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# The Flywheel Paradigm in Team-Sports: A Soccer Approach

## ABSTRACT

Strength training is a key strategy to improve performance and injury prevention in team-sports. [Accordingly](#), several methods have been used, although due to the benefits reported after training based on eccentric contractions, the use of flywheel devices (FW) 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-sports players, attending to their specific demands and objectives.

## KEYWORDS

Strength, eccentric-overload, in-season, performance, injury prevention.

## INTRODUCTION

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

49  
50 Several resistance training programs have been conducted to improve the HIA  
51 performance in team-sport players, although most of them have focused on and are  
52 limited by applying loads during the concentric (CON) phase of the movement (i.e., the  
53 muscle tension rises to overcome the resistance and then remains stable as the muscle  
54 shortens) (83). However, the advantages of training under an eccentric (ECC) regimen  
55 (i.e., the muscle lengthens as the resistance becomes greater than the force the muscle is  
56 producing) (60), has led to the development of new devices (i.e., YO-YO technology and  
57 Versapulley) which allow a greater application of load during the ECC phase while  
58 reproducing the stretch-shortening cycle (i.e., CON+ECC phases). Additionally, training  
59 with these devices following a series of indications (e.g., to delay the braking action to  
60 the last third of the ECC phase), favour the presence of greater load during the ECC phase  
61 than the CON one, which is named eccentric-overload (6).

62  
63 The aforementioned devices are based on the Flywheel (FW) paradigm, which is  
64 characterized by producing unlimited resistance during the entire range of motion (60).  
65 During the CON phase, the force applied allow for the unwinding of the cord/strap  
66 connected to the shaft within the device, which starts to rotate and store energy. Once the  
67 CON action is completed, the cord/strap rewinds and the participant must resist the pull  
68 of the device by braking, generating an ECC action (5). Due to its specific characteristics,

69 training through these devices leads to the increase of muscle mass (60,87) as well as  
70 improvements in various sports actions such as jumping (38,62), linear sprint (57,82) and  
71 COD (50,56). In addition, using these devices has shown positive effects in the prevention  
72 of sports injuries (4,50). However, no official guidelines exist about FW training at the  
73 moment. Therefore, this review aims to increase the knowledge about FW training in  
74 order to optimize its use for practitioners in team sports athletes' performance,  
75 specifically for those involved in soccer practice.

## 77 **FW PARADIGM AND SPORTING ACTIONS**

### 78 *Vertical Jump Performance*

79 Traditionally, plyometric training has been considered as an effective strategy to improve  
80 vertical jump ability in athletes (81,91), due to the high eccentric load produced and the  
81 involvement of high-speed stretch-shortening cycle (SSC), which is carried out in any  
82 sport specific task (76). Since FW paradigm is based on the repetition SSC increasing the  
83 ECC load due to an inertia (61,62), substantial improvements in team-sport players'  
84 vertical jump ability, measured through the countermovement jump (CMJ), have been  
85 reported. In this sense, several studies have used the half-squat FW exercise (38,40,62),  
86 proposing a training load of 4-6 sets of 6-10 reps at maximal velocity for a duration of 6-  
87 24 weeks, reporting improvements in CMJ of 3.26-10% in team-sport athletes. Other  
88 exercises (i.e., leg press and lateral half-squat) or the combination of two exercises in the  
89 same training program (i.e., half-squat + lunge or half-squat + leg curl) have been used to  
90 improve the CMJ performance in team-sport athletes, ranging from 4.53 to 9.80 %  
91 (50,57,62,69). On the other hand, previous studies have not observed improvements in  
92 the vertical jump ability after the application of resistance training programs based on the  
93 FW paradigm (38,72,78,89). These studies were characterized by using multi-exercise  
94 programs, focused on different movement vectors (i.e., vertical, horizontal and diagonal),  
95 and consequently, with lower training volume in relation to the vertical vector, while in  
96 those previous studies in which the CMJ performance was improved, vertical exercises  
97 were predominantly used. Therefore, and despite being a novel methodology, we must  
98 not forget the classical training principles (i.e., principle of specificity) (39), which should  
99 be applied to the training programs based on the FW paradigm.

100

### 101 *Linear Sprint*

102 Throughout the literature, several distances have been used to assess the linear-sprint  
103 performance in team athletes (19,50,82). In this sense, shorter distances (e.g., 5-10 m) are  
104 associated with a higher incidence of acceleration ability, while longer distances (e.g., 30-  
105 40 m) are needed to assess maximum speed, mainly in adult athletes (17,41). Several  
106 studies have included experimental protocols based on FW paradigm for the improvement  
107 of the linear sprint, however, these studies presented inconsistent findings  
108 (3,20,89,37,48,49,56,61,73,77,82). Regarding this, some authors have observed  
109 improvements in both short and long sprint distances (4,38,57,78,82), while other authors  
110 failed to improve the performance of athletes in linear sprint through these training  
111 programs, mainly over short distances (21,49,50,62,74,89). These results seem to be  
112 conditioned by three fundamental aspects. At first, it is believed that the performance in  
113 sprint tests depends largely on genetic factors, obtaining only relatively small  
114 improvements thanks to the training effect (73). Secondly, the individual adaptation  
115 potential of each athlete clearly influences the effects of a training program, making it  
116 more difficult to achieve improvements with highly trained professional athletes (54).  
117 Thirdly, it is known that sprint performance is the product of stride speed and stride  
118 length, in addition to numerous anthropometric components that influence this product  
119 (73). Therefore, a key component for the improvement of sprint performance through the  
120 FW paradigm may be the application of individualized training programs.

121

### 122 *Changes of direction*

123 COD maneuver is characterized by a high braking action followed by an immediate  
124 requirement of high propulsive forces to accelerate (52), similar to the movement pattern  
125 required during FW tasks' execution in the transition from ECC to CON phase (88).  
126 Therefore, and in accordance with the mentioned principle of specificity (42), it is  
127 expected that significant improvements were obtained in COD ability after strength  
128 training based on the FW paradigm. In this sense, the literature collects positive effects  
129 of this methodology in different COD tests and distances, as well as assessing both sports  
130 performance (21,38,57,69,89) and kinetics parameters (51). Attending to only-one COD  
131 maneuver tests (i.e., L-run with different turning angles and distances), Gonzalo-Skok et  
132 al. (38) showed substantial improvements in COD 45° 2m performance in both legs after  
133 the application of two FW training program configurations (i.e., vertical movement vs.  
134 multidirectional movements), while only the group who participated with the second  
135 configuration improved the COD 45° 10m performance. Similarly, Nuñez et al. (62)

136 observed improvements in COD 90° 10m performance in both legs after a unilateral  
137 program but only in the dominant leg with the bilateral program. Finally, Raya-González  
138 et al. (69) only increased the COD 90° 20m performance in the left leg after a 6 weeks  
139 training program based on the lateral squat. On the other hand, improvements between 5  
140 to 12% were observed in those studies which assessed the COD ability through multiple  
141 COD maneuver tests (i.e., T-test, 0-30m non-linear sprint test and V-cut test)  
142 (21,57,78,89). Most of the aforementioned studies applied 2 sessions/week, mainly for 6  
143 weeks, while in those in which only one weekly session was held, the experimental period  
144 was extended from 8 to 11 weeks (Table 1).

145

## 146 **FW AND INJURY PREVENTION**

147 Team-sports such as handball, basketball, soccer or Australian football are characterized  
148 by the unpredicted repetition of HIA over the course of the games, which involve an  
149 inherent risk of injury for athletes (79). Since injuries are one of the major problems that  
150 team-sport athletes have to face throughout their careers (29) due to its negative impact  
151 on team performance (43) and economy (28), great efforts have focused on reducing the  
152 injury incidence (68). In this regard, strength training has shown significant benefits in  
153 terms of reducing likelihood of injury (55), either preparing muscles and tendons to resist  
154 strains produced by high-intensity actions (20), reducing muscular asymmetries (37),  
155 modifying the angle of peak torque towards longer muscle lengths (10), or allowing a  
156 player to activate the required muscles suddenly and with adequate force-level ahead of  
157 unpredictable situations (25). Due to the fact that these effects are magnified thanks to  
158 the application of ECC loads (61) and the muscle's injury risk is influenced by its capacity  
159 to generate or absorb force during the ECC phase (32), it seems beneficial to include  
160 strength sessions additionally to standard on field training sessions across the team  
161 athletes' periodization in order to improve ECC power, and consequently to reduce the  
162 injury risk. Regarding this, FW devices are considered a valid alternative to traditional  
163 strength training programs in order to generate load during the ECC movement phase  
164 (61), allowing high-velocity executions as well as reproduction of specific sporting  
165 movement patterns. Thus, previous studies have analyzed the effects of strength training  
166 programs based on the FW paradigm in team-sports athletes' injury incidence. For  
167 example, De Hoyo et al. (50) applied a FW training program based on the half-squat and  
168 leg curl exercises in U-19 elite male soccer players and substantially reduced the severity  
169 of injuries (from  $5.9 \pm 8.2$  to  $1.9 \pm 1.8$  absence days), despite no differences in injury

170 incidence being observed (effect size = 0.18; possibly). On the other hand, Askling et al.  
171 (4) showed a significant lower number of hamstring injuries (3 versus 10) after the  
172 application of a 10-week eccentric-strength training program amongst professional soccer  
173 players. These results observed in the aforementioned studies revealed the beneficial  
174 effects of training programs based on the FW paradigm on injury rate and severity.

175  
176 **##Insert Table 1 near here, please##**  
177

## 178 **CONSIDERATIONS FOR FW PARADIGM TRAINING PRESCRIPTION: A** 179 **SOCCER PRACTICAL APPROACH**

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

196  
197 Despite the results obtained with soccer players (i.e., improvements in vertical jump,  
198 linear sprint and change of direction abilities), this methodology must be used with  
199 caution, periodizing training load and recovery periods adequately, due to ECC actions  
200 generated by FW devices could imply acute reductions in maximal isometric voluntary  
201 contraction values (14) as well as greater levels of fatigue and muscle damage (13),  
202 mainly when players start working with these devices (31). Regarding this, it is necessary  
203 to be aware that soccer schedules are often chaotic in nature and constantly changing, due

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204 to several factors which may include television rights and progression through knock-out  
205 tournaments (92). These handicaps characterize soccer as a sport with a highly dense  
206 competitive period, where multiple matches can be played per week (26), significantly  
207 hindering training periodization, and even minimizing the number of weekly training  
208 sessions, which are mainly aimed at post-effort recovery and activation for the  
209 competition. Additionally, differences between teams, starters and non-starters and  
210 matches per week influence the amount of time available to train and thus further  
211 complicates the organization of training. These aspects must be considered when locating  
212 strength training using FW devices in soccer periodization.

213  
214 In response to the specific demands and objectives of soccer, as well as the characteristics  
215 of this sport, the following methodology is proposed for training with FW devices, based  
216 on some key variables (i.e., type of programs, exercises, density, volume, intensity,  
217 recovery, familiarization, weekly frequency and blocks' duration) (Table 2).

#### 218 219 MULTI-EXERCISE PROGRAMS

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

#### 232 233 SEQUENCES

234 Soccer is dominated by acyclic actions defined as situations of an intermittent nature,  
235 which include periods of high intensity that are interspersed with others of low intensity  
236 (77), so it seems necessary to use a configuration for strength training programs based on  
237 the FW paradigm that allows to alternate between different acyclic actions in order to

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238 comply with the specificity principle (80). In this sense, an interesting option is the  
239 sequence of exercises, which also allows for the greater time efficiency and stimulus  
240 variability (23,27). Some authors indicated (79) that sequences in strength training  
241 programs could be performed following to different configurations (79). On one hand,  
242 sequences which develop one area mainly (e.g., hamstrings), and on the other hand  
243 sequences which develop several areas (e.g., hamstrings, quadriceps and core muscles).  
244 Sequences could include primary (i.e., FW exercises) and secondary (i.e., compensatory  
245 and complementary) exercises, and the proportion of each type depend on the main goal  
246 (e.g., prevention or performance), and it is related to the recovery needs (22). Finally,  
247 previous studies have postulated the need to include several elements (e.g., instability,  
248 concurrent vibratory stimuli, and unexpected and antiphase movements) to find an  
249 optimal degree of fluctuations between exercise progressions to optimize the FW training  
250 programs effects (38,48).

251

## 252 UNILATERAL EXECUTION

253 Most high-intensity actions in soccer occur unilaterally (7,36) being unlikely to be  
254 performed in equal amounts using both limbs (8). In this sense, previous studies have  
255 analyzed the comparative effects of strength training programs executed bilaterally or  
256 unilaterally, involving mainly FW exercises or plyometric protocols (35,62). The  
257 aforementioned studies are conclusive and have showed an increase effect on sporting  
258 actions (i.e., jumping, sprinting and COD ability) when training programs are prescribed  
259 based on unilateral executions. Despite this, some authors (67) have observed that  
260 changes in young soccer players' performance are specific to the modality of strength  
261 training (i.e., bilateral vs. unilateral). Thus, although a greater proportion of FW training  
262 programs must be composed of unilateral exercises, it could be interesting to combine  
263 unilateral and bilateral exercises during preparatory periods (38). On the other hand, some  
264 authors have postulated (44) that the differentiation between limbs' force-production  
265 generate the appearance of inter-limb asymmetries in soccer players, confirming that  
266 asymmetry is a by-product of playing soccer. Regarding this, thresholds of >10% are to  
267 be accepted as cutoffs where reduced performance (9) and increased risk of injury are  
268 present (71), so one of the main objectives of the training is the reduction of inter-limb  
269 asymmetries. In this sense, Gonzalo-Skok et al. (37) observed that only the unilateral  
270 strength training program had positive effects in the reduction of asymmetries, so its use  
271 is also justified in this regard.

272

273 REDUCED REPETITIONS

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

292

293 MAXIMAL INTENDED VELOCITY

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

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306 most of the studies based on the FW paradigm specify that the exercises were executed  
307 at maximal velocity, with the objective of achieving a specific execution to the gestures  
308 of the sport itself.

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#### 311 FAMILIARIZATION/PROGRESSION

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

329

#### 330 INERTIAL LOADS AND STRATEGIES TO IMPROVE ECC-OVERLOAD

331 As traditional exercises, the differences of using high, medium or low loads in terms of  
332 strength and power are widely studied, several authors have focused their work to  
333 characterize the FW-based strength training in response to the different inertial loads  
334 (15,58,75). In this sense, it has been assumed that the light inertial loads allow the  
335 development of higher values of movement velocity, moderate inertial loads optimize  
336 individual maximal power and high loads elicit higher levels of strength (both CON and  
337 ECC, especially), and consequently, higher ECC-overload values. From a practical point  
338 of view, medium-light loads seem adequate for optimizing sports performance, while  
339 high loads, due to the greater production of ECC-strength and ECC-overload, seem more

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340 suitable for injury prevention. Considering this is general proposal, it is crucial to  
341 advocate for the use and periodization of training load in an individualized, intelligent  
342 and responsible manner. Finally, several authors have reported the need to apply certain  
343 strategies, such as to provide instructions that encourage the participants to delay the  
344 braking action to the last third of the ECC phase (58), in order to optimize the presence  
345 of ECC-overload during FW programs.

346

#### 347 SESSIONS PER WEEK

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

360

#### 361 TRAINING BLOCKS

362 It seems pertinent to periodize training blocks of at least 6 weeks, since it is the minimum  
363 duration used in previous studies with FW devices (57,62,69). It therefore seems a  
364 rational duration for the realization of fixed assessments, with the aim of knowing the  
365 effectiveness of training not only in terms of performance improvement, but with a  
366 preventive orientation. Regarding this, it could be adequate to assess after blocks of 6-8  
367 weeks to know changes in muscle deficits/deficiencies have occurred, in order to re-orient  
368 training, if necessary. If larger blocks are proposed, the assessments become more spaced  
369 in time, so it may be too late to detect deficiencies of the training programme, and that  
370 training is not fulfilling its objective of reducing injury risk, prolonging the duration  
371 players are at an increased injury risk. As a practical strategy not to interfere with the  
372 daily performance of soccer players, it would be interesting to monitor these training  
373 sessions, and use some of them as an assessment, but as part of the proposed training

374 itself. For this purpose, to include a rotary encoder during training sessions could be a key  
375 strategy [63].

376

377 **##Insert Table 2 near here, please##**

378

## 379 **PRACTICAL APPLICATIONS**

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

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Table 1. Summary of research investigating flywheel (FW) training programs effects on power performances and injury prevention in team sports.

Study	Subject cohort	Training program	Weekly frequency	Duration	Effects on sprint performance	Effects on COD performance	Effects on jump ability performance	Effects on injury prevention
Asklings et al. (4)	15 males, 24 ± 2.6 y, professional soccer players	FW leg curl (4x8 all-out reps.)	1-2 sessions	10 weeks	0-30 m = -2.38% (p < 0.05)	-	-	Lower occurrence of hamstring injuries (3 vs 10)
Coratella et al. (22)	40 males, 23 ± 4 y, semi-professional soccer players	FW squat (4-6x8 all-out reps.)	1 session	8 weeks	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)	24 males, 20.5 ± 2 y, semi-professional and amateur team-sport players	FW half-squat (6x6-10 all-out reps.)	2 sessions	8 weeks	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)	24 males, 20.5 ± 2 y, semi-professional and amateur team-sport players	Multi-exercise program (1x6-10 all-out reps.)	2 sessions	8 weeks	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)	27 males and females, 22.5 ± 3.8 y, volleyball and basketball players	FW half-squat (4x8 all-out reps.)	1 session	24 weeks	-	-	CMJ = 3.26% (p < 0.05)	-
de Hoyo et al. (51)	17 males, 17 ± 0.1 y, professional soccer players	FW leg curl and FW half-squat (4-6x6 all-out reps.)	1-2 sessions	12 weeks	-	Substantial improvement of kinetic parameters during COD	-	-
de Hoyo et al. (51)	18 males, 18 ± 1 y, professional soccer players	FW leg curl and FW half-squat (4-6x6 all-out reps.)	1-2 sessions	10 weeks	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)	15 males, 19.8 ± 1 y, professional handball players	FW leg press (4x7 all-out reps.)	2-3 sessions	6 weeks	0-20 m = -10.81% (p < 0.001)	T-test = -6.52% (p < 0.001)	CMJ = 9.80% (p < 0.001)	-
Núñez et al. (63)	14 males, 22.8 ± 2.9 y, team sport players	FW half-squat (4x7 all-out reps.)	2 sessions	6 weeks	Unclear improvements in 0-10 m	COD 90° dominant leg = -3.19% (very likely)	CMJ = 5.40% (likely)	-
Núñez et al. (63)	13 males, 22.6 ± 2.7 y, team sport players	FW lateral half-squat (4x7 all-out reps.)	2 sessions	6 weeks	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)	8 males, 14.7 ± 0.3 y, professional soccer players	FW lateral half-squat (4x8 all-out reps.)	2 sessions	6 weeks	No substantial improvements in 0-20 m and 0-30 m	COD 90° left leg = -6.33% (very likely)	CMJ = 5.33% (likely)	-
Romero et al. (73)	12 males, 17.3 ± 1.2 y, professional soccer players	Multi-exercise program (2-3x6-8 all-out reps.)	1 session	15 weeks	-	-	No significant improvements in CMJ (p < 0.05)	-
Sabido et al. (75)	11 males, 23.9 ± 3.8 y, professional handball players	FW half-squat (4x8 all-out reps.) and FW lunge (2x8 all-out reps.)	1 session	7 weeks	Possibly improvements in 0-20 m	-	-	-
Sánchez-Sánchez et al. (79)	5 males, 23.7 ± 5.5 y, semi-professional futsal players	Multi-exercise program (4x6-8 all-out reps.)	1 session	8 weeks	0-30 m lineal = -2.78% (p < 0.05)	0-30 m non-lineal = -12.73% (p < 0.01)	No substantial improvements in CMJ	-
Suárez-Arrones et al. (83)	14 males, 17.5 ± 0.8 y, professional soccer players	Multi-exercise program (1-2x6-8-16 all-out reps.)	2 sessions	27 weeks	Substantial improvements in: 0-10 m; 0-30 m and 0-40 m	-	-	-
Tous-Fajardo et al. (90)	12 males, 17.0 ± 0.5 y, professional soccer players	Multi-exercise program (2x6-6-10 all-out reps.)	1 session	11 weeks	Unclear improvements in 0-10 m and 0-30 m	V-cut test = -5.50% (almost certainly)	Possibly improvements in CMJ	-

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Abbreviations: COD: change of direction; CMJ: countermovement jump.

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**Table 2.** Key variables to develop the Flywheel (FW) methodology in soccer players.

<b>Blocks' duration</b>	6-8 weeks	
<b>Weekly frequency</b>	1 session/week during in-season; 2 sessions/week during pre-season	
<b>Volume</b>	<i>Sets</i>	1-3 sets/sequence
	<i>Repetitions</i>	6-8 repetitions/set
<b>Intensity</b>	<i>Inertial loads</i>	Light-high for performance; High for injury prevention
	<i>Movement velocity</i>	Maximal intended velocity
<b>Recovery</b>	2 min between sets; 3 min between sequences	
<b>Density</b>	1:1 injury prevention; 2:1 performance (focused on several muscle groups); 1:1 and 1:2 performance (focused on one muscle group)	
<b>Familiarization</b>	At least 2 sessions, recommended 3 sessions	
<b>Exercises</b>	Multi-exercises program	
	Sequences	
	Unilateral execution	