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ABSTRACT

As the interest and popularity of female soccer has increased over the last few decades, there still lacks research conducted with the elite population, specifically ecological training interventions during the competitive season. Therefore, the aim of this study was to compare the effectiveness of 12 weeks (undertaken once a week) of plyometric (PLY) training on physical performance in professional female soccer players during the season. Using a randomized controlled trial design sixteen players were included in the current study (mean ± SD; age 23 ± 4 years, weight 60.3 ± 4.9 kg, height 167 ± 3.7 cm) and randomized in PLY (n=8) and Control groups (CON, n=8), respectively. Squat jump (SJ), counter movement jump (CMJ), long jump (LJ), single-leg triple jump distance test (triple jump test), change of direction 505 test (505-COD), and sprint 10 m and 30 m were performed before and after 12 weeks of PLY training. Significant within-group differences were found in triple jump test dominant (p=0.031, ES=*moderate*) and non-dominant limb (p=0.021, ES=*moderate*) and sprint 10 m (p=0.05, ES=*large*), while, the CON did not report any positive variation. However, neither group reported significant variation in SJ, CMJ, LJ, 505-COD, sprint 30 m (underlining the difficulties in obtain meaningful variation in season). These findings have strong practical applications as this study showed for the first time that a single session a week of plyometric training can significantly increase sport-specific fitness parameters in professional female soccer players during the season.

Keywords: football, team sports, performance, training, jumps

INTRODUCTION

The popularity of female soccer, or correctly termed Association Football, has increased exponentially over the past decade, coinciding with the FIFA Women's Football Survey (2014) stating that the total numbers of female players can be estimated at around 30 million worldwide (20). Within the professional female game, an increase in popularity and audience viewing figures has resulted in the 2023 World Cup growing from a 24-team tournament to a 32-team tournament, mirroring the tournament format of the men's World Cup. Despite this increased popularity, and more importantly professionalism throughout the European leagues, there is still a lack of published research around the sport of female soccer (16). There have been published reports characterizing the game activities and demands of female soccer players (1,16), seasonal changes in physical performance during the competitive season (17), characteristics of female youth players based on maturation (18), as well as a recent review article providing an applied physiological update on the sport (16). However, what is currently lacking within the published literature are sport specific training interventions for this under researched female population to support and inform practice to improve athletic development.

A recent report highlighted that international female soccer players cover a total distance of 10,321 ± 859 m during matches (15), which is comparable to distances covered at national levels by female players (12), but slightly less (approximately 500 m) than male players within the English Premier League (3). Greater importance for match outcomes and critical events during match play would suggest that total distance covered at high-intensities and sprinting play a more important factor than total distance alone (22,28,35). This has been highlighted, albeit in the men's game, with findings stating that straight-line sprinting is the most frequent action prior to goals scored in soccer (19), and that differences exist in high-intensity running and distances covered in sprinting between players of different level (27), suggest that this physical characteristic may be a key performance indicator of success in soccer (11,13). In addition to the need for high-intensity work within soccer, many utility movements such as changes of direction (COD), accelerations/decelerations, and jumps are required with locomotive activities changing every 4-6 s accounting for approximately 1,350 activities throughout a match (6,8,14,16). Therefore, the ability to perform rapid and forceful movements would be advantageous for soccer players, and as such training drills and methodologies are routinely utilized to develop these abilities (4,10).

Plyometric (PLY) training is a common and effective strategy used in applied settings and supported in the scientific literature to improve power and sprint in athletes (4,26). Furthermore, this activity has shown to improve markers of bone health and resistance to injury (26). PLY training involves bounding jumping (*e.g.* horizontal jumps) and high impact (*e.g.* drop jumps) exercises using the stretch-shortening cycle (SSC) action, in which an enhancement of the neural and musculotendinous systems to produce maximal force as quickly as possible is required (10). The current literature reports positive effects on sport specific performance (*e.g.* jumping and sprinting tasks) using a combination of vertical and horizontal PLY exercises (10,24), with the systematic review conducted by Markovic and Mikulic (2010) finding that 81% of the studies included observed a relative increase in muscular power with positive findings ranging from 2.4–31.3% (26). In addition, from a performance-enhancing perspective research recommended PLY for strength and conditioning coaches due to performance enhancements for muscle power, muscle strength, speed, and COD (4,23,24). Investigating specific PLY for females established positive results for power and speed parameters (16,32,33). Players may achieve greater physical fitness due to several neuromuscular related functions of the SSC such as neural drive, superior ability to generate relative force per motor unit, greater leg muscle qualities, and running economy (26,30).

Professional soccer players have a relatively low amount of time to dedicate to strength and PLY training as specific tactical and technical requirements of the sport take priority for many coaches (12,15). This is exacerbated by professional duties associated with games and travels (25). Much of the literature has reported that two or three session of PLY a week may be effective to develop lower-limb performance in athletes but this training frequency is unrealistic within professional soccer players in season (5). However, a recent research conducted in elite male soccer players reported that one PLY training session a week may offer equivalent benefits of training twice a week on jump, sprint and COD ability (10). Thus, protocols evaluating the effectiveness of low PLY training dose, such as one session a week, may have a great importance in the applied elite female soccer environment. Moreover, the literature evaluating the effect of PLY training, by robust design such as a randomized controlled trial, and enrolling a professional population, is very limited (26,31). As such future recommendations proposed by Ramirez-Campillo et al. (2017) in their methodological review into PLY included an improvement of methodological quality, greater diversity of research subjects, and with more studies conducted in subjects with high athletic performance (31).

The current investigation aimed to investigate the effect of adding a 12-week PLY training program (single session per week) within regular team training on players power, COD and sprint performance. Following the most recent PLY literature recommendations (31,32), this investigation utilized an elite group of senior professional female soccer players during their competitive season. Authors have hypothesized that the addition of PLY would enhance physical performance indicators further during the in-season training program.

METHODS

Experimental approach to the problem

The current study was designed to examine the effect of 12 weeks of PLY (a single session per week) training on jumps, sprint and COD in a sample of professional female soccer players. This study used a randomized controlled group trial design. Randomization was performed according to a computer-generated sequence. Subjects were then assigned to either a PLY group (n = 8 players) or Control group (CON, n = 8 players) as reported in the CONSORT flow (Figure 1). Fifteen players completed the study, while one subject of the CON dropping out due to a contact injury during a training session. Sixteen players (including the drop out) were considered in the final statistical analysis (intention to treat analysis) (34). In this investigation the statistical power of the sample was calculated *a priori* to verify that a power of 0.80 was respected. A sample size of sixteen (using intention to treat analysis to avoid a decrement in subjects) reported a power > 0.80 based on $p < 0.05$ and a *moderate* to *large* effect size (ES). This study enrolled professional soccer players in their competitive season, therefore readers should be aware of such a limitation (small sample size used).

Please report Figure 1 here. CONSORT flow

The PLY training utilized in the current protocol is supported by previous evidence (10). A training duration of 12 weeks is generally appropriate to obtain some relevant sport-specific fitness variations (26). PLY training was divided into two parts, where the first six weeks utilized a specific jumps volume, which was increased from weeks seven to twelve.

Training protocols, baseline tests and post-training assessments, were performed in-season. Players had previous experience with these tests as the same battery was utilized in pre-season therefore, further familiarization was not needed. During this study, every player performed a minimum of four soccer training sessions and a match per week. Authors utilized a CON that maintained the team training routine previously utilized. The training program and tests were selected and performed in agreement with the coaches of the team in order to optimize and positively impact the probability of the clubs' success during the season.

Please Table 1 here. An in-season weekly program

Subjects

Twenty-three professional female soccer players were considered during the enrollment process. Only outfield players (three goalkeepers were excluded) and first team players were included (U19 players were excluded), therefore, sixteen players were finally included in the current study (mean ± SD; age 23 ± 4 (range 18-29) years, body mass 60.3 ± 4.9 kg, height 1.67 ± 3.7 m). All subjects were informed about the potential risks and benefits of the study and signed a written informed consent. The Ethics Committee of the University of Suffolk (UK) approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies.

Experimental procedure

Researchers requested the players maintain their normal nutritional routine during the intervention period. No alcohol or caffeine was allowed 24 hrs before the testing sessions. Tests and training sessions were performed between 10.00 and 12.00 to avoid any circadian effect. The players performed each test three times. The best score in each test was considered for the data final analysis.

Squat jump (SJ) and counter movement jump (CMJ) were assessed in a random order. Three jumps were performed for each test. Jump height was measured using an infrared device (OptoJump, Microgate, Bolzano, Italy). The players were instructed to stand, lower themselves to a self-selected knee flexion and immediately jump and were encouraged to maximally perform each jump. The players were instructed to avoid any knee flexion before the landing and to keep their hands on their hips to prevent the influence of arm movements on vertical jump performance, under the supervision of an experienced strength and conditioning coach (9).

Players' power abilities of the leg muscles were assessed by a standing long jump test (LJ). LJ was used to evaluate improvement of horizontal non-rebounding ability (4). Distance was evaluated using a meter tape. Players performed a maximal bilateral anterior jump with arm swing (three trials). Jump distance was measured from the starting line to the point at which the heel contacted the ground on landing.

A single-leg triple jump distance test (triple jump test) was performed with both the legs to evaluate the performance in rebounding jump ability. Jump were recorded using dominant (D) and non-dominant limb (ND). D limb was determined based on player's favorite technical foot. Players performed 3 consecutive maximal jumps forward with the same limb (10).

The 505-COD test was utilized to evaluate improvements in COD. Its reliability was previously reported (37). On the "Go" command, the subjects were instructed to sprint for 15 m (through the timing gates at 10 m), turn on their preferred foot, and sprint back through the timing gates.

Sprints of 10 and 30 m were performed to evaluate improvements in linear sprint ability (4). Infrared timing gates (Microgate, Bolzano, Italy) were placed at the start and end of each of the mentioned distances.

Training

Training was designed *a priori* considering the period of the season and team aims. A single session per week was considered adequate for the period of the season (in-season), while two sessions a week were considered too demanding. PLY group performed the training reported in table 2. CON performed a recovery session composed of balance exercises and dynamic stretching. CON did not perform any PLY exercise during the experimental period but both groups performed the same drills during the weekly routine.

***Please table 2 here. Plyometric training ***

Statistical analysis

Data were presented as mean ± standard deviation (SD). Before the beginning of the study, researchers performed a test-retest reliability assessment of each test between familiarization session and testing session and it was reported as interclass coefficient correlation (ICC). ICC (two-way mixed model) was calculated as test-retest (1 week distance) and interpreted as follows: > 0.9 = *excellent*; > 0.8 = *good*; > 0.7 = *acceptable*; > 0.6 = *questionable*; > 0.5 = *poor*; < 0.5 = *unacceptable* (2). Intention to treat analysis was adopted (every player was considered for the final analysis) (7). Shapiro-Wilk test was used for checking the normality (assumption). Robust estimates of 95% confidence interval (CI) and heteroscedasticity were calculated using bootstrapping technique (randomly 1000 bootstrap samples). Analysis of variance (ANOVA) and covariance (ANCOVA), using baseline values as covariate, was employed to detect possible within- and between-groups differences, respectively (21). Statistical significance was set at $p < 0.05$. Threshold values for meaningful benefit effects were evaluated based on the smallest worthwhile change (SWC) (0.2 multiplied by the between-subjects SD). Effect size (ES) based on the Cohen d principle was interpreted as *trivial* < 0.2, *small* 0.2-0.6, *moderate* 0.6-1.2, *large* 1.2-2.0, *very large* > 2.0 (21). Statistical analyses were performed by JASP software version 0.10.2 (Amsterdam, Netherland) for MAC.

RESULTS

CMJ and SJ had an ICC of 0.94 and 0.92, *excellent*, respectively. SWC was 0.8 cm and 0.7 cm for CMJ and SJ, respectively.

LJ reported an ICC of 0.95, *excellent*. SWC was 2.5 cm.

D triple hop test and ND triple hop test had an ICC of 0.90 and 0.92, *excellent*, respectively. SWC was 9.3 cm and 11.7 cm for D and ND, respectively.

505-COD test reported an ICC of 0.88, *good*. SWC was 0.02 s.

Sprint 10 m and 30 m reported an ICC of 0.87 and 0.93, *good* and *excellent*, respectively. SWC was for 0.02 and 0.04 s sprint 10 m and 30 m, respectively.

An attendance of 95% and 90% for PLY and CON, respectively, was reported at the end of this study.

Within-group variations after 12 weeks of training for both PLY and CON are reported in Table 3.

Table 3 here, please

After 12 weeks of training, between-group analysis following ANCOVA did not report any statistical difference in SJ (p = 0.703, ES = 0.12, *trivial*), CMJ (p = 0.309, ES = 0.38, *small*), LJ (p = 0.535, ES = -0.25, *small*), triple jump dominant (p = 0.226, ES = 0.43, *small*), triple jump non-dominant (p = 0.303, ES = 0.20, *small*), 505-COD (p = 0.913, ES = 0.06, *trivial*), Sprint 10 m (p = 0.767, ES = -0.17, *trivial*), and Sprint 30 m (p = 0.505, ES = -0.30, *small*).

DISCUSSION

The aims of this study were to evaluate the effect of 12 weeks (a single session per week) of PLY training on jumps, COD, and sprint performance, in a sample of professional female soccer players during the official season. After 12 weeks of PLY, some significant within-group differences were found in the triple jump test (D and ND, 27.1 cm and 18.9 cm, respectively) and 10 m sprint (-0.18 s). Such improvements were meaningful because greater than the smallest worthwhile change of these tests such as 9.3 cm and 11.7 cm for D and ND, respectively and 0.02 s for 10 m sprint test. While, the CON demonstrated no significant variations. PLY group has not reported any significant variation in SJ, CMJ, LJ, and 505-COD after the training period, however, *small* differences in Sprint 30 m (p=0.064) were found and should be considered as *likely* beneficial (due to the small sample involved). This finding underlined the difficulties in obtaining meaningful variation in season with professional players. These findings have a strong practical application since this study showed for the first time that a single session a week of PLY training can significantly increase sport specific fitness parameters in professional female soccer players during the season (4,25).

Plyometric training is a commonly used type of physical conditioning involving jumping exercises wherein the SSC muscle action represents the potentiating underlying neurophysiological mechanism (1). Research suggests that PLY training can be effective for improving neuromuscular impulse-dependent components, which are likely important for sport (36,40). Specifically, it is possible to achieve positive transfer to sport specific tasks such as sprinting, jumping, accelerating and COD, which make it particularly attractive to coaches (36,39). Recently, it was shown that there were positive effects from both low- and high-volume PLY in youth male soccer players (ES from 0.28 to 1.0) (10), which suggests the findings of the present study may be relevant also for male players and not only for a female population. Moreover, Loturco et al. (24) found that PLY can improve acceleration of soccer players, which is also in line with our results. The data in our present study further supports the existing evidence for the use of plyometrics in eliciting positive effects relevant to soccer players.

The findings of this study are especially interesting as they specifically relate to professional female soccer players during the official season. The effective prescription is especially important because professional players have a very limited time to dedicate to specific physical development as a consequence of factors such as congested match schedules and the need for tactical and technical skills training (5,38). Relatively, a large volume of data exists regarding strength and conditioning for elite male soccer players, though without specific data comparisons with females becomes only inference. For this reason, it is interesting and useful to find improvements in both triple jumps (D and ND) and 10 m sprint following only one PLY session per week (Table 3). The training volume reported in Table 1 demonstrates relatively little time dedicated to non-soccer specific training, which is in line with previously published work in male soccer academies (4,29). This suggests positive effects seen here could be increased further if exposure time were greater or that benefits from PLY may be reduced if overall training stimuli were greater. Conversely, this could suggest that where training time is limited that the addition of only one 20-25 min PLY session per week could lead to improved acceleration, which has previously been shown to be directly influential in goal-scoring opportunities (19).

Despite the within-group differences highlighted above, authors were unable to find any between-group difference following the training intervention. This finding underlines the importance to perform further research on the effect of a low volume of PLY training in soccer. This finding is in line with Bianchi et al., (10) who postulated this was due to the low volume of the PLY session (~90 jumps). In this study the first half of the intervention was 108 jumps and the second half was 140 jumps. Despite the increased volume from the previous work mentioned authors suggest that, with player training age in mind, the number of ground contacts may be sensibly increased further (4,26). This of course must be done appropriately and with considerations for match schedules and other training programming. With this in mind, previous literature specific to female soccer players and plyometrics has shown that a single session a week of 60 min led to increased triple jump, CMJ, standing LJ, peak power and 20 m sprint all improved compared to a CON. This suggests that even a modest increase in PLY session volume could improve training adaptation further. During this study jumps were increased from 90 to 220 over 8 weeks also suggesting greater volume may be advantageous. Another study by Rubley et al., (33) in youth female soccer players found that PLY training (of around 100 jumps per week for 14 weeks) improved kicking distance and vertical jump performance. This may also suggest that if training volume cannot be increased (more than once a week) then length of intervention may have to be greater. This is supported by the literature on PLY training (and from the current study) that at least 8 weeks of intervention are needed to observe some significant variations (26).

As with all studies, this was not without limitations. A drawback of this study may be that there was a relatively low sample size. Although significant differences were seen in some variables a greater sample size may have offered a better understanding about the effect of this type of training specifically. This limitation exists also if the authors of this study adopted a robust design such as a randomized controlled trial, follow CONSORT guidelines, using an intention to treat analysis to account for drop outs. Another limitation may be that authors only considered players from one club. This means it is only one type of playing and training style influencing training and intervention adaptations. However, this was a necessary characteristic of this study design since training intervention is specific for each club (ecological intervention), therefore it was not possible to add any additional player from other teams to the current sample. Future studies may look to combine multiple teams (multicenter research trial) to consider reproducibility of results.

In conclusion, this study supports previous findings in male soccer players that a single PLY training dose per week can elicit training adaptations deemed desirable in a professional female soccer players. The positive effects reported in jumping and sprinting tests may be useful to underline the importance to work on marginal gains in professional populations. Further studies may look to consider whether these effects would remain in those partaking in greater training volume.

PRACTICAL APPLICATIONS

Based upon the data collected in this study it is clear that there are benefits to be achieved from elite female soccer players implementing PLY training into their programs. Specifically, this study has shown that only one session a week for 20-25 min, involving a PLY volume of 108 to 140 jumps, can yield such benefits. Therefore, strength and conditioning practitioners can utilize these data when considering long-term athlete development models and also when looking to optimize training adaptation. Moreover, a single session of PLY training per week, with the volume progression proposed, seem sufficient to maintain professional soccer players' fitness level in season, which is still a very important aim for practitioners.

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