of using high, medium, or low loads in terms of strength and power are widely studied, and several authors have focused their work to characterize the FW-based strength training in response to the different inertial loads (15,58,75). In this sense, it has been assumed that the light inertial loads allow the development of higher values of movement velocity, moderate inertial loads optimize individual maximal power and high loads elicit higher levels of strength (both CON and ECC, especially), and consequently, higher ECC-overload values. From a practical point of view, medium-light loads seem adequate for optimizing sports performance, while high loads, due to the greater production of ECC-strength and ECC-overload, seem more suitable for injury prevention. Considering this is a general proposal, it is crucial to advocate for the use and periodization of training load in an individualized, intelligent, and responsible manner. Finally, several authors have reported the need to apply certain strategies, such as to provide instructions that encourage the participants to delay the braking action to the last third of the ECC phase (58), to optimize the presence of ECC-overload during FW programs.

SESSIONS PER WEEK

As previously mentioned, a very limited amount of time is available between weekly matches to introduce intensive strength and power-training sessions, so a normal frequency of 1 session per week in-season could be adequate. In response to this, it seems necessary during the preseason (more time available), to incorporate a second weekly session, to familiarize players with the methodology and thus mitigate muscle damage once the player works with these devices during the season, preventing it from interfering with the performance in competition or contributing, involuntarily, to increased injury risk because of the muscle damage or fatigue generated. On the other hand, and although there are studies that show improvements after the application of 1 session per week of a training program based on the FW paradigm, mainly in the vertical jump (21,40), Otero-Esquinas et al. (65) observed that sprint values (linear and COD) only improved in soccer players who perform the training program with a frequency of 2 sessions/week.

TRAINING BLOCKS

It seems pertinent to periodize training blocks of at least 6 weeks, since it is the minimum duration used in previous studies with FW devices (57,62,69). It therefore seems a rational duration for the realization of fixed assessments, with the aim of knowing the effectiveness of training not only in terms of performance improvement, but with a preventive orientation. Regarding this, it could be adequate to assess after blocks of 6–8 weeks to know changes in muscle deficits/deficiencies have occurred, to reorient training, if necessary. If larger blocks are proposed, the assessments become more spaced in time, so it may be too late to detect deficiencies of the training program, and that training is not fulfilling its objective of reducing injury risk, prolonging the duration players are at an increased injury risk. As a practical strategy not to interfere with the daily performance of soccer players, it would be interesting to monitor these training sessions, and use some of them as an assessment, but as part of the proposed training itself. For this purpose, to include a rotary encoder during training sessions could be a key strategy (63).

PRACTICAL APPLICATIONS

Training with FW devices produces several benefits, both for the improvement of sports physical performance and for injury prevention. However, the high workload encountered by soccer players and the concentrated soccer schedules should be taken into account when FW exercises are included in the training process. Specifically, the strength and conditioning coach must apply these FW programs in a progressive, individualized manner and following a rigorous familiarization process. In addition, aspects related to the training load (e.g., number of series and repetitions) or the selection of exercises (e.g., unilateral exercises) should be considered in the design of training programs based on the FW paradigm to optimize their conditional effects.

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Javier Raya-González *is the professor in Strength and Conditioning, Faculty of Health Sciences, Universidad Isabel I.*

Daniel Castillo *is PhD in Sports Sciences, Faculty of Health Sciences, Universidad Isabel I.*

Marco Beato *is the senior lecturer in Strength and Conditioning, School of Health and Sports Sciences, University of Suffolk.*

REFERENCES

1. Ben Abdelkrim N, El Fazaa S, El Ati J, Tabka Z. Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med* 41: 69–75, 2007.
2. Ade J, Fitzpatrick J, Bradley PS. High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *J Sports Sci* 34: 2205–2214, 2016.
3. Arnason A, Sigurdsson SB, Gudmundsson A, et al. Physical fitness, injuries, and team performance in soccer. *Med Sci Sports Exerc* 36: 278–285, 2004.
4. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports* 13: 244–250, 2003.
5. Beato M, McErlain-Naylor SA, Halperin I, Dello Iacono A. Current evidence and practical applications of flywheel eccentric overload exercises as postactivation potentiation protocols: A brief review. *Int J Sports Physiol Perform* 1–8, 2019.
6. Beato M, Stiff A, Coratella G. Effects of postactivation potentiation after an eccentric overload bout on countermovement jump and lower-limb muscle strength. *J Strength Cond Res* 1: 2019.
8. Bishop C, Lake J, Loturco I, Papadopoulos K, Turner A, Read P. Interlimb asymmetries: The need for an individual approach to data analysis. *J Strength Cond Res* 1: 2018.
9. Bishop C, Turner A, Maloney S, et al. Drop jump asymmetry is associated with reduced sprint and change-of-direction speed performance in adult female soccer players. *Sports* 7: 29, 2019.
10. Bishop C, Turner A, Read P. Effects of inter-limb asymmetries on physical and sports performance: A systematic review. *J Sports Sci* 36: 1135–1144, 2018.
11. Brughelli M, Nosaka K, Cronin J. Application of eccentric exercise on an Australian Rules football player with recurrent hamstring injuries. *Phys Ther Sport* 10: 75–80, 2009.
12. Buchheit M, Haddad HAl, Simpson BM, et al. Monitoring accelerations with gps in football: Time to slow down. *Int J Sports Physiol Perform* 9: 2014.
13. Cardinale M, Whiteley R, Hosny AA, Popovic N. Activity profiles and positional differences of handball players during the World Championships in Qatar 2015. *Int J Sports Physiol Perform* 12: 908–915, 2017.
14. Carmona G, Guerrero M, Cussó R, et al. Muscle enzyme and fiber type-specific sarcomere protein increases in serum after inertial concentric-eccentric exercise. *Scand J Med Sci Sports* 25: e547–e557, 2015.
15. Carmona G, Mendiguchía J, Alomar X, et al. Time course and association of functional and biochemical markers in severe semitendinosus damage following intensive eccentric leg curls: Differences between and within subjects. *Front Physiol* 9: 54, 2018.
16. Carroll KM, Wagle JP, Sato K, et al. Characterising overload in inertial flywheel devices for use in exercise training. *Sports Biomech* 18: 390–401, 2018.
17. Castillo D, Domínguez R, Rodríguez-Fernández A, Raya-González J. Effects of caffeine supplementation on power performance in a flywheel device: A randomised, double-blind cross-over study. *Nutrients* 11: 255, 2019.
18. Castillo D, Raya-González J, Manuel Clemente F, Yanci J. The influence of youth soccer players' sprint performance on the different sided games' external load using GPS devices. *Res Sport Med* 1–12, 2019.
19. Castillo D, Raya-González J, Weston M, Yanci J. Distribution of external load during acquisition training sessions and match play of a professional soccer team. *J Strength Cond Res* 1: 2019.
20. Castillo D, Rodríguez-Fernández A, Nakamura FY, et al. Influence of different small-sided game formats on physical and physiological demands and physical performance in young soccer players. *J Strength Cond Res* 1: 2019.
21. Cheung RTH, Smith AW, Wong DP. H:q ratios and bilateral leg strength in college field and court sports players. *J Hum Kinet* 33: 63–71, 2012.
22. Coratella G, Beato M, Cè E, et al. Effects of in-season enhanced negative work-based vs traditional weight training on change of direction and hamstrings-to-quadriceps ratio in soccer players. *Biol Sport* 36: 241–248, 2019.
23. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power: Part 2 training considerations for improving maximal power production. *Sport Med* 41: 125–146, 2011.
24. Cronin J, McNair PJ, Marshall RN. Velocity specificity, combination training and sport specific tasks. *J Sci Med Sport* 4: 168–178, 2001.
25. Cronin J, Sleivert G. Challenges in understanding the influence of maximal power training on improving athletic performance. *Sport Med* 35: 213–234, 2005.
26. Dallinga JM, Benjaminse A, Lemmink KAPM. Which screening tools can predict injury to the lower extremities in team sports?: A systematic review. *Sports Med* 42: 791–815, 2012.
27. Dellal A, Lago-Peñas C, Rey E, Chamari K, Orhant E. The effects of a congested fixture period on physical performance, technical

activity and injury rate during matches in a professional soccer team. *Br J Sports Med* 49: 390–394, 2015.

28. Ebben WP. Complex training: A brief review. *J Sports Sci Med* 1: 42–46, 2002.
29. Ekstrand J. Keeping your top players on the pitch: The key to football medicine at a professional level. *Br J Sports Med* 47: 723–724, 2013.
30. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med* 39: 1226–1232, 2011.
31. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci* 30: 625–631, 2012.
32. Fernandez-Gonzalo R, Lundberg TR, Alvarez-Alvarez L, de Paz JA. Muscle damage responses and adaptations to eccentric-overload resistance exercise in men and women. *Eur J Appl Physiol* 114: 1075–1084, 2014.
33. Garrett WE. Muscle strain injuries. *Am J Sports Med* 24: S2–S8, 1996.
34. González-Badillo J, Rodríguez-Rosell D, Sánchez-Medina L, et al. Short-term Recovery following resistance exercise leading or not to failure. *Int J Sports Med* 37: 295–304, 2015.
35. González-Badillo JJ, Rodríguez-Rosell D, Sánchez-Medina L, Gorostiaga EM, Pareja-Blanco F. Maximal intended velocity training induces greater gains in bench press performance than deliberately slower half-velocity training. *Eur J Sport Sci* 14: 772–781, 2014.
36. Gonzalo-Skok O, Sánchez-Sabaté J, Izquierdo-Lupón L, Sáez de Villarreal E. Influence of force-vector and force application plyometric training in young elite basketball players. *Eur J Sport Sci* 19: 305–314, 2019.
37. Gonzalo-Skok O, Tous-Fajardo J, Suarez-Arrones L, et al. Single-leg power output and between-limbs imbalances in team-sport players: Unilateral versus bilateral combined resistance training. *Int J Sports Physiol Perform* 12: 106–114, 2017.
38. Gonzalo-Skok O, Tous-Fajardo J, Suarez-Arrones L, et al. Single-leg power output and between-limb imbalances in team-sports players: Unilateral vs. bilateral combined resistance training. *Int J Sports Physiol Perform* 32: 1–44, 2016.
39. 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.
40. Grosser M, Luldjuraj P, Starischka S, Zimmermann E. *Principios del entrenamiento deportivo*. Martinez Roca, 1988.
41. Gual G, Fort-Vanmeerhaeghe A, Romero-Rodríguez D, Tesch PA. Effects of in-season inertial resistance training with eccentric overload in a sports population at risk for patellar tendinopathy. *J Strength Cond Res* 30: 1834–1842, 2016.
42. Al Haddad H, Simpson BM, Buchheit M, Di Salvo V, Mendez-Villanueva A. Peak match speed and maximal sprinting speed in young soccer players: Effect of age and playing position. *Int J Sports Physiol Perform* 10: 888–896, 2015.
43. Haff GG, Nimphius S. Training principles for power. *Strength Cond J* 34: 2–12, 2012.
44. Hägglund M, Waldén M, Magnusson H, et al. Injuries affect team performance negatively in professional football: An 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 47: 738–742, 2013.
45. Hart NH, Nimphius S, Weber J, et al. Musculoskeletal asymmetry in football athletes. *Med Sci Sport Exerc* 48: 1379–1387, 2016.
46. Helgerud J, Rodas G, Kemi OJ, Hoff J. Strength and endurance in elite football players. *Int J Sports Med* 32: 677–682, 2011.
47. Higbie EJ, Cureton KJ, Warren GL, Prior BM. Effects of concentric and eccentric training on muscle strength, cross-sectional area, and neural activation. *J Appl Physiol* 81: 2173–2181, 1996.
48. Hortobagyi T, Hill JP, Houmard JA, et al. Adaptive responses to muscle lengthening and shortening in humans. *J Appl Physiol* 80: 765–772, 1996.
49. Hossner E-J, Käch B, Enz J. On the optimal degree of fluctuations in practice for motor learning. *Hum Mov Sci* 47: 231–239, 2016.
50. de Hoyo M, de la Torre A, Pradas F, et al. Effects of eccentric overload bout on change of direction and performance in soccer players. *Int J Sports Med* 36: 308–314, 2015.
51. de Hoyo M, Pozzo M, Sanudo B, et al. Effects of a 10-week in-season eccentric overload training program on muscle injury prevention and performance in junior elite soccer players. *Int J Sport Physiol Perform* 10: 46–52, 2015.
52. 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.
53. Jones P, Bampouras TM, Marrin K. An investigation into the physical determinants of change of direction speed. *J Sports Med Phys Fitness* 49: 97–104, 2009.
54. Kawamoto R, Ishige Y, Watarai K, Fukashiro S. Quantitative investigation of torsional loading of the tibia during quick change of running direction. *Int J Sport Health Sci* 1: 24–33, 2003.
55. Keul J, König D, Huonker M, et al. Adaptation to training and performance in elite athletes. *Res Q Exerc Sport* 67: S-29–S-36, 1996.
56. Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: A systematic review and meta-analysis of randomised controlled trials. *Br J Sports Med* 48: 871–877, 2014.
57. Maroto-Izquierdo S, García-López D, Fernandez-Gonzalo R, et al. Skeletal muscle functional and structural adaptations after eccentric overload flywheel resistance training: A systematic review and meta-analysis. *J Sci Med Sport* 20: 943–951, 2017.
58. Maroto-Izquierdo S, García-López D, de Paz JA. Functional and muscle-size effects of flywheel resistance training with eccentric-overload in professional handball players. *J Hum Kinet* 60: 133–143, 2017.
59. 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.
60. McHugh MP. Recent advances in the understanding of the repeated bout effect: The protective effect against muscle damage from a single bout of eccentric exercise. *Scand J Med Sci Sport* 13: 88–97, 2003.
61. Norrbrand L, Fluckey JD, Pozzo M, Tesch PA. Resistance training using eccentric overload induces early adaptations in skeletal muscle size. *Eur J Appl Physiol* 102: 271–281, 2008.
62. Nuñez FJ, Sáez de Villarreal E. Does flywheel paradigm training improve muscle volume and force? A meta-analysis. *J Strength Cond Res* 31: 3177–3186, 2017.
63. Núñez FJ, Santalla A, Carrasquila I, et al. 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.

64. Okazaki VHA, Rodacki ALF, Satern MN. A review on the basketball jump shot. *Sport Biomech* 14: 190–205, 2015.

65. Ortega-Becerra M, Pareja-Blanco F, Jiménez-Reyes P, Cuadrado-Peñafiel V, González-Badillo JJ. Determinant factors of physical performance and specific throwing in handball players of different ages. *J Strength Cond Res* 32: 1778–1786, 2018.

66. Otero-Esquina C, de Hoyo Lora M, Gonzalo-Skok Ó, Domínguez-Cobo S, Sánchez H. Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players? *Eur J Sport Sci* 17: 1241–1251, 2017.

67. Pareja-Blanco F, Rodríguez-Rosell D, Sánchez-Medina L, et al. Acute and delayed response to resistance exercise leading or not leading to muscle failure. *Clin Physiol Funct Imaging* 37: 630–639, 2017.

68. Ramirez-Campillo R, Sanchez-Sanchez J, Gonzalo-Skok O, et al. Specific changes in young soccer player's fitness after traditional bilateral vs. unilateral combined strength and plyometric training. *Front Physiol* 9, 2018.

69. Raya-González J, Suárez-Arrones L, Navandar A, Balsalobre-Fernández C, Sáez de Villarreal E. Injury profile of elite male young soccer players in a Spanish professional soccer club: A prospective study during 4 consecutive seasons. *J Sport Rehabil* 1–7, 2019.

70. Raya-González J, Suarez-Arrones LJ, Risquez-Bretones AJ, Sáez de Villarreal E. Short-term effects of an eccentric-overload training program on the physical performance on U-16 elite soccer. *Retos Educ Física y Dep* 33: 106–111, 2018.

71. Roberts TJ, Azizi E. The series-elastic shock absorber: Tendons attenuate muscle power during eccentric actions. *J Appl Physiol* 109: 396–404, 2010.

72. Rohman E, Steubs JT, Tompkins M. Changes in involved and uninvolved limb function during rehabilitation after anterior cruciate ligament reconstruction: Implications for limb Symmetry Index measures. *Am J Sports Med* 43: 1391–1398, 2015.

73. Romero S, Madueño AF, Corrales BS, et al. Effects of strength training using a isoinertial device on jump ability in young elite soccer players. *Retos* 2041: 180–182, 2014.

74. Ross A, Leveritt M, Riek S. Neural influences on sprint running. *Sport Med* 31: 409–425, 2001.

75. Sabido R, Hernández-Davó JL, Botella J, Navarro A, Tous-Fajardo J. Effects of adding a weekly eccentric-overload training session on strength and athletic performance in team-handball players. *Eur J Sport Sci* 17: 530–538, 2017.

76. 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.

77. Sáez de Villarreal E, Requena B, Cronin JB. The effects of plyometric training on sprint performance: A meta-analysis. *J Strength Cond Res* 26: 575–584, 2012.

78. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in premier league soccer. *Int J Sports Med* 30: 205–212, 2009.

79. Sánchez-Sánchez J, Guillen Rodríguez J, Martín García D, et al. Effects of training with eccentric loads on the performance of futsal players. *Sport TK-Revista Euro Ciencias del Dep* 6: 57, 2017.

80. Schelling X, Torres-Ronda L. An integrative approach to strength and neuromuscular power training for basketball. *Strength Cond J* 38: 72–80, 2016.

81. Seirul-lo F. *El entrenamiento en los deportes de equipo*. Barcelona, Spain: Mastercede, 2017.

82. Söhnlein Q, Müller E, Stöggl TL. The effect of 16-week plyometric training on explosive actions in early to mid-puberty elite soccer players. *J Strength Cond Res* 28: 2105–2114, 2014.

83. Suarez-Arrones L, Saez de Villarreal E, Núñez FJ, et al. In-season eccentric-overload training in elite soccer players: Effects on body composition, strength and sprint performance. *PLoS One* 13: e0205332, 2018.

84. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The importance of muscular strength: Training considerations. *Sport Med* 48: 765–785, 2018.

85. Swinton PA, Lloyd R, Keogh JWL, Agouris I, Stewart AD. Regression models of sprint, vertical jump, and change of direction performance. *J Strength Cond Res* 28: 1839–1848, 2014.

86. Taber C, Bellon C, Abbott H, Bingham GE. Roles of maximal strength and rate of force development in maximizing muscular power. *Strength Cond J* 38: 71–78, 2016.

87. Taylor JB, Wright AA, Dischiavi SL, Townsend MA, Marmon AR. Activity demands during multi-directional team sports: A systematic review. *Sport Med* 47: 2533–2551, 2017.

88. Tesch PA, Ekberg A, Lindquist DM, Trieschmann JT. Muscle hypertrophy following 5-week resistance training using a non-gravity-dependent exercise system. *Acta Physiol Scand* 180: 89–98, 2004.

89. Tesch PA, Fernandez-Gonzalo R, Lundberg TR. Clinical applications of iso-inertial, eccentric-overload (YoYo™) resistance exercise. *Front Physiol* 8: 241, 2017.

90. Tous-Fajardo J, Gonzalo-Skok O, Arjol-Serrano JL, Tesch P. Enhancing change-of-direction speed in soccer players by functional inertial eccentric overload and vibration training. *Int J Sports Physiol Perform* 11: 66–73, 2016.

91. 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.

92. Váczi M, Tollár J, Meszler B, Juhász I, Karsai I. Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. *J Hum Kinet* 36: 17–26, 2013.

93. Wing C. In-season strength and power training considerations for professional soccer teams competing within national level competitions. *Strength Cond J* 40: 12–22, 2018.