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Effect of 5-Week Plyometric Training on Sand Versus Grass on Jumping and Sprinting Performance in Under-20s Soccer Players

Charles Ricardo Lopes[1]*, Marcelo Monteiro Moraes[2], Orival Andries Junior[2], Felipe Beloso[3], Moises Diego Germano[3], Tiago Volpi Braz[3], Marcio Antônio Gonsalves Sindorf[3], Alex Harley Crisp[3], Bruno Roberto Alves Zwarg[3], Hermes Ferreira Balbino[3], Rozangela Verlengia[3], Paulo Henrique Marchetti[4], Marcelo Saldanha Aoki[3], Enrico Gori Soares[3]

[1]Adventist College of Hortolândia, Hortolândia, São Paulo, Brazil, [2]School of Arts, Sciences, and Humanities, University of São Paulo, São Paulo, Brazil, [3]Methodist University of Piracicaba, Piracicaba, São Paulo, Brazil, [4]California State University, USA, [5]University of São Paulo, São Paulo, Brazil

**Corresponding author: charles_ricardo@hotmail*

ABSTRACT

The aim of this study was to investigate the effect of five-week plyometric training (PT) using different surfaces (sand vs. grass) on sprint and jump performance in young soccer players of the under-20 category. Nineteen soccer players from a professional club in São Paulo (19.3 ± 1.1 years, 1.78 ± 0.06 m; 71.1 ± 6.84 kg) participated in the study. The subjects were divided into 2 groups that performed PT on sand (*n*=10) or grass (*n*=9) for five weeks. The PT incorporated exercises like CMJ, drop jumps, and multiple jumps, with the number of jumps increasing from 48 in the initial week to 120 by the final week. ANOVAs were utilized to compare the squat jump (SJ), the countermovement jump (CMJ), the drop jump (DJ), and 15 m sprinting time. A significance level of $P \leq 0.05$ was adopted. The results indicated an improvement in performance, as measured by the SJ (Sand: 18.2%; Grass: 17.6%), CMJ (Sand: 12.5%; Grass: 12.4%), DJ from 44cm (Sand: 8.3%; Grass: 5.8%), drop DJ 66 cm (Sand: 7.5%; Grass: 7.1%), DJ from 88cm (Sand: 6.5%; Grass: 5.7%), and 15m sprint time (Sand: -2.2%; Grass: -2.3%). However, no significant difference was found between the two surfaces. In conclusion, 5-week PT on either sand or grass surfaces can improve sprint and jump performance in young soccer players.

Keywords: power; force-velocity; explosive exercises.

INTRODUCTION

Soccer is team sport characterized by intermittent periods of intensive effort. Athletes in a soccer match must perform a range of power-dependent activities, including sprints, jumps, kicks, and changes of direction. As a result, power development is a critical component of training for soccer players. By incorporating exercises that target power, soccer players might improve their overall performance on the field (1).

Jump-based plyometric training (PT) is one of the most used methods for improving lower body power in soccer athletes (1-4) and involves performing different types of jumps, such as squat jump (SJ), countermovement jump (CMJ) and drop jumps (DJ) (1, 3). This training method relies on the stretch-shortening cycle (SSC), which involves the rapid coupling phase from muscle extension (eccentric phase) to contraction (concentric phase). The SSC may enhance concentric output by increasing muscle stiffness through a combination of greater pre-activation and the stimulation of stretch reflexes, allowing for more effective storage and reutilization of elastic energy in the muscle-tendon unit (5).

By choosing the appropriate landing surface to perform the PT, coaches may adequately promote progression, variety, and safety in a PT program. Grass surfaces can reduce the coupling phase of the SSC, enhancing the use of stored elastic energy during the concentric phase and providing a realistic training environment that mimics actual soccer conditions (6, 7). Conversely, sand surfaces are believed to lower mechanical stress, reduce delayed onset muscle soreness, and decrease the risk of injury (8), which might be preferable for youth athletes given their already high workloads.

Despite these theoretical benefits, few studies have compared the chronic effects of PT performed on grass vs. sand on the performance of soccer players (8, 9), especially in young professionals. For instance, Impellizzeri et al. (8) found that 4 weeks of PT on both sand and grass surfaces led to a positive change in CMJ, SJ, and sprint time (10 and 20m) among adult amateur soccer players. Pereira et al. (9) observed that 6 weeks of sand vs. grass training program including both sprint and jump exercises caused an improvement in CMJ, SJ, and change of direction, but not in sprint time (20m) of young professional under-20s soccer players.

Understanding whether one surface yields more significant performance improvements than the other is crucial for optimizing the physical preparation of youth players. Therefore, this study aims to investigate the effect of five-week plyometric training (PT) using different surfaces (sand vs. grass) on sprint and jump performance in young soccer players of the under-20 category.

METHODS

Experimental Approach to the Problem

This study followed a two-group randomized design to test the effect of five-week PT using different surfaces (Sand vs. Grass) on sprint and jump performance in young soccer players of the under-20s category. Subjects were pair-matched based on their countermovement jump performance and then randomly assigned to one of two experimental groups using the Research Randomizer app (https://www.randomizer.org/): sand group (n = 10) and grass group (n = 9). The study was conducted in the 8-week period leading up a state-level competition (Figure 1). During the first week, the athletes underwent two familiarization sessions with the tests and exercises. If necessary, additional sessions were provided to ensure proper technique. The second and eighth week served for the acquisition of pre and post training data collection respectively. PT was performed from the third to the seventh week using traditional plyometric exercises that have been recommended for increasing jump performance in soccer athletes (1, 10). The PT protocol was performed concurrently with training sessions targeting different physical capacities. On Mondays and Thursdays, athletes engaged in maximum strength training with squat exercises—3 sets of 3RM, with 3 to 5 minutes of recovery between sets. On Tuesdays and Fridays, they focused on anaerobic resistance with small-sided games (30m x 30m), performing 8 sets of 2-minute intervals with 4 minutes of recovery. Wednesdays were dedicated to muscle endurance, with athletes completing 3 sets of 15RM squats, allowing for 1 minute of recovery between sets. Participants were instructed to refrain from any additional resistance-type training throughout the study. During the intervention period, athletes continued their technical and tactical training, ensuring a 6-hour interval between plyometric sessions and other physical activities. To maintain consistency, athletes were required to wear the same shoes for all sessions, and all experimental procedures were conducted at the same time each day (14:00).

Sprint performance was assessed using a 15m sprinting time, while jump performance was evaluated using squat jump, countermovement jump, and drop jump from 44, 66, and 88cm.

Subjects

Nineteen male soccer athletes (19.3 ± 1.1 years; 178 ± 6 cm; 71.1 ± 6.8 kg) participated in the study. They were members of a state-level under-20s soccer team, with an average of 4.5 ± 1.2 years of soccer experience and trained 5.0 ± 1.1 times per week. The sample size was determined through a priori power analysis based on a pilot study, which aimed to assess the difference in 15m sprints with a target effect size of 0.75, alpha level of 0.05, and power of 0.80. All subjects had a minimum of one year of experience with sprint and plyometric training, including the exercises performed in this study. Moreover, subjects were free from any musculoskeletal disorders and did not have a

1st week Familiarization	2nd week Pre-training Tests: CMJ DJ 15m Sprint	3rd-7th week 5-week plyometric training	8th week Post-training Tests: CMJ DJ 15m Sprint

Week	Exercise	Session	Sets x Repetitions	Jumps per Sessions	Jumps per Week	Rest Interval (min)
1	CMJ	1 and 2	3 x 8	24	48	2
2	DJ	3 and 4	3 x 8	24	48	2
3	CMJ + DJ	5 and 6	4 x 8	32	64	2
4	Multiple Jumps	7 and 8	5 x 8	40	80	2
5	Multiple Jumps	9, 10 and 11	5 x 8	40	120	2

Figure 1. Experimental design. CMJ=countermovement jump, DJ=Drop-jump.

history of injury in the trunk, upper limbs, or lower limbs within the past year. They also stated that they had not taken any illegal substances known to increase muscle size. To participate in the study, subjects had to answer negatively to all questions on the Physical Activity Readiness Questionnaire. All subjects read and signed an informed consent document approved by the Methodist University of Piracicaba research ethics committee (Protocol 38/12).

Procedures

Ball restituition coefficient (RC)

The differences in surface stiffness were evaluated by calculating the ball restitution coefficient on three surfaces (cement, grass, and sand). A video analysis was conducted to determine the height that the ball reached after the first impact with the ground. A custom-made device was used to drop an official soccer ball Topper; circumference: 0.68 m; mass: 0.409 kg; pressure: 0.80 bar) from a height of 1.42 m onto each of the three surfaces. The ball was dropped in a translational motion, without rotation. The position, speed, and acceleration data were filtered using a second-order Savitzky - Golay polynomial filter. The restitution coefficient was calculated using the equation RC = √ (drop height/ reached height). After 3 trials for each surface, the mean resulting values for the surfaces were 0.84 for cement, 0.72 for grass, and 0.50 for sand.

Jump performance

Jump height was assessed using a contact mat (Hidrofit Brazil, Model: Jump System). To minimize the influence of the upper limb movements, the subjects were instructed to keep their hands on their waists during all jump tests. Each type of jump was performed three times with a one-minute rest between attempts, and the mean value of the three trials was used for statistical analysis.

For the squat jump (SJ), subjects started in a half squat position (approximately 90° of knee flexion) on the contact mat and held the position for two seconds. Then, they were instructed to jump as high and fast as possible, leaving the contact mat with fully extended knees and ankles and landing in the same extended position.

For the Countermovement Jump (CMJ), the subject stood on the contact mat, and upon verbal instruction, they performed a squat and jumped as high and fast as possible, leaving the contact mat with fully extended knees and ankles and landing in the same extended position.

For the drop jump, subjects stood on plyometric boxes of 22, 44, 66, and 88 cm and were instructed to land and jump on the contact mat. Those heights were chosen for convenience (equipment availability) and based on previous demonstrations of increased jump and sprint performance (3, 7, 9). Subjects were instructed to land and rebound as “fast and high” as possible upon contacting the floor.

15m sprinting speed

The sprinting speed test was carried out on a 15-meter section of a soccer field, following the protocol outlined by Casartelli, Muller, and Maffiuletti (REF). Three 15-meter sprints were completed by the athletes, with a one-minute passive recovery period between each sprint. The speed of the athletes was measured using a Speed TEST 6.0

photocell system (CEFISE®, Nova Odessa, São Paulo, Brazil), which was positioned at two points along the track (0 and 15 meters).

Statistical Analyses

The normality and homogeneity of the variances were assessed using the Shapiro-Wilk and Levene tests, respectively. Prior to analysis, all data were log-transformed for analysis to reduce bias arising from non-uniformity error (heteroscedasticity). The mean, standard deviation (SD) and 95% confidence intervals (CI) were used after data normality was assumed. A repeated measures analysis of variance (ANOVA) was used to compare SJ, CMJ, DJ and 15 m sprinting time (pre vs post week 5) x two groups (Sand vs Grass). Post hoc comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied. In addition, effect sizes were evaluated using a partial eta squared (η^2p), with < 0.06, 0.06 - 0.14 and, > 0.14 indicating a small, medium, and large effect, respectively. Effect sizes in absolute differences (pre vs post 5 week) in raw values of the variables using the standardized difference based on Cohen's *d* units by means (*d* value) (7). The d results were qualitatively interpreted using the following thresholds: < 0.2, trivial; 0.2 - 0.6, small; 0.6 -1.2, moderate; 1.2 - 2.0, large; 2.0 - 4.0, very large and; > 4.0, extremely large. If the 90% confidence limits overlapped, small positive and negative values for the magnitude were deemed unclear; otherwise that magnitude was deemed to be the observed magnitude (10). Trivial area *d* <0,2 (gray bar) was used in Forrest Plot Graph. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $P \leq 0.05$. The figures were formatted in GraphPad Prism version 6.0 software (La Jolla, CA, USA) following the assumptions for continuous data.

RESULTS

The results are summarized in table 1. All the dependent variables showed a significant main effect of time (SJ: $F_{1,13} = 70.881$, $p = 0.001$, $\eta^2p = 0.845$; CMJ: $F_{1,13} = 114.016$, $p = 0.001$, $\eta^2p = 0.898$; DJ44: $F_{1,13} = 35.417$, $p = 0.001$, $\eta^2p = 0.732$; DJ66: $F_{1,13} = 87.506$, $p = 0.001$, $\eta^2p = 0.871$; DJ88: $F_{1,13} = 24.313$, $p = 0.001$, $\eta^2p = 0.652$; and 15m sprinting time: $F_{1,13} = 21.682$, $p = 0.001$, $\eta^2p = 0.625$). However, no significant group x time interaction was found for any of the dependent variables (SJ:

Table 1. Pre and post 5 weeks vertical jumps and sprint measures (mean ± SD).

Variables	Pre	Post 5 weeks	MD (CI95%)	Δ% pre vs post 5 weeks	ES (d) pre vs post 5 weeks	ANOVA 2x2 time *P* value	time*group *P* value
SJ (cm)							
Sand	32.7 ± 3.8	38.6 ± 5.1^A	5.9 (0.9)	18.2	1.32***	0.001	0.627
Grass	30.5 ± 4.3	35.8 ± 4.1^A	5.3 (1.1)	17.6	1.28***		
CMJ (cm)							
Sand	38.4 ± 4.8	43.2 ± 5.3^A	4.8 (1.6)	12.5	0.95**	0.001	0.819
Grass	36.5 ± 4.5	41.0 ± 3.8^A	4.5 (1.3)	12.4	1.08**		
DJ44 (cm)							
Sand	45.6 ± 5.3	49.4 ± 6.1^A	3.8 (1.4)	8.3	0.66**	0.001	0.621
Grass	44.8 ± 3.9	47.4 ± 3.9^A	2.6 (1.2)	5.8	0.67**		
DJ66 (cm)							
Sand	45.4 ± 5.2	48.8 ± 6.6^A	3.4 (1.8)	7.5	0.57*	0.001	0.781
Grass	44.3 ± 3.8	74.4 ± 3.4^A	3.1 (1.5)	7.1	0.86**		
DJ88 (cm)							
Sand	45.7 ± 5.5	48.7 ± 6.9^A	3.0 (1.9)	6.5	0.48*	0.001	0.634
Grass	44.4 ± 3.8	47.0 ± 3.3^A	2.6 (1.4)	5.7	0.72**		
Sprint 15m (s)							
Sand	2.40 ± 0.08	2.35 ± 0.09^A	-0.05 (-0.02)	-2.2	-0.62**	0.001	0.881
Grass	2.46 ± 0.10	2.40 ± 0.10^A	-0.06 (-0.03)	-2.3	-0.58*		

SJ = squat jump; CMJ = countermovement jump; DJ44 = drop jump in box of 44cm; DJ66 = drop jump in box of 66cm; DJ88 = drop jump in box of 88cm; MD (CI95%) = Mean difference and 95% confidence interval; ES = effect size small, moderate**, large***. ^A = Significantly greater than the corresponding pre-intervention value (P < 0.05).*

$F_{1,13}$ = 0.248, p = 0.627, η^2p = 0.019; CMJ: F1,13 = 0.055, p = 0.819, η2p = 0.004; DJ44: $F_{1,13}$ = 0.257, p = 0.621, η^2p = 0.019; DJ66: $F_{1,13}$ = 0.081, p = 0.781, η2p = 0.006; DJ88: $F_{1,13}$ = 0.238, p = 0.634, η^2p = 0.018; and 15m sprinting time: $F_{1,13}$ = 0.023, p = 0.881, η^2p = 0.002).

Between-Group Effect Sizes

The effect sizes for the difference in the dependent variables between the Sand and Grass groups, from pre- to post-week 5, were trivial (SJ = 0.17 [90% CI = -0.47 to 0.13]; CMJ = 0.10 [90% CI = -0.40 to 0.20]; DJ66 = -0.12 [90% CI = -0.32 to 0.08]; DJ88 = -0.16 [90% CI = -0.41 to 0.11]; and 15m sprinting time = 0.06 [90% CI = -0.38 to 0.26]) or small (DJ44 = -0.19 [90% CI = -0.49 to 0.09]). These results are depicted in Figure 2.

DISCUSSION

The aim of this study was to investigate the effect of five-week plyometric training (PT) using different surfaces (sand vs. grass) on sprint and jump performance in young soccer players of the under-20s category. Our results revealed that both groups showed significant improvements in response to the training. Specifically, both groups showed improvements in their performance on SJ, CMJ, DJ, and 15m sprinting speed, with no significant differences between the two groups.

Following plyometric training (PT), jump performance increased similarly, regardless of training surface. Our results align with a recent meta-analysis showing that jump capacity improves similarly after PT on both sand and hard surfaces (10). Previous studies have also demonstrated increased jump performance after PT on grass (8, 9, 11, 12) and sand (8, 9, 11, 13, 14) exclusively. However, to our knowledge, only three studies have directly compared PT effects on grass vs. sand among soccer athletes (8, 9, 15). Impellizzeri et al. (8) found that 4 weeks of PT on both sand and grass surfaces led to a positive change in CMJ, SJ among adult amateur soccer players. Similarly, Pereira et al. (9) observed that 6 weeks of sand vs. grass training program induced an improvement in CMJ, SJ of young professional under-20s soccer players. However, a follow-up study by Pereira et al. (15) observed no significant changes in CMJ and SJ after 8 weeks of sand vs. grass training, which included 12 sessions of vertical and horizontal jump

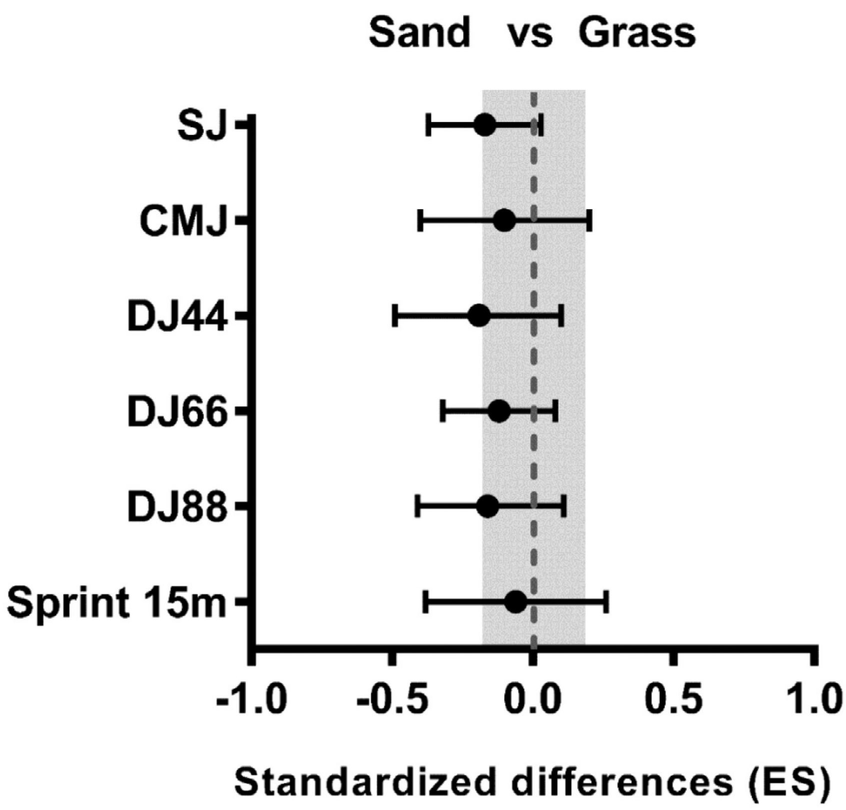

Figure 2. Cohen´s of effect size (ES) principle ± 90% confidence intervals was used to compare the absolute differences between groups Sand vs Grass (Δ post 5 weeks – pre) of the variables Sprint 15 meters, Squat Jump (SJ), Countermovement Jump (CMJ) and Drop Jump (DJ) in 44, 66 and 88cm. Grey bar represents the trivial area (d <0,2).

exercises, along with sprint drills.

Although the differences in outcomes between sand and grass training were not statistically significant in the present or previous studies (8, 9, 15), effect sizes suggest that sand training may lead to greater SJ improvements, while grass training may enhance CMJ more, consistent with the current study's findings. Additionally, it was observed a greater effect size on drop jump (DJ) height in the grass group. Previous acute studies demonstrated that the compliant and unstable surface of sand, in comparison to harder surfaces, may decrease peak power, ground contact force, and take-off velocity and ultimately reduce jump height. Apparently, PT performed in harder surfaces may present a greater transfer to the CMJ and DJ tests, possibly to the greater synchronization of the antagonist muscles, uptake of muscle slack, and dependence upon the SSC (10). Conversely, training on softer surfaces may be more specific to the SJ and sprint tests, as it requires greater demand on the concentric portion of the jumps (16-18).

Both groups also presented similar reductions in 15m sprinting time following the PT intervention. Again, our results are aligned to the recent meta-analysis (10) that demonstrated the positive impact of sand training interventions, including PT, on sprinting time in team sport athletes. Studies focusing specifically on soccer players have also reported an improvement in sprinting performance following PT on both grass (8, 9, 12) and sand surfaces (8, 9). For instance, Chelly et al. (12) reported a significant increase in acceleration (0-5m) and maximum speed (0-40m) after eight weeks of PT on grass, while Impellizzeri et al. (8) that reported reduced 10 and 20m sprinting time after PT on both sand and grass. Similarly, Pereira et al. (9) reported an improvement in 20m zigzag change of direction test but, no significant change in 20m linear sprinting speed following 6 weeks of sprint and PT on sand or grass.

To the authors knowledge, this is the first study that investigated the RC between grass and sand surfaces. RC were found to be 0.72 on the grass and 0.50 on the sand. Campillo et al. (19) previously reported that 7 weeks of a moderate volume of PT (120 jumps per week) performed on a harder surface (gymnasium floor, RC =0.80) caused a significant increase in DJ (20cm and 40cm) , whereas, the same amount of PT performed on a softer surface (athletic mat, RC=0.53) caused a significant increase solely on SJ.

While the present study has yielded valuable insights, it is not without limitations. The primary limitations include the short duration of the training intervention in different surfaces and the relatively small sample size. However, it is worth noting that the preparatory period for teams typically ranges between 4 to 8 weeks, and professional soccer teams usually consist of no more than thirty athletes. Despite the differences observed between the grass and sand surfaces, the results suggest that there is no significant difference in lower limb power training for soccer athletes when other training variables such as volume, intensity, density, and rest interval are controlled. Furthermore, sand appears to be as effective as grass to develop lower body power, as evidenced by improved pre- and post-test results for the SJ, CMJ, DJ, and 15m sprinting time.

The results of this study demonstrate that plyometric training performed on grass or sand surfaces is similarly effective in improving vertical jump and sprint performance in soccer athletes. One point to consider when choosing the surface for plyometric training is the athletes' strength level and experience with this type of training. For instance, weaker athletes, those inexperienced with plyometric training, or those in the rehabilitation process may benefit from practicing plyometric exercises on sand. On the other hand, stronger athletes experienced in this training method may choose to perform the exercises on grass. Coaches and trainers should also consider the timing of plyometric training within the season. They may opt to conduct training on sand during the first half of the preparatory period and leave training on grass (more specific to the sport) for the second half of the preparatory period.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest regarding the research conducted or the results presented.

FUNDING DETAILS

This study received no specific funding in order to

be completed.

ETHICAL APPROVAL

The study was approved by the Universities Ethics Committee. All subjects read and signed an informed consent document approved by the Methodist University of Piracicaba research ethics committee (Protocol 38/12).

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