1875-399X/22

Send Orders for Reprints to reprints@benthamscience.net

The Open Sports Sciences Journal

Content list available at: https://opensportssciencesjournal.com

CrossMark

RESEARCH ARTICLE

Effects Of Jump Training On Youth Female Soccer Player's Physical Fitness

Mario Sanchez[1], Javier Sanchez-Sanchez[1], Luis Bermejo-Martín[1], María Villa Del Bosque[1], Jason Moran[2], Blanca Romero-Moraleda[3,4] and Rodrigo Ramirez-Campillo[5,*]

[1]*Universidad Pontificia de Salamanca. Salamanca, España*
[2]*School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, United Kingdom*
[3]*Department of Physical Education, Sport and Human Movement, Autonomous University of Madrid, Madrid, Spain*
[4]*Applied Biomechanics and Sports Technology Research Group, Autonomous University of Madrid, Madrid, Spain*
[5]*Exercise and Rehabilitation Sciences Institute. School of Physical Therapy. Faculty of Rehabilitation Sciences. Universidad Andres Bello. Santiago 7591538, Chile*

Abstract:

Background:

Youth female soccer players require high muscular power to overcome their opponents. Jump training can facilitate improvements in muscular power as has been demonstrated in youth male soccer players. However, studies in female players are comparatively scarce.

Objective:

The aim of this study was to assess the effects of a jump-training program, as compared to soccer training alone, on the physical fitness of youth female soccer players.

Methods:

Fourteen physically active youth female soccer players (age: 16.0±2.2 years) were randomly divided into a jump-training group (n=8) or control group (n=6). Before and after a 4-week intervention period, the players were assessed with a countermovement jump (CMJ) test, multiple 4-bounds test (4BT), a 20-m sprint, maximal kicking velocity (MKV) and the Yo-Yo intermittent recovery test (level 1; Yo-Yo IR1).

Results:

No significant changes in any of the dependent variables were noted in the control group, although small effect sizes were observed in CMJ (ES=0.33) and 4BT (ES=0.27). In contrast, the jump training group achieved significant improvements in CMJ (p=0.001; ES=0.85), 4BT (p=0.002; ES=1.01) and MKV (p=0.027; ES=0.77), with small to medium effect sizes observed in the 20-m sprint (p=0.069; ES=0.59) and Yo-Yo IR1 (p=0.299; ES=0.20) tests.

Conclusion:

Compared to regular soccer training that induced only small improvements in CMJ and 4BT, a jump training intervention resulted in small to large improvements in the physical fitness of youth female soccer players with changes seen in CMJ, 4BT, 20-m sprint, MKV, and Yo-Yo IR1.

Keywords: Human physical conditioning, Resistance training, Plyometric exercise, Sports, Youth sports, Athletes, Football, Musculoskeletal and neural physiological phenomena.

Article History	Received: March 2, 2022	Revised: March 31, 2022	Accepted: April 22, 2022

1. INTRODUCTION

Soccer is a very popular sport worldwide and the number of women playing this game has grown extensively in recent years. Currently, there is an aim to reach 60 million female players by 2026 [1] but despite this high projected growth, relatively little scientific evidence has emerged on female soccer players, most particularly youth female players [2].

To increase the potential for success in soccer, players require high levels of physical fitness [3]. The sport is now

* Address correspondence to this author at the Exercise and Rehabilitation Sciences Institute, School of Physical Therapy, Faculty of Rehabilitation Sciences, Universidad Andres Bello, Santiago 7591538, Chile;
Tel: +56951399868; E-mail: rodrigo.ramirez@unab.cl

played at a greater pace than at any time in the past with players requiring a very high standard of physical fitness to meet the demands of competition. Data collected across seven seasons have indicated increased (up to 63%) high-intensity running distances as well as a greater amount of explosive sprints in competitive games [4]. Of relevance to the current study, these trends have also been observed in female players indicating an increased physical demand in women's soccer [3]. Actions such as linear sprints (*i.e*., 45%), jumps (*i.e*., 16%) and change-of-direction sprints (CODS; *i.e*., 6%) are common actions preceding goal-scoring opportunities [5], indicating their importance in underpinning successful play. Interestingly, lower-limb power and jumping ability have been shown to be significantly related to a team's final league standing (unstandardized beta = -0.36-0.31, P=0.012-0.009) [6] thus indicating their importance in underpinning success in the sport. Moreover, the maintenance of repeated short-duration maximal and near-maximal actions across a 90-minute game are also considered to be important [3] with increased endurance enabling players to execute a greater number of maximal-intensity actions during play [7]. Furthermore, physical fitness characteristics such as repeated-sprint ability (RSA), linear running speed (*e.g*., 10-30-m), strength, and muscular power of the lower limbs (*e.g*., vertical jump height) may discriminate between soccer players of different competitive levels [8], potentially serving as a basis for coaches in the selection of teams and squads.

A plethora of different training methods reported in the scientific literature aimed to improve soccer players' physical fitness levels. One such method is jump training which offers unique benefits to the player. Jump training is a highly versatile method that can be conducted within a relatively small physical space and with no equipment. This may be an important advantage during certain scenarios in which athletes may be forced to train at their homes [9], as was the case during the recent Covid 19 pandemic. Moreover, jump training may be considered more fun and engaging than other training methods (*e.g*., flexibility, endurance), particularly among younger soccer players [10]. Importantly, jump-training exercises can mimic the unique short-duration high-intensity actions of soccer, potentially increasing the transfer of performance effects from training to competitive play due to the principle of specificity [11]. On this, jump training has previously been shown to be beneficial for a myriad of physical fitness outcomes such as jumping itself, linear sprinting, agility and CODS, RSA with and without a COD, short-term endurance, long-term endurance, maximal strength, balance, kicking speed, range of motion and coordination [12 - 14].

Despite the above-mentioned benefits of jump training, the evidence relating to the effects of this type of activity on the physical fitness of youth female soccer players is very limited due to numerous methodological and study design issues. In one study in youth female soccer players (age, 13.4 years) [15], after 12 weeks of jump training, participants improved kicking distance and vertical jump height. However, this study included no randomization procedure. In another study [16], youth female soccer players (age, 16.5 years) undertook a 10-week in-season training program to improve physical fitness. However, the program incorporated jumps, resistance training and high-intensity anaerobic sprints, making the identification of an isolated effect of jump training impossible. Similarly, another study [17] in youth female soccer players (age, 15.4 years) incorporated six weeks of an anterior cruciate ligament injury prevention program which included jumps mixed with resistance training, COD, and core exercises.

With the above limitation in mind, we sought to carry out the first randomized-controlled trial that assessed the isolated effect of a jump training program on physical fitness in youth female soccer players. Our aim was to compare the effects of jump training with soccer training alone. We hypothesized that there would be significant improvements in the physical fitness of youth female soccer players following jump training, with no such changes observed in the control group.

2. MATERIALS AND METHODS

2.1. Design

A single blind (*i.e*., researchers) randomized controlled trial was conducted to compare the effects of four weeks of jump training (experimental group) against four weeks of regular soccer training (control group). The participants in the experimental group added two jump training sessions per week to their usual soccer training schedule. All participants had at least one year of soccer and strength and conditioning experience but had no experience in jump training. Baseline and follow-up tests included the countermovement jump (CMJ), four-bound test for distance (4BT), 20-m linear sprint-time test, maximal kicking velocity (MKV), and Yo-Yo IR1. Two weeks prior to the start of the study, two 30-minute familiarization sessions were conducted and these included jump training exercises and testing procedures.

2.2. Participants

To calculate the sample size, statistical software (GPower; University of Dusseldorf, Dusseldorf, Germany) was used. Based on i) our study design (two groups, two repeated measures), ii) previous results reported on vertical jump height following jump training by female soccer players (effect size = 0.7) [15], and iii) software-based statistical assumptions (*i.e*., alpha-error ≤0.05; nonsphericity correction € = 1; correlation between repeated measures = 0.5; desired power 1-ß error = 0.8), the sample size resulted in the allocation of eight participants per group.

All the participants were recruited from a high-level soccer team (*i.e*., professional Club) competing at the national level. In the most recent national championship prior to the study taking place, the team finished in fifth place. During the study, which took place in the in-season period, the participants completed three training sessions and an official match every week, maintaining this schedule throughout the duration of the investigation.

Twenty youth female soccer players volunteered for the study. The following inclusion criteria were applied: (i) ≥12 months of systematic soccer and strength and conditioning training, (ii) no musculoskeletal injuries in the previous two months prior to the start of the study, (iii) familiarization with jump training must have been undertaken but without any systematic program being performed over preceding five months, (iv) no medical issues that could compromise study participation, and (v) absence of any lower-extremity surgery during the previous two years. Subjects with a soccer and strength and conditioning background, but without systematic jump training experience, were recruited to reduce the potential musculoskeletal problems that have been associated with repeated jumping activities. From the initial 20 volunteers, one was unable to participate due to not conforming to all of the inclusion criteria. The remaining 19 participants were randomly assigned to the experimental and control groups. The randomization sequence was generated electronically (https://www.randomizer.org) and was concealed until the interventions were assigned. After the completion of the intervention, another five participants had to be removed from the study because they did not achieve the targeted training adherence rate (*i.e.*, they had more than three absences from training) or did not present for post-training fitness tests. Therefore, 14 participants (mean age: 16.0±2.2 years) completed the study, with eight athletes in the jump training group and six in the control group. The enrolment to analysis process is depicted in Fig. (**1**). Subjects' characteristics are displayed in Table **1**. We standardized physical activity behaviour and diet over the course of the study by asking the participants to maintain their habitual physical activity levels and diet throughout the intervention.

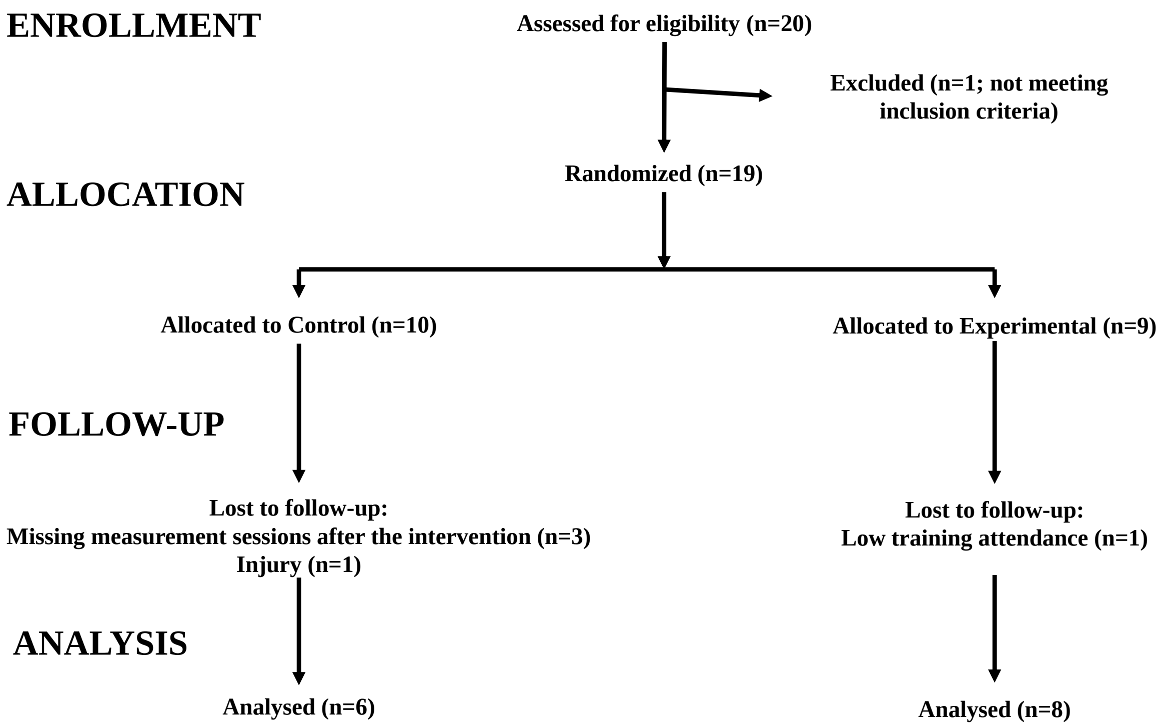

Fig. (1). Enrolment, allocation, follow-up and analysis phases of the study.

Table 1. Characteristics of participants.

-	Jump-training Group (n=8)	Control Group (n=6)
Age (y) [a]	16.0 ± 2.3 (14.1 - 17.9)	16.0 ± 2.7 (13.2 – 18.8)
Height (m) [b]	161.9 ± 6.2	164.0 ± 6.8
	(156.7 – 167.1)	(156.9 - 171.2)
Body mass (kg) [b]	60.7 ± 6.3	56.5 ± 12.8
	(55.5 – 65.9)	(43.1 – 69.9)
Body mass index (kg.m^{-2}) [b]	23.2 ± 2.0	20.8 ± 3.1
	(21.5 – 24.8)	(17.6 – 24.1)
Breast maturity stage (Tanner scale 0-5) [a]	3.9 ± 0.6	4.5 ± 0.6
	(3.3 - 4.4)	(3.9 – 5.0)
Pubic hair maturity stage (Tanner scale 0-5) [a]	4.1 ± 0.4	4.5 ± 0.6
	(3.8 - 4.4)	(3.9 – 5.0)
Weekly time in physical education (h) [a]	1.5 ± 0.9	2.3 ± 1.5
	(0.7 – 2.3)	(0.8 - 3.9)

(Table 1) contd.....

Weekly hours of other sport or soccer in other club (h) [a]	2.0 ± 2.9	0.5 ± 1.2
	(0.4 – 4.4)	(0.8 - 1.8)
Soccer experience (y) [a]	8.8 ± 2.2	7.3 ± 3.9
	(6.9 – 10.6)	(3.3 - 11.4)

[a]: denotes non-parametric outcomes analyzed with the Mann-Whitney U test.
[b]: denotes parametric outcomes analyzed with the t-test for independent samples.
[c]: values in parenthesis denotes the 95% confidence interval of the means.

The participants in both groups had similar levels of competitive experience and involvement in soccer drills, resulting in comparable soccer-specific weekly training loads for all involved (Table **1**). Additionally, a similar number of goalkeepers (1, 1), defenders (3, 2), midfielders (3, 1) and forwards (1, 2) were divided across the experimental and control groups, respectively.

The study was carried out in accordance with recommendations of the latest version of the Declaration of Helsinki. Participants (and their respective parents or guardians) were informed about the experimental procedures, possible risks and benefits associated with participation in this study. After institutional review board approval, they then signed informed assent and consent forms, respectively, before performing any of the fitness tests and training sessions.

2.3. Testing Procedures

All tests were carried out between the hours of 10 am and 2 pm. All participants (and their parents or guardians) were instructed to a) have a meal rich in carbohydrates and to be well hydrated before tests were undertaken, and b) to use the same sports footwear during all testing sessions. Maximum effort was encouraged throughout the performance of the tests. Ten minutes of a standard warm-up protocol were performed before each test session. This included five minutes of sub-maximal running with 180° changes of direction every 20-m, and five minutes of sub-maximal jumping drills (20 vertical and 10 horizontal jumps). Specific warm-up activities before each test were also performed (*e.g*., kicking a ball). Measurements were performed by experienced professionals (and their assistants) who were blinded to participants' group allocation.

Stature was measured using a stadiometer (Seca 202, Seca®, Hamburg, Germany, to 0.1 cm) and body mass on a scale (BC-418MA, TANITA®, Arlington Heights, IL, USA, to 0.1 kg). Sexual maturity status was determined through Tanner stages self-assessment as previously outlined [18, 19]. Briefly, subjects were asked to self-determine the Tanner stage that was equivalent to their level of sexual development using standard diagrams of pubic hair growth and breast development. Privacy was maintained for other participants and investigators by providing booths for completing the required forms which were placed in sealed, coded envelopes for analysis.

For the jumping tests, previously published procedures were followed [20, 21]. Briefly, the athletes completed the CMJ test with minimal flexion of the trunk during the take-off stage of the jump. Jumping was measured with a commonly used contact mat (Optogait®, Codogne, Italy). Participants performed two trials at maximal effort with one minute of recovery between each. The maximum jump height achieved was used in subsequent analysis. Additionally, the participants also performed the 4BT. This test was initiated from a standing position with participants performing a set of four forward jumps with alternative dominant and non-dominant leg contacts in an attempt to traverse the longest distance possible. The final distance achieved was measured to the nearest 0.5 cm using a tape measure and the maximum distance was used in analysis. The athletes performed two trials with maximal effort and a recovery period of three minutes was afforded between each. In all jumps, the arms were used freely. At the end of each horizontal jump attempt, athletes maintained the landing position for a momentary period and avoided touching the ground with their hands.

Following previously published procedures [20, 21], sprint time was assessed to the nearest 0.01 s using electronic timing gates (WittySEM, Microgate ®, Bolzano, Italy). Participants initiated the sprint from a standing start with the toe of their preferred lead foot placed in front of them but just behind the starting line. The sprint was timed from when the participant voluntarily initiated the movement with this action triggering the timing mechanism. The timing gates were positioned at the start of the course (0.3 m in front of the starting line) and 20-m point. They were set approximately 0.7 m above the ground (*i.e*., hip level) to avoid the chance of being triggered by a leading limb during sprinting. To increase the accuracy and reliability of measurements, two synchronized single-beam timing gates were mounted one over the other. With this double-photocell system, only the simultaneous interruption of both single-beam photocells generated a signal.

The MKV test was performed as previously outlined [22]. The participants performed a maximal instep kick with their dominant leg (*i.e*., preferred leg with which to kick a ball) after a leading run-up of two strides. A size-5 soccer ball (mass, 410-450 g; circumference, 68-70 cm; Adidas Starlancer V®, FIFA certified) was used for the test. Maximal kick velocity was measured using a radar gun (Sports Radar SR-3600 Radar Gun; Sports Radar®, Homosassa, Florida, USA).

For the Yo-Yo Intermittent Recovery Test Level 1, previously published procedures were followed [23]. Briefly, two markers were positioned at a distance of 20-m indicating the start and finish lines of the course. Participants performed repeated 20-m shuttle runs between these markers and these were interspersed with 10-seconds of recovery time. The time allowed to complete a shuttle run was progressively decreased (*i.e*., running speed increased) as the test progressed. The final result was determined as the total distance covered during the timeframe of the test which was determined by the participant discontinuing performance once volitional fatigue was reached. Throughout the testing procedure, an investigator to subject ratio of 1:1 was maintained to ensure the accuracy of data collection. Participants were instructed to exert maximal effort during the test (±10% of predicted maximal heart rate). The data of any participant that did not achieve this level of exertion was excluded from the final analysis.

2.4. Training Program

The jump training program was completed during the in-season period. The control group participants did not perform this program but did continue their usual soccer training (*i.e.*, 50% technical- tactical drills; 40% small-sided and simulated games; 10% injury-prevention drills). The design of the jump training program was based on the consideration of multiple factors including the participants' previous training experience, current research recommendations [13, 24], extensive discussion between researchers, recommendations from three top-rated experts in the field of plyometric exercise (https://www.expertscape.com/ex/plyometric+exercise) and two top-rated experts in the field of soccer (https://www.expertscape.com/ex/soccer).

Each training session included eight jumping exercises of multiple types including cyclical, acyclical, horizontal, vertical, unilateral and bilateral variations. Jumps with short ground contact [<250 ms] and long ground contact [>250 ms] times were also used with emphasis placed on the involvement of stretch-shortening cycle in the case of the former. Jumps that included concentric-only movement (*i.e.*, squat jump) jumps were also included in the program. The participants were instructed to exert maximal effort (*i.e.*, intensity) in each jump with emphasis placed on measurable elements, such vertical height, horizontal distance or maximal reactive strength index (*i.e.*, minimal ground contact time and maximal jump height), according to the type of exercise.

For some jumps, the *intensity* of the training sessions was verified in a randomly selected subsample (n=2) of participants during two randomly selected training sessions (sixth and eighth sessions). The intensity was gauged by assessing jump ground contact times, height, and distance, using the same procedures as described above.

Before starting the jump-training program, players were instructed on how to perform all of the exercises with sound technique, an emphasis being placed on the quality of execution before overload methods were introduced. In addition, a drop jump test was performed (Optogait®, Codogne, Italy) to determine the reactive strength index and to individualize the height of the drops to be used in the program (10 to 40 cm). The exercises, sets, repetitions and progressions for each week of the program are detailed in Table **2**.

An investigator to participant ratio of 1:2 was achieved in all training sessions and particular attention was paid to technical competency throughout each. All jump training sessions were performed just after the warm-up to the main soccer session. The jump training was completed on a grass soccer-field with rest intervals of ≥48 h between sessions, 30 to 60 seconds between sets [19] and 5 to 15 seconds (*i.e.*, acyclic jumps) between repetitions [18].

2.5. Statistical Analyses

Data are presented as group mean values and standard deviations. Beside non-parametric pre-intervention CMJ data, for which logaritmization procedures were applied (with back-transformation for presentation purposes), all data normality was verified with the Shapiro-Wilk test. The independent samples t-test was used to compare the groups at baseline. A repeated measure 2 (time; before vs after intervention) × 2 (groups; control vs experimental) ANOVA was used to detect statistically significant ($P < 0.05$) changes in the dependent variables with p-values reported for the group, time and group by time interactions. A within group paired t test was used for post hoc analysis with Cohen's *d* effect sizes (ES) used to assess the magnitude of identified changes [25]. These were classified as 'trivial' (<0.2), 'small' (>0.2-0.6), 'moderate' (>0.6-1.2), 'large' (>1.2-2), or 'very large' (>2) according to established standards in the field of sport science [26]. Statistical analyses were carried out using the STATISTICA statistical package (Version 8.0; StatSoft, Inc., Tulsa, USA). Significance levels were set at $\alpha = 5\%$. The reliability of all dependent variables was acceptable with intra-class correlation coefficient values equalling or exceeding 0.89 for all outcomes and coefficients of variation being less than 10.0%.

3. RESULTS

Of the subjects considered for data analyses, all received the treatment as allocated. Neither group reported any changes in their training habits during the four week intervention period, as compared to their training routine prior to the study.

Table 2. Training program.

-	Week 1 [b]	Week 2	Week 3	Week 4
Abalakov jump	2x4 [c]	2x5	2x6	2x5
Standing long jump	2x4	2x5	2x6	2x5
Standing long jump, right leg	2x4	2x5	2x6	2x5
Standing long jump, right leg	2x4	2x5	2x6	2x5
Squat jump	2x4	2x5	2x6	2x5
Squat jump, right leg	2x4	2x5	2x6	2x5
Squat jump, left leg	2x4	2x5	2x6	2x5
Drop jump [a]	2x4	2x5	2x6	2x5

[a]: box height between 10 cm to 40 cm, according to inter-individual differences to achieve maximal reactive strength index.

[b]: the indicated values denotes the volume of jumps per session.

[c]: 2x4 denotes two sets of four repetitions each.

Table 3. Group-specific means and standard deviations (SD) for all outcome measures before (Pre) and after (Post) the intervention period.

-	Pre	Post*	ANOVA Outcomes		
			Group F(1, 12), p-value	Time F(1, 12), p-value	Group x Time F(1, 12), p-value
Countermovement jump (cm) Control group (n=6) Jump-training group (n=8)	22.4±2.7 [19.6-25.2][¥] 24.6±2.6 [22.5-26.7]	23.5±3.8 (0.33) [19.5-29.5][d] 27.2±3.2 (0.85) [b] [24.6-29.9]	F=3.5, p=0.086	F=13.1, p=0.004	F=2.4, p=0.147
Four bound test for distance (cm) Control group (n=6) Jump-training group (n=8)	646±105 [536-756] 684±44.5 [647-721]	669±70.0 (0.27) [596-742] 733±41.6 (1.01) [b] [699-768]	F=2.3, p=0.155	F=10.5, p=0.007	F=1.4, p=0.267
20-m sprint time (s) Control group (n=6) Jump-training group (n=8)	3.44±0.13 [3.30-3.58] 3.38±0.14 [3.26-3.49]	3.43±0.20 (0.06) [3.23-3.64] 3.29±0.15 (0.59) [c] [3.16-3.42]	F=2.0, p=0.180	F=1.8, p=0.209	F=1.1, p=0.312
Maximal kicking velocity ($km.h^{-1}$) Control group (n=6) Jump-training group (n=8)	72.8±6.5 [66.0-79.7] 75.5±4.3 [71.9-79.1]	72.5±3.8 (-0.07) [68.5-76.5] 79.4±5.2 (0.77) [a] [75.0-83.7]	F=3.6, p=0.082	F=3.0, p=0.109	F=4.2, p=0.062
Yo-Yo level 1 test (m) Control group (n=6) Jump-training group (n=8)	1,153±546 [580-1,727] 1,150±475 [753-1,547]	1,167±433 (0.03) [712-1,621] 1,235±455 (0.20) [854-1,616]	F=0.0, p=0.893	F=0.2, p=0.638	F=0.1, p=0.731

*: values in parenthesis represents within-group Cohen's *d* effect sizes. [¥]: values in squared brackets denotes the 95% confidence interval of the means. [a, b]: significant pre-post change (p<0.01, and p<0.05, respectively; paired t-test). [c]: p=0.069.

There were no significant differences between the groups in any descriptive- (Table **1**) or fitness-based variables (Table **3**) at baseline. The group, time, and group by time interaction effects are displayed in Table **3**.

No significant changes were noted in the control group in any of the dependent variables although small effect sizes were observed in CMJ (ES=0.33) and 4BT (ES=0.27). In contrast, the jump training group demonstrated significant improvements in CMJ (p=0.001; ES=0.85), 4BT (p=0.002; ES=1.01), and MKV (p=0.027; ES=0.77), with small to medium effect sizes observed in the 20-m sprint (p=0.069; ES=0.59) and Yo-Yo IR1 (p=0.299; ES=0.20) tests.

4. DISCUSSION

The aim of this study was to evaluate the effects of a jump training program, as compared to standard soccer training, on measures of physical fitness youth female soccer players. To the best of our knowledge, and based on the characteristics of the extant evidence on this particular topic, our research represents a novel approach to determining the benefits of jump training for young female players. Indeed, in a recent jump training scoping review, which included 420 articles, just three studies undertaken in a youth female soccer player population were identified [13]. Of these studies, none featured a randomized-controlled design that could determine the isolated effect of a jump-training program on youth female soccer player's physical fitness. Further, in two recent meta-analyses, on the effects of jump training on female soccer players [24, 27], just two studies included youth players both also failed to adopt adequate randomization protocols.

In the context of the above evidence, our study is probably the first randomized-controlled trial which can quantify the isolated effects of a jump program on youth female soccer players' physical fitness levels in the absence of other forms of strength and conditioning training. Previous studies conducted on youth females [15] combined jumping with other training methods (*e.g.*, traditional resistance training) making it impossible to isolate the effect of the former from the latter. The current findings are therefore novel and offer valuable and scientifically sound data for practitioners to leverage in the field. On this, our results support the use of jump training to induce improvements in a wide array of performance tests, such as CMJ, 4BT, 20-m sprint, MKV, and Yo-Yo IR1, in this population. In contrast, regular soccer training induced only small improvements that were restricted to CMJ and 4BT only. This is important information for soccer and strength and conditioning coaches alike who should collaborate closely so that both technical and fitness-based training can be integrated into players' programs for maximal performance benefits. The improvements in performance that we observed might be mediated by differing physiological adaptations such as improvements in neuromuscular-related functioning of the stretch-shortening cycle (SSC) [28], neural drive to the agonist muscles [29], optimization of relative force generated per motor unit recruited [28], leg muscle qualities (*e.g.*, stiffness) [30], the direction of force production and application (as a result from physiological adaptations) [31] and running economy [32].

The jump training group improved jumping performance with medium effects size observed in the CMJ and 4BT. The beneficial effects of jump training on jumping ability in youths have previously been reported [33]. However, a lack of clarity in how the aforementioned neuromuscular improvements induced by jump training [29] are exhibited in females of different maturation status, in addition to the confounding effects of maturation-related changes on the SSC function [28], means that explanations of the effects are speculative and more research is needed to elucidate underlying mechanisms. Similarly, the beneficial effects of jump training on sprint performance have been previously reported, most notably after interventions in youths that incorporated horizontally oriented jumping movements [22], as in the current study (~40% of all jump exercises). Improvements of this nature may be related to an individual's ability to apply greater force in a horizontal direction [31] in addition to other factors [34] such as increased muscular power, muscle composition and neuromuscular adaptations. Indeed, a recent meta-analysis [35] suggested that horizontal jumps could be superior to vertical jumps because there is both a horizontal and a vertical component to the former, but only a vertical component to the latter. Of note, the jump training group demonstrated a borderline small to moderate improvement in sprint time as compared to the control group which demonstrated no change over the four week period. Considering that speed-related athleticism is a key trait for optimal long-term athletic development, its improvement may contribute to youths' health and fitness, physical performance, injury resistance, confidence and competence [36]. Particularly relevant for soccer players, greater sprinting capability might help individuals to cope with the greater speed demands of modern competitive soccer [4]. Moreover, with linear sprinting being the most common action (*i.e*., 45%) preceding a goal-scoring scenario [5], its importance in underpinning successful soccer play must be acknowledged by coaches.

Although a considerable number of studies have previously reported increases in MKV after jump training programs, most of these have focused on the kicking ability of male players [37, 38], with the age of the participants ranging from 10.3 to 15.5 years, and the training programs lasting between 6 to 12 weeks. Increases in kicking velocity of ~7.0-16.0% and kicking distance of ~11.0-37.0% have been reported. Larger changes were observed after interventions that incorporated progressive load increases (*e.g*., volume) [39], a combination of vertical and horizontal and unilateral and bilateral jumps [22], and jumps that were loaded with external resistance [38, 40]. Similar findings were noted in youth female [15], young adult female [41] and young adult male soccer players [42], with significant improvements in kicking velocity (8-13%) and kicking distance (~23%) after eight to twelve weeks of training. For those studies that reported improvements in kicking performance for the dominant (7-12%) and non-dominant legs (8-13%), similar improvements were observed between limbs [42, 43]. Overall, the extant evidence supports our own findings with effect sizes in MKV being substantially larger in youth female soccer players in the experimental group (ES = 0.77) as compared to their control group counterparts (ES = -0.07). Such adaptations may offer advantages during competitive play with an apparent transfer of training effect to soccer-specific skill performance in young female players. Despite this encouraging result, the underlying mechanisms of these adaptations are not clear, with further research required for clarification of this element of training.

In relation to endurance performance in youth male soccer players, some studies have reported no significant changes in Yo-Yo IR1 test results (5.8-6.2%; ES = ~0.3) [44, 45]. This contrasts with other investigations which observed significant improvements in Yo-Yo IR1 test scores after jump training programs, in youth male players (~11-19%; ES = 0.27-0.41) [22, 39], and in adult female players (~10%; ES ~0.3) [41]. Although some contrasting findings have emerged in the literature, jump training seems to improve running endurance performance, particularly in tasks requiring a sudden change of direction with such movements requiring utilization of the SSC (*e.g*., Yo-Yo IR1 test). The above findings corroborate the observation in our study that jump training can improve youth female soccer players' performance in the Yo-Yo IR1 test as compared to regular soccer training. However, the observed effect was of only small magnitude (ES = 0.20 *vs*. 0.03) in our investigation. Larger improvements in endurance may be achieved with jump training programs involving a progressive overload (*e.g*., volume-based overload) and a combination of bilateral and unilateral and vertical and horizontal jumps [13, 22, 39], all of which are key programing elements in the current study.

The current study does have its limitations. Our analysis is limited by the small sample size (n = 14) though it is important to emphasize that the statistical power analysis revealed that six participants per group provided 80% power (at $\alpha < 0.05$) to detect an effect size of 0.2 when comparing changes in physical performance in youth soccer players. In addition, we did not incorporate more sophisticated physiological or biomechanical measures to and elucidate the underlying mechanisms related to the physical fitness improvements observed after the jump training program. Future studies should address this limitation with mechanistic measures of performance.

CONCLUSION

Based on these results, a multidimensional jump training program is effective in increasing different elements of physical fitness in youth female soccer players. The observed fitness changes relate to jump height, sprint speed, kicking ability and endurance. Our jump training program was comprehensive in that it incorporated all the characteristics of a multidimensional approach to enhancing SSC function and muscular power in athletic populations and adaptations were achieved in a very short timeframe. Coaches are advised to prescribe a combination of cyclical, acyclical, horizontal, vertical, unilateral and bilateral jumps using both short ground contact [<250 ms] and long ground contact [>250 ms] times to address the nature of the SSC as it is utilized in sport. With consideration of these components, coaches can prescribe jump training programs that address the diverse demands of soccer which requires players to execute dynamic actions that share many of the same movement characteristics of the aforementioned jump types.

In addition to the above, we emphasize the safety of jump training (*i.e*. no injuries occurred during the intervention) and the feasibility of carrying out two training sessions per week alongside regular soccer training. Our results demonstrate positive effects on relevant physical fitness measures for youth female soccer players and the various training techniques can easily be integrated into conventional training with minimal resources.

LIST OF ABBREVIATIONS

CMJ	=	Countermovement Jump
COD	=	Change-of-direction Sprint
CODS	=	Change-of-direction Sprints
ES	=	Effect Size
MKV	=	Maximal Kicking Velocity
RSA	=	Repeated-sprint Ability
SSC	=	Stretch-shortening Cycle
Yo-Yo IR1	=	Yo-Yo intermittent Recovery Level 1 Test

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the institutional review board (Pontifical University of Salamanca).

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. All the humans used were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975.

CONSENT FOR PUBLICATION

Signed informed consent and assent were obtained from guardians and athletes, respectively.

STANDARDS OF REPORTING

STROBE guidelines were followed

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available upon request to the corresponding author [R.R-C].

FUNDING

The authors received no specific funding for this work.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

We are grateful to all the participants that volunteered in this study.

REFERENCES

[1] FIFA. FIFA Women's Development Programme. 2020.

[2] Okholm Kryger K, Wang A, Mehta R, Impellizzeri FM, Massey A, McCall A. Research on women's football: a scoping review. Sci Med Football 2021; pp. 1-10.

[3] Datson N, Hulton A, Andersson H, *et al.* Applied physiology of female soccer: an update. Sports Med 2014; 44(9): 1225-40. [http://dx.doi.org/10.1007/s40279-014-0199-1] [PMID: 24803162]

[4] Bush M, Barnes C, Archer DT, Hogg B, Bradley PS. Evolution of match performance parameters for various playing positions in the English Premier League. Hum Mov Sci 2015; 39: 1-11. [http://dx.doi.org/10.1016/j.humov.2014.10.003] [PMID: 25461429]

[5] Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. J Sports Sci 2012; 30(7): 625-31. [http://dx.doi.org/10.1080/02640414.2012.665940] [PMID: 22394328]

[6] Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical fitness, injuries, and team performance in soccer. Med Sci Sports Exerc 2004; 36(2): 278-85. [http://dx.doi.org/10.1249/01.MSS.0000113478.92945.CA] [PMID: 14767251]

[7] Helgerud J, Engen LC, Wisloff U, Hoff J. Aerobic endurance training improves soccer performance. Med Sci Sports Exerc 2001; 33(11): 1925-31. [http://dx.doi.org/10.1097/00005768-200111000-00019] [PMID: 11689745]

[8] Slimani M, Nikolaidis PT. Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: a systematic review. J Sports Med Phys Fitness 2019; 59(1): 141-63. [PMID: 29199782]

[9] Gentil P, Ramirez-Campillo R, Souza D. Resistance training in face of the coronavirus outbreak: time to think outside the box. Front Physiol 2020; 11(859): 859. [http://dx.doi.org/10.3389/fphys.2020.00859] [PMID: 32733287]

[10] Ward P, Hodges NJ, Starkes JL, Williams MA. The road to excellence: deliberate practice and the development of expertise. High Abil Stud 2007; 18(2): 119-53. [http://dx.doi.org/10.1080/13598130701709715]

[11] Ramirez-Campillo R, Alvarez C, García-Pinillos F, Gentil P, Moran J, Pereira LA, *et al.* Plyometric training in young male soccer players: potential effect of jump height. Pediatr Exerc Sci 2019; 31(3): 306-13. [http://dx.doi.org/10.1123/pes.2018-0207] [PMID: 30736711]

[12] Ramirez-Campillo R, Álvarez C, García-Hermoso A, *et al.* Methodological characteristics and future directions for plyometric jump training research: A scoping review. Sports Med 2018; 48(5): 1059-81. [http://dx.doi.org/10.1007/s40279-018-0870-z] [PMID: 29470823]

[13] Ramirez-Campillo R, Moran J, Chaabene H, *et al.* Methodological characteristics and future directions for plyometric jump training research: A scoping review update. Scand J Med Sci Sports 2020; 30(6): 983-97. [http://dx.doi.org/10.1111/sms.13633] [PMID: 32034819]

[14] Ramirez-Campillo R, Miñano J, Sanchez-Sanchez J. Efecto del entrenamiento pliométrico sobre el rendimiento del futbolista. Revista de Preparación Física en el Fútbol 2019; 30: 1-10.

[15] Rubley MD, Haase AC, Holcomb WR, Girouard TJ, Tandy RD. The effect of plyometric training on power and kicking distance in female adolescent soccer players. J Strength Cond Res 2011; 25(1): 129-34. [http://dx.doi.org/10.1519/JSC.0b013e3181b94a3d] [PMID: 19966586]

[16] Siegler J, Gaskill S, Ruby B. Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. J Strength Cond Res 2003; 17(2): 379-87. [PMID: 12741882]

[17] Taylor JB, Ford KR, Schmitz RJ, Ross SE, Ackerman TA, Shultz SJ. Sport-specific biomechanical responses to an ACL injury prevention programme: A randomised controlled trial. J Sports Sci 2018; 36(21): 2492-501. [http://dx.doi.org/10.1080/02640414.2018.1465723] [PMID: 29671383]

[18] Ramírez-Campillo R, Meylan C, Álvarez C, *et al.* Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. J Strength Cond Res 2014; 28(5): 1335-42. [http://dx.doi.org/10.1519/JSC.0000000000000284] [PMID: 24751658]

[19] Ramirez-Campillo R, Andrade DC, Alvarez C, *et al.* The effects of interset rest on adaptation to 7 weeks of explosive training in young soccer players. J Sports Sci Med 2014; 13(2): 287-96. [PMID: 24790481]

[20] Sanchez-Sanchez J, Ramirez-Campillo R, Petisco C, Nakamura FY, Hernandez D. Effects of short-term strength and jumping exercises distribution on soccer player's physical fitness. Kinesiology 2021; 53(2): 236-44.

[http://dx.doi.org/10.26582/k.53.2.6]

[21] Ramirez-Campillo R, Moran J, Drury B, *et al.* Effects of equal volume but different plyometric jump training intensities on components of physical fitness in physically active young males. J Strength Cond Res 2021; 35(7): 1916-23. [PMID: 30741877]

[22] Ramírez-Campillo R, Gallardo F, Henriquez-Olguín C, *et al.* Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. J Strength Cond Res 2015; 29(7): 1784-95. [http://dx.doi.org/10.1519/JSC.0000000000000827] [PMID: 25559903]

[23] Sanchez-Sanchez J, Raya-González J, Ramirez-Campillo R, Chaabene H, Petisco C, Nakamura FY. The increased effectiveness of resistance training on unstable *vs*. stable surfaces on selected measures of physical performance in young male soccer players. J Strength Cond Res 2022; 36(4): 888-94. [http://dx.doi.org/10.1519/JSC.0000000000003590] [PMID: 32412970]

[24] Ramirez-Campillo R, Sanchez-Sanchez J, Romero-Moraleda B, Yanci J, García-Hermoso A, Manuel Clemente F. Effects of plyometric jump training in female soccer player's vertical jump height: A systematic review with meta-analysis. J Sports Sci 2020; 38(13): 1475-87. [http://dx.doi.org/10.1080/02640414.2020.1745503] [PMID: 32255389]

[25] Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale, N.J.: Lawrence Erlbaum 1988.

[26] Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009; 41(1): 3-12. [http://dx.doi.org/10.1249/MSS.0b013e31818cb278] [PMID: 19092709]

[27] Sánchez M, Sanchez-Sanchez J, Nakamura FY, Clemente FM, Romero-Moraleda B, Ramirez-Campillo R. Effects of plyometric jump training in female soccer player's physical fitness: a systematic review with meta-analysis. Int J Environ Res Public Health 2020; 17(23): 8911. [http://dx.doi.org/10.3390/ijerph17238911] [PMID: 33266195]

[28] Radnor JM, Oliver JL, Waugh CM, Myer GD, Moore IS, Lloyd RS. The influence of growth and maturation on stretch-shortening cycle function in youth. Sports Med 2018; 48(1): 57-71. [http://dx.doi.org/10.1007/s40279-017-0785-0] [PMID: 28900862]

[29] Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med 2010; 40(10): 859-95. [http://dx.doi.org/10.2165/11318370-000000000-00000] [PMID: 20836583]

[30] Sheppard JM, Young WB. Agility literature review: Classifications, training and testing. J Sports Sci 2006; 24(9): 919-32. [http://dx.doi.org/10.1080/02640410500457109] [PMID: 16882626]

[31] Morin JB, Bourdin M, Edouard P, Peyrot N, Samozino P, Lacour JR. Mechanical determinants of 100-m sprint running performance. Eur J Appl Physiol 2012; 112(11): 3921-30. [http://dx.doi.org/10.1007/s00421-012-2379-8] [PMID: 22422028]

[32] Coyle EF. Integration of the physiological factors determining endurance performance ability. Exerc Sport Sci Rev 1995; 23: 25-64. [http://dx.doi.org/10.1249/00003677-199500230-00004] [PMID: 7556353]

[33] Moran JJ, Sandercock GRH, Ramírez-Campillo R, Meylan CMP, Collison JA, Parry DA. Age-related variation in male youth athletes' countermovement jump after plyometric training: A meta-analysis of controlled trials. J Strength Cond Res 2017; 31(2): 552-65. [http://dx.doi.org/10.1519/JSC.0000000000001444] [PMID: 28129282]

[34] Sáez de Villarreal E, Requena B, Cronin JB. The effects of plyometric training on sprint performance: a meta-analysis. J Strength Cond Res 2012; 26(2): 575-84. [http://dx.doi.org/10.1519/JSC.0b013e318220fd03] [PMID: 22240550]

[35] Moran J, Ramirez-Campillo R, Liew B, *et al.* Effects of vertically and horizontally orientated plyometric training on physical performance: a meta-analytical comparison. Sports Med 2021; 51(1): 65-79. [http://dx.doi.org/10.1007/s40279-020-01340-6] [PMID: 32897526]

[36] Lloyd RS, Cronin JB, Faigenbaum AD, *et al.* National Strength and Conditioning Association position statement on long-term athletic development. J Strength Cond Res 2016; 30(6): 1491-509. [http://dx.doi.org/10.1519/JSC.0000000000001387] [PMID: 26933920]

[37] Bouguezzi R, Chaabene H, Negra Y, *et al.* Effects of different plyometric training frequency on measures of athletic performance in prepuberal male soccer players. J Strength Cond Res 2020; 34(6): 1609-17. [http://dx.doi.org/10.1519/JSC.0000000000002486] [PMID: 32453304]

[38] Negra Y, Chaabene H, Sammoud S, *et al.* The increased effectiveness of loaded versus unloaded plyometric jump training in improving muscle power, speed, change of direction, and kicking-distance performance in prepubertal male soccer players. Int J Sports Physiol Perform 2020; 15(2): 189-95. [http://dx.doi.org/10.1123/ijspp.2018-0866] [PMID: 31094246]

[39] Ramírez-Campillo R, Henríquez-Olguín C, Burgos C, *et al.* Effect of progressive volume-based overload during plyometric training on explosive and endurance performance in young soccer players. J Strength Cond Res 2015; 29(7): 1884-93. [http://dx.doi.org/10.1519/JSC.0000000000000836] [PMID: 25559905]

[40] Rosas F, Ramirez-Campillo R, Diaz D, *et al.* Jump training in youth soccer players: effects of haltere type handheld loading. Int J Sports Med 2016; 37(13): 1060-5. [http://dx.doi.org/10.1055/s-0042-111046] [PMID: 27557406]

[41] Ramirez-Campillo R, García-Pinillos F, García-Ramos A, *et al.* Effects of different plyometric training frequencies on components of physical fitness in amateur female soccer players. Front Physiol 2018; 9: 934. [http://dx.doi.org/10.3389/fphys.2018.00934] [PMID: 30065665]

[42] Sedano S, Matheu A, Redondo JC, Cuadrado G. Effects of plyometric training on explosive strength, acceleration capacity and kicking speed in young elite soccer players. J Sports Med Phys Fitness 2011; 51(1): 50-8. [PMID: 21297563]

[43] Campo SS, Vaeyens R, Philippaerts RM, Redondo JC, de Benito AM, Cuadrado G. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. J Strength Cond Res 2009; 23(6): 1714-22. [http://dx.doi.org/10.1519/JSC.0b013e3181b3f537] [PMID: 19675492]

[44] Sáez de Villarreal E, Suarez-Arrones L, Requena B, Haff GG, Ferrete C. Effects of plyometric and sprint training on physical and technical skill performance in adolescent soccer players. J Strength Cond Res 2015; 29(7): 1894-903. [http://dx.doi.org/10.1519/JSC.0000000000000838] [PMID: 25635606]

[45] Michailidis Y, Tabouris A, Metaxas T. Effects of plyometric and directional training on physical fitness parameters in youth soccer players. Int J Sports Physiol Perform 2019; 14(3): 392-8. [http://dx.doi.org/10.1123/ijspp.2018-0545] [PMID: 30204520]