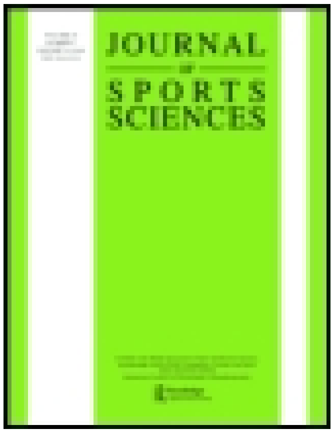

Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players

Rodrigo Ramírez-Campillo[a], Marcelo Vergara-Pedreros[a], Carlos Henríquez-Olguín[b], Cristian Martínez-Salazar[c], Cristian Alvarez[d], Fábio Yuzo Nakamura[e], Carlos I. De La Fuente[f], Alexis Caniuqueo[g], Alicia M. Alonso-Martinez[h] & Mikel Izquierdo[hi]
[a] Department of Physical Activity Sciences, Universidad de Los Lagos, Osorno, Chile
[b] Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile
[c] Department of Physical Education, Sport and Recreation, Universidad de La Frontera, Temuco, Chile
[d] Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile
[e] Departament of Physical Education, Universidade Estadual de Londrina, Londrina, Brazil
[f] Foot and Ankle Unit, Instituto Traumatologico “Teodoro Gebauer Weisser”, Santiago, Chile
[g] Laboratory of Physiology and Biomechanics, Universidad Autónoma de Chile, Temuco, Chile
[h] Department of Health Sciences, Public University of Navarre, Navarra, Spain
[i] Facultad de Cultura Física, Deporte y Recreación, Universidad Santo Tomás, Bogotá D.C., Colombia
Published online: 22 Jul 2015.

JOURNAL OF SPORTS SCIENCES, 2015
http://dx.doi.org/10.1080/02640414.2015.1068439

Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players

Rodrigo Ramírez-Campillo[1], Marcelo Vergara-Pedreros[1], Carlos Henríquez-Olguín[2], Cristian Martínez-Salazar[3], Cristian Alvarez[4], Fábio Yuzo Nakamura[5], Carlos I. De La Fuente[6], Alexis Caniuqueo[7], Alicia M. Alonso-Martinez[8] and Mikel Izquierdo[8,9]

[1]Department of Physical Activity Sciences, Universidad de Los Lagos, Osorno, Chile; [2]Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile; [3]Department of Physical Education, Sport and Recreation, Universidad de La Frontera, Temuco, Chile; [4]Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile; [5]Departament of Physical Education, Universidade Estadual de Londrina, Londrina, Brazil; [6]Foot and Ankle Unit, Instituto Traumatologico "Teodoro Gebauer Weisser", Santiago, Chile; [7]Laboratory of Physiology and Biomechanics, Universidad Autónoma de Chile, Temuco, Chile; [8]Department of Health Sciences, Public University of Navarre, Navarra, Spain; [9]Facultad de Cultura Física, Deporte y Recreación, Universidad Santo Tomás, Bogotá D.C., Colombia

ABSTRACT

In a randomised controlled trial design, effects of 6 weeks of plyometric training on maximal-intensity exercise and endurance performance were compared in male and female soccer players. Young (age 21.1 ± 2.7 years) players with similar training load and competitive background were assigned to training (women, n = 19; men, n = 21) and control (women, n = 19; men, n = 21) groups. Players were evaluated for lower- and upper-body maximal-intensity exercise, 30 m sprint, change of direction speed and endurance performance before and after 6 weeks of training. After intervention, the control groups did not change, whereas both training groups improved jumps (effect size (ES) = 0.35–1.76), throwing (ES = 0.62–0.78), sprint (ES = 0.86–1.44), change of direction speed (ES = 0.46–0.85) and endurance performance (ES = 0.42–0.62). There were no differences in performance improvements between the plyometric training groups. Both plyometric groups improved more in all performance tests than the controls. The results suggest that adaptations to plyometric training do not differ between men and women.

ARTICLE HISTORY
Accepted 26 June 2015

KEYWORDS
Muscle strength; muscle action; sports; women; strength training

1. Introduction

Numerous maximum- and high-intensity muscle actions are required during soccer, including jumping, passing, kicking, tackling, turning, sprinting and quick changing pace (Stølen, Chamari, Castagna, & Wisløff, 2005). In addition, endurance is also important to sustain repeated changes of direction, as players must complete up to 1400 short-burst activities, changing every 4–6 s throughout the 90 min of match play (Stølen et al., 2005). Plyometric training has a favourable effect on maximal-intensity exercise and endurance performance in soccer players (Datson et al., 2014; Siegler, Gaskill, & Ruby, 2003), even during the most competitive periods of the year (i.e., in-season) (Brito, Vasconcellos, Oliveira, Krustrup, & Rebelo, 2014). However, to our knowledge, there is no data regarding the independent effect of sex during plyometric training on performance adaptations in soccer players (Markovic, 2007).

Because strength before a plyometric training intervention is an important variable (Barr & Nolte, 2014), and because men tend to be stronger than women, they might be better suited to plyometric training. This was demonstrated by de Villarreal, Kellis, Kraemer, and Izquierdo (2009), whereby men had greater gains than women (ES = 0.8 and 0.5, respectively) in vertical jump performance after plyometric training. Conversely, similar sprint (ES = 0.36–0.37) (de Villarreal, Requena, & Cronin, 2012) and endurance (~4%) (Ramírez-Campillo, Álvarez, et al., 2014) performance adaptations have been reported in men and women after plyometric training. Moreover, similar plyometric training-induced adaptations have occurred in men and women, independent of initial performance before training (Ramírez-Campillo, Álvarez, et al., 2014) or basal differences in important performance-related hormonal markers (Guadalupe-Grau et al., 2009). However, because none of these studies have analysed the independent effect of the sex of participants on adaptations induced by plyometric training in soccer players and because the adaptations might differ according to the type of sport practised (de Villarreal et al., 2012), or standard (i.e., non-trained compared with trained participants) (de Villarreal et al., 2009), extrapolation of results to soccer players is unwise.

Given the limitations and conflictive results previously cited, there is a need to study the independent effect of sex on plyometric training-induced performance adaptations in soccer players. Thus, our objective was to compare adaptations to plyometric training in male and female soccer players matched according to soccer training load and competitive experience.

CONTACT Mikel Izquierdo mikel.izquierdo@gmail.com Department of Health Sciences, Public University of Navarra, Campus of Tudela, Av. de Tarazona s/n. 31500, Tudela, Navarra, Spain.
Present affiliation for Carlos I. De La Fuente is Carrera de Kinesiología, UDA Ciencias de la Salud, Facultad de Medicina, Pontificia Universidad Católica, Santiago, Chile

2. Methods

2.1. Participants

With institutional ethics approval, 91 participants were recruited from amateur male and female soccer teams competing at the national level (i.e., college). In the last college national championship, players were positioned between the fourth and second places. At recruitment, players completed four training sessions plus a competitive match per week and had won 70% of their matches in the current season. Players had similar competitive schedules and similar involvement in soccer drills, resulting in comparable soccer-specific weekly training loads for all groups in the study design (Table I). In a randomised controlled design, participants were allocated to one of the four groups separated by sex: two training and two control groups. The training groups underwent a plyometric training programme, whereas the control groups did their regular soccer training (control condition). Before and after a 6 week period, all players performed a battery of seven tests related to maximal-intensity exercise and endurance performance. The randomisation sequence was generated electronically and concealed until interventions were assigned. Soccer players fulfilled the following inclusion criteria: (1) a background of more than 2 years of systematic soccer training and competitive experience; (2) continuous soccer training for the previous 6 months with absence of musculoskeletal injury, (3) no plyometric training experience in the previous 6 months, (4) no participation in other competitive sport activity aside from soccer during the intervention period. Initially, 91 participants who fulfilled the inclusion criteria were chosen to participate in the study. To be included in the final analyses, participants were required to complete all the training sessions and attend all assessment sessions. As a result of these requirements, 11 participants were excluded from the study. Therefore, 80 soccer players (38 women) were included in the final analyses. For the final analysis, the four study groups were as follows: male plyometric training group (MPT, n = 21), female plyometric training group (FPT, n = 19), male control group (MCG, n = 21), and female control group (FCG, n = 19). Details of the characteristics for each group are given in Table I. Similar number of goalkeepers (2; 2; 3; 2), defenders (6; 6; 7; 5), midfielders (7; 6; 5; 6) and forwards (6; 5; 6; 6) were present in the MPT, FPT, MCG and FCG, respectively.

Table I. Descriptive data of the female control group (FCG; n = 19), female plyometric training group (FPT; n = 19), male control group (MCG; n = 21) and male plyometric training group (MPT; n = 21).

	FCG	FPT	MCG	MPT
Age (y)	20.5 ± 2.5	22.4 ± 2.4	20.8 ± 2.7	20.4 ± 2.8
Stature (cm)	159 ± 6[b]	161 ± 5[b]	174 ± 6	171 ± 8
Body mass (kg)	60.2 ± 9.3[b]	60.7 ± 9.3[b]	71.5 ± 6.9	68.4 ± 8.5
Body mass index (kg.m^{-2})	23.7 ± 3.2	23.5 ± 3.3	23.5 ± 1.5	23.4 ± 2.0
Soccer experience (y)	10.6 ± 3.0	12.3 ± 3.0	12.0 ± 2.5	11.5 ± 3.1
Soccer training load[a]	404 ± 241	417 ± 318	440 ± 183	371 ± 178

Notes: [a]Soccer training load was determined by multiplying the minutes of soccer training by the rating of perceived exertion after each soccer training session. [b]Denotes significant difference compared to MCG and MPT, $P < 0.05$.

Sample size was determined according to changes in plyometric (i.e., reactive strength index) performance in a group of trained men and women submitted to a control (Δ = −0.01 cm.ms^{-1}; SD = 0.047) or to a short-term plyometric training (Δ = 0.026 cm.ms^{-1}; SD = 0.035) (Ramírez-Campillo, Álvarez, et al., 2014) comparable with that applied in this study. A total of 11 participants per group would yield a power of 80% and α = 0.05, with a detectable ES of 0.2.

2.2. Experimental protocol

Participants were accustomed to procedures (four learning sessions during two weeks) to reduce learning effects. In addition, some of the performance tests were regularly used on the basis of monitoring training seasons. Before, and immediately after the intervention period, standardised tests were scheduled >72 h after a match or hard physical training session and were completed in the same order, at the same time of day (between 15:00 and 19:00 h) and indoor venue, with the same sports clothes and by the same investigator, who was blinded to the training group of the participants. All players were instructed to (1) have a good night's sleep (≥8 h) before each testing day and (2) have a meal rich in carbohydrates and be well hydrated before assessment. The participants were motivated via strong verbal encouragement (e.g., "come on", "you can do it") to give their maximum effort during testing, in addition to performance feedback. Players were evaluated in 2 days. On day 1, age, stature, body mass, soccer experience, soccer-specific weekly training demand, countermovement jump, countermovement jump with arms, 40 cm drop jump reactive strength index and 3 kg medicine ball throwing test were completed. On day 2, the 30 m sprint, change of direction speed and the 20 m multi-stage shuttle run endurance test were carried out. The best score from three attempts was recorded for all performance tests, apart from the single shuttle run endurance test. A rest interval of at least 2 min was allowed between each physical performance trial to reduce effects of fatigue. While waiting, participants performed low-intensity activity to maintain readiness for the next test. Ten minutes of general warm-up (i.e., submaximal running with change of direction, 20 vertical and 10 horizontal submaximal jumps) were used before each testing session. In addition, participants performed a specific warm-up that comprised two practice jumps or runs, except for the shuttle run endurance test, where players completed the first minute of the test for warm-up.

Anthropometry comprised stature on a stadiometer (Bodymeter 206, SECA, Germany to 0.1 cm) and body mass on an electrical scale (BF 100_Body Complete, Beurer, Germany to 0.1 kg). Protocols used for the jump, 30 m sprint, change of direction speed and shuttle run endurance tests were according to Ramírez-Campillo, Andrade, and Izquierdo (2013), Ramírez-Campillo, Meylan, et al. (2015) and Ramírez-Campillo, Gallardo, et al. (2015). Briefly, for the vertical jumps, players executed maximal effort jumps on a mobile contact mat (Ergojump; Globus, Codogne, Italy) with arms akimbo, except during countermovement jump with arms, where arm swings were used. Take-off and landing were standardised to full knee and ankle extension on the same spot. The participants were instructed to maximise jump height. In addition, for the 40 cm drop jump reactive strength index, players were instructed to minimise ground contact time after dropping down from a 40 cm drop box. Reactive strength index was calculated from jump height (cm) divided by contact time (ms). Jump height was determined using an acknowledged flight-time equation (Ramírez-Campillo et al., 2013).

The sprint time was assessed to the nearest 0.01 s using single-beam infrared photoelectric cells (Globus Italia, Codogne, Italy). Participants had a standing start with the toe of the preferred foot forward and just behind the starting line. Sprint start was given by a random-delay sound (1–3 s) which triggered timing. The photoelectric signal was positioned at 30 m and set ~0.7 m above the floor (i.e., hip level) to capture trunk movement rather than a false trigger from a limb. For the change of direction speed test (i.e., *Illinois agility test*), the timing system and procedures were same as for the 30 m sprint, except that players started supine and completed a circuit with several changes of directions.

For the shuttle run endurance test, players ran back and forth between two lines, spaced 20 m apart, in time with the "beep" sounds from an electronic audio recording. Each successful run of the 20 m distance was a completion of a shuttle. The beep sounded at a progressively increasing pace with every minute of the test, and the player had to increase speed accordingly. The player was warned if he/she did not reach the end line in time once. The test was terminated when the examinee: (1) could not follow the set pace of the beeps for two successive shuttles or (2) stopped voluntarily. The scores were expressed as the last minute that the player completed.

The medicine ball throw test was conducted according to Palao and Valadés (2013). Briefly, the player threw a 3 kg medicine ball with both arms as far as possible, with an extension movement of the shoulders, elbows and wrists from behind their neck, using a concentric muscle action. The player's back is always in contact with a bench, where he/she remains in a supine position during throwing. The distance was assessed from the player's shoulders.

Total training load was assessed to ensure that all players received the same soccer training stimulus during the intervention. Session rating of perceived exertion was determined (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Briefly, each player's session rating of perceived exertion was collected about 30 min after each soccer training session and match to ensure that the perceived effort reflected the entire session rather than the most recent exercise intensity. In this study, the Chilean translation of the 10 point category ratio scale modified by Foster et al. (2001) was used. This scale was modified to reflect the Chilean idiomatic English. Total training load was calculated as rating of perceived exertion × training session duration (i.e., minutes).

2.3. Training programme

The plyometric training was completed during the mid-portion of player's competition period. The control groups did not perform the plyometric training, but performed their usual soccer training (i.e., mainly technical-tactical, small-sided and simulated games). The design of the plyometric intervention was based on the players' previous training records (Ramírez-Campillo, Meylan, et al., 2015). Plyometric training was not added to the regular training of soccer players, instead a replacement of some low-intensity technical-tactical soccer drills by plyometric drills was performed within their usual 120 min training, twice per week, during the 6 week intervention period.

Each plyometric session included 12 jump exercises (i.e., cyclic and acyclic horizontal and vertical jumps, with left, right and both legs) performed with involvement of stretch-shortening cycle muscle activity, similar to a countermovement jump with arms. For the acyclic drills, participants were instructed during each jump to achieve maximal vertical height or horizontal distance (according to the type of exercise), while during cyclic jumps, participants were motivated to maximise the ratio between vertical height or horizontal distance and ground contact time. The reliability of jump heights was verified in a randomly assigned subsample of participants (two from each group) during two randomly assigned training sessions, by assessment of contact times, height and distance of jumps, using same procedures as described above. Before beginning the training period, players were instructed on how to perform all the exercises. The order of tasks was randomised in each session to add variation during training. In the first week of training, players completed two sets of five repetitions for each exercise, for a total of 80 jumps per leg during each session. In the plyometric training weeks, one repetition per set was added. In this way, players completed 160 jumps per leg during each session in the last week of plyometric training. In addition to the lower-body plyometric training, in each session, participants completed three sets of eight repetitions of medicine ball throw as described above. All training sessions were supervised by an investigator at a participant ratio of 1:4 and particular attention was paid to technique. All plyometric sessions lasted approximately 40 min and were performed just after the warm-up. The FPT and MPT completed the same number of total repetitions during intervention, using the same surface (i.e., grass soccer-field) and time of day (afternoon) for plyometric training, with the same rest intervals between sessions (i.e., 72 h), sets (i.e., 60 s) and jumps or throws [i.e., 15 s for acyclic jumps – as previously recommended (Read & Cisar, 2001)].

2.4. Data analysis

Statistical analyses were via STATISTICA statistical package (Version 8.0; StatSoft, Inc, Tulsa). All values are reported as mean ± standard deviation. Relative changes (%) in performance and Cohen's d ES are expressed with 90% confidence limits. Normality and homoscedasticity assumptions for all data before and after intervention were checked with the Shapiro–Wilk and Levene tests, respectively. To determine effects of the intervention on performance adaptations, groups were compared via a mixed-design factorial ANOVA. When a significant *F*-value occurred for interaction between groups or for main effects of group or time, Scheffé post hoc procedures were performed. In addition, a between-groups one-way analysis of variance compared changes between groups, i.e., the difference between scores before and after the intervention. The α level was set at $P < 0.05$ for statistical significance. In addition to this null hypothesis testing, data were also assessed for practical meaningfulness using a magnitude-based inference approach. Threshold values for assessing magnitudes of ES were 0.20, 0.60, 1.2 and 2.0 for small, moderate, large and very large, respectively (Hopkins, Marshall, Batterham, & Hanin, 2009). Magnitudes of differences in training effects between groups were evaluated non-clinically (Hopkins et al., 2009): if the confidence interval overlapped thresholds for substantial positive and negative values, the effect was deemed unclear (i.e., trivial). The effect was otherwise clear and reported as the magnitude of the observed value with a qualitative probability, as above (i.e., small, moderate, large and very large). The reliability of assessments was determined using the technical error of measurement (Pederson & Gore, 1996), and ranged from 0.9% to 6.5%.

3. Results

3.1. Baseline

Men were taller and heavier than women (Table I) and performed better in all physical tests (Table II), although there were no differences between groups of the same sex.

3.2. Plyometric training effects

The factorial ANOVA (four groups × two times) identified an interaction between groups, where replacement of low-intensity technical-tactical soccer drills by plyometric drills produced greater ($F_{3,76} > 7.20$, $P < 0.001$) performance improvements in all (except shuttle run endurance test) performance tests in the plyometric training groups than control groups with small-to-large ES of 0.35–1.59 in the former versus trivial-to-small ES of up to 0.31 in the latter (Table II). In addition, the plyometric training groups had small-to-large greater meaningful training effects on performance variables (Table III).

Table II. Training effects (with 90% confidence limits) for the performance variables of the female control group (FCG; n = 19), female plyometric training group (FPT; n = 19), male control group (MCG; n = 21) and male plyometric training group (MPT; n = 21).

	Baseline	After training		
	Mean ± SD	Mean ± SD	Performance change (%)	ES
Countermovement jump (cm)				
FCG	26.6 ± 4.8	26.6 ± 4.3	0.5 (−1.2, 2.3)	0.03 (−0.07, 0.13)
FPT	26.7 ± 5.5	29.4 ± 5.8	10.7 (8.9, 12.5)[e, f]	0.48 (0.41, 0.56)[a]
MCG	33.2 ± 3.9[d]	32.8 ± 3.8	−1.2 (−2.6, 0.3)	−0.09 (−0.2, 0.02)
MPT	35.3 ± 3.3[d]	37.6 ± 4.0	6.4 (4.9, 8.0)[e, f]	0.57 (0.44, 0.7)[a]
Countermovement jump with arms (cm)				
FCG	29.2 ± 5.5	28.9 ± 5.1	−1.1 (−4.7, 2.7)	−0.06 (−0.25, 0.14)
FPT	30.3 ± 6.5	32.6 ± 6.5	8.3 (6.6, 10.1)[e, f]	0.35 (0.28, 0.42)[a]
MCG	37.5 ± 4.4[d]	37.6 ± 4.0	0.3 (−0.9, 1.4)	0.02 (−0.08, 0.12)
MPT	41.0 ± 3.8[d]	44.3 ± 3.9	7.9 (6.3, 9.5)[e, f]	0.76 (0.61, 0.91)[b]
40 cm drop jump reactive strength index (cm.ms^{-1})				
FCG	0.101 ± 0.03	0.107 ± 0.03	8.0 (4.2, 11.9)	0.27 (0.14, 0.39)
FPT	0.119 ± 0.04	0.144 ± 0.04	21.5 (17.0, 26.2)[e, f]	0.61 (0.49, 0.73)[b]
MCG	0.162 ± 0.03[d]	0.170 ± 0.03	4.2 (1.1, 7.4)	0.2 (0.05, 0.37)
MPT	0.162 ± 0.02[d]	0.204 ± 0.03	26.3 (22.9, 29.8)[e, f]	1.59 (1.4, 1.77)[c]
3 kg medicine ball throwing (m)				
FCG	4.62 ± 0.47	4.59 ± 0.39	−0.6 (−2.3, 1.2)	−0.06 (−0.23, 0.12)
FPT	4.55 ± 0.35	4.86 ± 0.38	6.7 (4.1, 9.4)[e, f]	0.78 (0.48, 1.08)[b]
MCG	6.18 ± 0.52[d]	6.19 ± 0.53	0.0 (−0.7, 0.7)	0.0 (−0.08, 0.08)
MPT	6.16 ± 0.53[d]	6.46 ± 0.54	4.9 (3.9, 5.9)[e, f]	0.62 (0.49, 0.75)[b]
30 m sprint time (s)				
FCG	5.72 ± 0.28	5.82 ± 0.31	1.7 (0.5, 3.0)	0.31 (0.08, 0.53)[a]
FPT	5.69 ± 0.31	5.40 ± 0.32	−5.2 (−6.3, −4.1)[e, f]	−0.86 (−1.05, −0.68)[b]
MCG	5.05 ± 0.18[d]	5.05 ± 0.12	−0.1 (−0.6, 0.4)	−0.05 (−0.24, 0.14)
MPT	5.05 ± 0.17[d]	4.79 ± 0.18	−5.4 (−6.3, −4.4)[e, f]	−1.44 (−1.67, −1.15)[c]
Change of direction speed time test (s)				
FCG	19.79 ± 1.0	19.93 ± 0.9	0.7 (0.3, 1.2)	0.14 (0.05, 0.24)
FPT	19.48 ± 0.9	18.73 ± 1.0	−4.0 (−4.9, −3.1)[e, f]	−0.85 (−1.04, −0.66)[b]
MCG	17.55 ± 0.6[d]	17.65 ± 0.7	0.2 (−0.5, 0.8)	0.05 (−0.16, 0.26)
MPT	17.72 ± 0.7[d]	17.32 ± 0.7	−2.1 (−3.0, −1.2)[e, f]	−0.46 (−0.66, −0.26)[a]
20 m multi-stage shuttle run test (min)				
FCG	8.6 ± 1.6	8.6 ± 1.1	0.8 (−3.2, 4.9)	0.05 (−0.21, 0.31)
FPT	8.4 ± 1.9	9.1 ± 1.2	9.7 (4.4, 15.2)[e]	0.42 (0.19, 0.64)[a]
MCG	11.8 ± 1.1[d]	11.7 ± 1.5	−1.9 (−5.1, 1.5)	−0.15 (−0.41, 0.12)
MPT	11.4 ± 1.4[d]	12.2 ± 1.2	6.8 (5.0, 8.5)[e]	0.62 (0.46, 0.77)[b]

Notes: [a, b, c]Denote small, moderate and large ESs, respectively; [d]denotes significant difference compared to FCG and FPT ($P < 0.05$); [e]denotes significant difference from pre- to post training ($P < 0.05$); [f]denotes significant difference compared to FCG and MCG ($P < 0.05$).

Table III. Differences between the female control group (FCG; n = 19), female plyometric training group (FPT; n = 19), male control group (MCG; n = 21) and male plyometric training group (MPT; n = 21) in the training effects[a] (with 90% confidence limits) on performance variables.

	MCG – FCG[c]	FPT – FCG	MPT – FCG	FPT – MCG	MPT – MCG	MPT – FPT
Countermovement jump	−2.0 (−4.2, 0.2) Trivial	10.2 (7.6, 12.9) Small[b]	6.0 (3.6, 8.3) Small[b]	12.4 (10.0, 14.9) Small[b]	7.9 (5.8, 10.1) Small[b]	3.4 (1.5, 5.4) Trivial
Countermovement jump with arms	1.6 (−2.0, 5.0) Trivial	9.2 (5.1, 13.6) Small[b]	8.6 (4.6, 12.9) Small[b]	8.0 (5.8, 10.1) Small[b]	7.3 (5.3, 9.3) Small[b]	−0.5 (−2.7, 1.7) Trivial
40 cm drop jump reactive strength index	−2.3 (−6.7, 2.3) Trivial	14.6 (8.9, 20.5) Small[b]	18.2 (13.2, 23.5) Small[b]	17.4 (12.3, 22.8) Small[b]	21.5 (17.2, 25.9) Moderate[b]	−4.1 (−7.8, −0.3) Trivial
3 kg medicine ball throwing	0.6 (−1.2, 2.4) Trivial	8.6 (6.2, 11.0) Moderate[b]	5.7 (3.8, 7.6) Small[b]	8.0 (6.3, 9.8) Small[b]	4.8 (3.6, 6.0) Small[b]	2.7 (1.0, 4.4) Trivial
30 m sprint time	−1.6 (−2.9, 2.4) Small	−6.8 (−8.3, −5.3) Large[b]	−6.8 (−8.2, −5.3) Moderate[b]	−5.3 (−6.5, −4.0) Moderate[b]	−5.2 (−6.3, −4.1) Large[b]	−0.1 (−1.6, 1.5) Trivial
Change of direction speed time test	0.0 (−0.8, 0.8) Trivial	−4.9 (−5.7, −4.0) Moderate[b]	−2.9 (−3.9, −1.9) Small[b]	−4.7 (−5.6, −3.7) Moderate[b]	−2.4 (−3.4, −1.3) Moderate[b]	−1.9 (−3.1, −0.8) Trivial
20 m multi-stage shuttle run test	−0.7 (−5.2, 4.0) Trivial	11.8 (5.3, 18.7) Small[b]	5.4 (1.0, 10.0) Small[b]	14.1 (8.1, 20.5) Small[b]	7.0 (3.6, 10.6) Small[b]	3.1 (−2.1, 8.6) Trivial

Notes: [a] Effects are shown in percentage units with 90% confidence limits and probabilistic inferences about the true ES; [b] meaningfully higher training effect with plyometric training; [c] data of the group indicated at the right of each of the six comparative columns was used as the outset value.

3.3. Sex-linked effects

There were no interactions for sex, i.e., no differences between the plyometric training groups' performance improvements (adaptations) after 6 weeks of plyometric training intervention (Tables II and III).

4. Discussion

To our knowledge, this is the first study to systematically examine the maximal-intensity exercise and endurance-adaptive sex differences from plyometric training in male and female soccer players with similar competitive background and training load. We observed that both sexes achieved similar changes in performance during jumps, 3 kg medicine ball throwing, 30 m sprint time, change of direction speed and shuttle run endurance tests. Both control groups failed to demonstrate improved performance in any test, suggesting that regular soccer training in the studied teams was not effective in inducing further physiological adaptations in addition to those gained before intervention. Therefore, replacement of low-intensity technical-tactical soccer drills by plyometric drills might be a practical approach in both male and female players to improve maximal-intensity exercise and endurance performance during the competition period.

In modern soccer, the need to improve players' maximal-intensity performance along with endurance performance is evident in both sexes (Datson et al., 2014; Stølen et al., 2005). Since both male and female players demonstrated similar performance improvements in maximal-intensity exercise, speed, change of direction speed and endurance in response to plyometric training, this time-saving method can be adopted in soccer teams of both sexes. Although the reasons for the similar plyometric training-induced adaptations between sexes are not clear, the differences between men and women in initial levels of performance before training intervention (Ramírez-Campillo, Álvarez, et al., 2014) or important performance-related hormonal markers (Guadalupe-Grau et al., 2009) might not be the underlying mechanisms. In fact, basal performance differences between men and women were observed (Table II); however, both sexes showed a similar training-induced adaptive response. Moreover, this fitness-independent effect was valid both for maximal-intensity exercise (de Villarreal et al., 2012) and endurance (Ramírez-Campillo, Álvarez, et al., 2014) performance variables. However, sex differences may exist regarding the potential injury-reducing effects of plyometric training, with a clearer effect in women than in men (Ter Stege, Dallinga, Benjaminse, & Lemmink, 2014).

For jump performance, both plyometric training groups had similar improvements, which were greater than those of the control groups (Tables II and III). In the present study, the magnitude or relative improvement was similar to that previously reported for analogous slow stretch-shortening cycle (i.e., countermovement and countermovement with arms jumps) (Faude, Roth, Di Giovine, Zahner, & Donath, 2013) and fast stretch-shortening cycle (i.e., 40 cm drop jump) muscle actions (Faude et al., 2013; Michailidis et al., 2013) after plyometric training with male and female soccer players using interventions of similar duration or number of sessions. These changes might have a positive effect on the percentage of games won (Faude et al., 2013) and could have been induced by neuromuscular adaptations (Markovic & Mikulic, 2010).

The plyometric training groups showed a similar increase in medicine ball throwing performance, which was greater compared to control groups (Tables II and III). Upper-body maximal-intensity exercise should not be overlooked in soccer players, as an important number of goals during competitive games occur after upper-body-dependant maximal-intensity exercise (Cerrah & Gurol, 2011). In addition, upper-body maximal-intensity exercise performance is positively related to lower-body maximal-intensity exercise (Lehman, Drinkwater, & Behm, 2013), suggesting that upper-body plyometric training might positively affect both, upper- and lower-body maximal-intensity performance.

Both plyometric training groups presented a similar decrease in 30 m sprint times and the change was greater compared to non-plyometric trained groups (Tables II and III). Although the differences in the type of training programme applied make comparisons between different studies difficult, others have also found an increase in sprint performance after plyometric training in male (Brito et al., 2014) and female (Ozbar, Ates, & Agopyan, 2014) soccer players; however, this was the first study to compare the effects of in-season short-term plyometric training on 30 m sprint times in both male and female soccer players. Because vertical strength and maximal-intensity exercise are related with sprint performance (Loturco et al., 2015), the maximal-intensity vertical jump drills completed during intervention might have positively affected sprint performance in the plyometric training groups. However, due to the importance of horizontal force production and application in sprint performance, the incorporation of horizontal drills during plyometric training probably played at least an equally important role in sprint performance improvement (de Villarreal et al., 2012; Ramírez-Campillo, Gallardo, et al., 2015). From a neuromuscular standpoint, the increase in sprint performance is related to mechanical impulse development by legs (Chelly & Denis, 2001), which can be increased with plyometric training in soccer players (Ozbar et al., 2015), in addition to changes in muscle activation patterns that occur in response to plyometric training in soccer players that achieve better sprint performance (Chimera, Swanik, Swanik, & Straub, 2004).

The present study demonstrated that both plyometric training groups had similar increases in change of direction speed performance. Change was greater than for the control groups (Tables II and III). Using the same change of direction speed test (Ramírez-Campillo, Meylan, et al., 2014), or a similar duration change of direction speed test (Ramírez-Campillo, Meylan, et al., 2015), after completion of an almost equal plyometric training intervention as in this study, we reported an improvement in change of direction speed performance in young soccer players. During plyometric training, soccer players performed exercises designed to induce short ground contact times and high reactive strength index, which predict change of direction speed performance (Young, James, & Montgomery, 2002). Also, an improved change of direction speed performance could be related to changes in impulse development or increased eccentric strength, which can enhance change of direction performance during the deceleration phase (Nedergaard, Kersting, & Lake, 2014; Sheppard & Young, 2006). In addition, plyometric training might enhance mental preparation before maximal-intensity exercise (Beck et al., 2007), which might allow better performance during a change of direction speed task (Young et al., 2002).

Our results demonstrated that both plyometric training groups achieved a similar improvement in shuttle run endurance performance (Table II), which was greater compared to their non-plyometric training counterparts (Table III). Although studies have shown a meaningful effect of plyometric training on endurance performance (Barnes & Kilding, 2015), a relatively novel finding to this study is the improvement of endurance performance in a test with repeated changes of direction such as the 20 m shuttle run endurance test, which might be more specific for soccer players (Ramírez-Campillo, Meylan, et al., 2015). This improvement might be related with a better running economy (Marta, Marinho, Barbosa, Izquierdo, & Marques, 2013), which in turn might be explained by decreased ground contact times, increased musculotendinous stiffness, elastic energy return (Barnes & Kilding, 2015; Spurrs, Murphy, & Watsford, 2003), neuromuscular activity or enhanced running mechanics (Barnes & Kilding, 2015). However, direct assessment of potential mechanisms that could improve endurance performance after plyometric training deserves further consideration.

We realise that by replacing low-intensity soccer drills with high-intensity plyometric jumps, differences in training loads might have arisen between control and intervention groups. However, when soccer training load was determined, similar soccer training loads were observed among control and plyometric training groups (Table I). Regarding male and female plyometric training groups, both completed the same training programme, for a total of 1440 jumps per leg during the 6 week intervention period. A possible limitation of the present study was the absence of more physiological assessments to better understand the underlying mechanisms of training-induced adaptations in both male and female soccer players.

5. Conclusions

For male and female soccer players, replacement of some low-intensity technical-tactical soccer drills during the in-season period with maximal-intensity exercise plyometric drills, in a short-term (i.e., 6 weeks) plyometric training intervention, induced higher maximal-intensity exercise and endurance performance improvements compared to soccer training alone, and the improvements induced by plyometric training were not affected by sex. In practical terms, sex should not be seen as a special concern while applying plyometric training in adult soccer players, at least when the target is improving specific physical performance. Therefore, male and female soccer players with similar competitive background and training load can be submitted to similar programmes (e.g., volume, intensity, frequency) of plyometric training.

Acknowledgements

The authors wish to thank all the volunteers who participated in this study.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Izquierdo Mikel http://orcid.org/0000-0002-1506-4272

References

Barnes, K. R., & Kilding, A. E. (2015). Strategies to improve running economy. *Sports Medicine*, *45*, 37–56.

Barr, M. J., & Nolte, V. W. (2014). The importance of maximal leg strength for female athletes when performing drop jumps. *Journal of Strength and Conditioning Research*, *28*, 373–380.

Beck, S., Taube, W., Gruber, M., Amtage, F., Gollhofer, A., & Schubert, M. (2007). Task-specific changes in motor evoked potentials of lower limb muscles after different training interventions. *Brain Research*, *1179*, 51–60.

Brito, J., Vasconcellos, F., Oliveira, J., Krustrup, P., & Rebelo, A. (2014). Short-term performance effects of three different low-volume strength-training programmes in college male soccer players. *Journal of Human Kinetics*, *40*, 121–128.

Cerrah, A. O., & Gurol, B. (2011). Analysis of goal scored in Turkish first division soccer leagues from 2001 to 2009. *Turkiye Klinikleri Journal of Sports Sciences*, *3*, 79–85.

Chelly, S. M., & Denis, C. (2001). Leg power and hopping stiffness: Relationship with sprint running performance. *Medicine and Sciences in Sports and Exercises*, *33*, 326–333.

Chimera, N. J., Swanik, K. A., Swanik, C. B., & Straub, S. J. (2004). Effects of plyometric training on muscle-activation strategies and performance in female athletes. *Journal of Athletic Training*, *39*, 24–31.

Datson, N., Hulton, A., Andersson, H., Lewis, T., Weston, M., Drust, B., & Gregson, W. (2014). Applied physiology of female soccer: An update. *Sports Medicine*, *44*, 1225–1240.

de Villarreal, E. S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining variables of plyometric training for improving vertical jump height performance: A meta-analysis. *Journal of Strength and Conditioning Research*, *23*, 495–506.

Faude, O., Roth, R., Di Giovine, D., Zahner, L., & Donath, L. (2013). Combined strength and power training in high-level amateur football during the competitive season: A randomised-controlled trial. *Journal of Sports Sciences*, *31*, 1460–1467.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., & Parker, S., … Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*, 109–115.

Guadalupe-Grau, A., Perez-Gomez, J., Olmedillas, H., Chavarren, J., Dorado, C., Santana, A., … Calbet, J. A. L. (2009). Strength training combined with plyometric jumps in adults: Sex differences in fat-bone axis adaptations. *Journal of Applied Physiology (1985)*, *106*, 1100–1111.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, *41*, 3–13.

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Medicine & Science in Sports & Exercise*, *36*, 1042–1047.

Lehman, G., Drinkwater, E. J., & Behm, D. G. (2013). Correlation of throwing velocity to the results of lower-body field tests in male college baseball players. *Journal of Strength and Conditioning Research*, *27*, 902–908.

Loturco, I., D'Angelo, R. A., Fernandes, V., Gil, S., Kobal, R., Cal Abad, C. C., … Nakamura, F. Y. (2015). Relationship between sprint ability and loaded/unloaded jump tests in elite sprinters. *Journal of Strength and Conditioning Research*, *29*, 758–764.

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine*, *41*, 349–355; discussion 355.

Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Medicine*, *40*, 859–895.

Marta, C., Marinho, D. A., Barbosa, T. M., Izquierdo, M., & Marques, M. C. (2013). Effects of concurrent training on explosive strength and VO2max in prepubescent children. *International Journal of Sports Medicine*, *34*, 888–896.

Michailidis, Y., Fatouros, I. G., Primpa, E., Michailidis, C., Avloniti, A., Chatzinikolaou, A., … Kambas, A. (2013). Plyometrics' trainability in preadolescent soccer athletes. *Journal of Strength and Conditioning Research*, *27*, 38–49.

Nedergaard, N. J., Kersting, U., & Lake, M. (2014). Using accelerometry to quantify deceleration during a high-intensity soccer turning manoeuvre. *Journal of Sports Sciences*, *32*, 1897–1905.

Ozbar, N., Ates, S., & Agopyan, A. (2014). The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. *Journal of Strength and Conditioning Research*, *28*, 2888–2894.

Palao, J. M., & Valadés, D. (2013). Testing protocol for monitoring upper-body strength using medicine balls. *Journal of Human Sport and Exercise*, *8*, 334–341.

Pederson, D., & Gore, C. (1996). Anthropometry measurement error. In K. Norton & T. Nolds (Eds.), *Anthropometrica: A textbook of body measurement for sports and health courses* (pp. 77–96). Sydney: UNSW Press.

Ramírez-Campillo, R., Álvarez, C., Henríquez-Olguín, C., Baez, E. B., Martínez, C., Andrade, D. C., & Izquierdo, M. (2014). Effects of plyometric training on endurance and explosive strength performance in competitive middle- and long-distance runners. *Journal of Strength and Conditioning Research*, *28*, 97–104.

Ramírez-Campillo, R., Andrade, D. C., & Izquierdo, M. (2013). Effects of plyometric training volume and training surface on explosive strength. *Journal of Strength and Conditioning Research*, *27*, 2714–2722.

Ramírez-Campillo, R., Gallardo, F., Henríquez-Olguín, C., Meylan, C., Martínez, C., Álvarez, C., … Izquierdo, M. (2015). Effect of vertical, horizontal and combined plyometric training on explosive, balance and endurance performance of young soccer players. *Journal of Strength and Conditioning Research*, 29, 1784–1795.

Ramírez-Campillo, R., Meylan, C., Álvarez, C., Henríquez-Olguín, C., Martínez, C., Cañas-Jamett, R., … Izquierdo, M. (2014). Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *Journal of Strength and Conditioning Research*, *28*, 1335–1342.

Ramírez-Campillo, R., Meylan, C. M., Álvarez-Lepín, C., Henriquez-Olguín, C., Martinez, C., Andrade, D. C., … Izquierdo, M. (2015). The effects of inter-day rest on adaptation to 6weeks of plyometric training in young soccer players. *Journal of Strength and Conditioning Research*, *29*, 972–979.

Read, M. M., & Cisar, C. (2001). The influence of varied rest interval lengths on depth jump performance. *Journal of Strength and Conditioning Research*, *15*, 279–283.

de Villarreal, E. S., Requena, B., & Cronin, J. B. (2012). The effects of plyometric training on sprint performance: A meta-analysis. *Journal of Strength and Conditioning Research*, *26*, 575–584.

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, *24*, 919–932.

Siegler, J., Gaskill, S., & Ruby, B. (2003). Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. *Journal of Strength and Conditioning Research*, *17*, 379–387.

Spurrs, R. W., Murphy, A. J., & Watsford, M. L. (2003). The effect of plyometric training on distance running performance. *European Journal of Applied Physiology*, *89*, 1–7.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, *35*, 501–536.

Ter Stege, M. H., Dallinga, J. M., Benjaminse, A., & Lemmink, K. A. (2014). Effect of Interventions on potential, modifiable risk factors for knee injury in team ball sports: A systematic review. *Sports Medicine*, *44*, 1403–1426.

Young, W. B., James, R., & Montgomery, I. (2002). Is muscle power related to running speed with changes of direction? *Journal of Sports Medicine and Physical Fitness*, *42*, 282–288.