Ribeiro, Joao, Teixeira, Luis, Lemos, Rui, Teixeira, Anderson S., Moreira, Vitor, Silva, Pedro, and Nakamura, Fabio Y. (2020) ***Effects of plyometric versus optimum power load training on components of physical fitness in young male soccer players.*** **International Journal of Sports Physiology and Performance, 15 (2) pp. 222-230.**

Note. This article will be published in a forthcoming issue of the *International Journal of Sports Physiology and Performance*. The article appears here in its accepted, peer-reviewed form, as it was provided by the submitting author. It has not been copyedited, proofread, or formatted by the publisher.

Section: Original Investigation

Article Title: Effects of Plyometric vs Optimum Power Training on Components of Physical Fitness in Young Male Soccer Players

Authors: João Ribeiro,[1,2] Luís Teixeira,[3] Rui Lemos,[1] Anderson Santiago Teixeira,[4] Vitor Moreira,[1] Pedro Silva,[5,6] and Fábio Yuzo Nakamura.[7,8,9]

Affiliations: [1]Department of Performance Optimization, GOD, Sporting Clube de Braga SAD, Braga, Portugal. [2]Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, Portugal; University Institute of Maia, ISMAI, Portugal. [3]Faculty of Sport, University of Porto, Porto, Portugal. [4]Sports Center, Federal University of Santa Catarina, Physical Effort Laboratory, Florianópolis - SC, Brazil. [5]Centre of Research, Education, Innovation and Intervention in Sport, Faculty of Sports, University of Porto, Porto, Portugal. [6]Shanghai SIPG Footbal Club. [7]Associate Graduate Program in Physical Education UPE/UFPB, João Pessoa, PB, Brazil. [8]The College of Healthcare Sciences, James Cook University, Townsville, Australia. [9]Department of Medicine and Aging Sciences, "G. d'Annunzio" University of Chieti-Pescara, Chieti, Italy.

Journal: *International Journal of Sports Physiology and Performance*

Acceptance Date: April 29, 2019

DOI: https://doi.org/10.1123/ijspp.2019-0039

"Effects of Plyometric vs Optimum Power Training on Components of Physical Fitness in Young Male Soccer Players"
by Ribeiro J et al.
International Journal of Sports Physiology and Performance

EFFECTS OF PLYOMETRIC VS OPTIMUM POWER TRAINING ON COMPONENTS OF PHYSICAL FITNESS IN YOUNG MALE SOCCER PLAYERS

Original Investigation

Abstract word Count: 250
Text-only word count: 4440
Number of Tables: 3
Number of Figures: 3

Running Head: Plyometric vs optimum power load training in soccer

João Ribeiro,[1,2] Luís Teixeira,[3] Rui Lemos,[1] Anderson Santiago Teixeira,[4] Vitor Moreira,[1] Pedro Silva,[5,6] Fábio Yuzo Nakamura.[7,8,9]

[1]Department of Performance Optimization, GOD, Sporting Clube de Braga SAD, Braga, Portugal.

[2]Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, Portugal; University Institute of Maia, ISMAI, Portugal.

[3]Faculty of Sport, University of Porto, Porto, Portugal

[4]Sports Center, Federal University of Santa Catarina, Physical Effort Laboratory, Florianópolis - SC, Brazil

[5]Centre of Research, Education, Innovation and Intervention in Sport, Faculty of Sports, University of Porto, Porto, Portugal

[6]Shanghai SIPG Footbal Club

[7] Associate Graduate Program in Physical Education UPE/UFPB, João Pessoa, PB, Brazil.

[8]The College of Healthcare Sciences, James Cook University, Townsville, Australia

[9]Department of Medicine and Aging Sciences, "G. d'Annunzio" University of Chieti-Pescara, Chieti, Italy

Corresponding Author
João Ribeiro
Address: Rua Alfredo Cunha 101, 8º C – 4450-023 Matosinhos. Portugal
Email: jamribeiro@icloud.com
Contact: Phone: +351 965068112

“Effects of Plyometric vs Optimum Power Training on Components of Physical Fitness in Young Male Soccer Players”
by Ribeiro J et al.
International Journal of Sports Physiology and Performance

ABSTRACT

Purpose: The current study aimed to compare the effects of plyometric (PT) vs. optimum power load (OPL) training on physical performance of young high-level soccer players. **Methods**: Athletes were randomly divided into PT (horizontal and vertical drills) and OPL (squat+hip thrust exercises at the load of maximum power output) interventions, applied over 7 weeks during the in-season period. Squat (SJ) and countermovement (CMJ) jumps, maximal sprint (10 and 30 m) and change of direction (COD; agility T test) were the pre-and post-training measured performance variables. Magnitude-based inference was used for within-and between-group comparisons. **Results**: OPL training induced moderate improvements in vertical SJ (ES:0.97; 90%CI:0.32-1.61) and CMJ (ES:1.02; 90%CI:0.46-1.57), 30 m sprint speed (ES:1.02; 90%CI:0.09-1.95) and COD performance (ES:0.93; 90%CI:0.50-1.36). After PT training method, vertical SJ (ES:1.08; 90%CI:0.66-1.51) and CMJ (ES:0.62; 90%CI:0.18-1.06) were moderately increased, while small enhancements were noticed for 30 m sprint speed (ES:0.21; 90%CI:-0.02-0.45) and COD performance (ES:0.53; 90%CI:0.24-0.81). The 10 m sprint speed *possibly* increased after PT intervention (small ES: 0.25; 90%CI:-0.05-0.54), but no substantial change (small ES:0.36; 90%CI:-0.40-1.13) was noticed in OPL. For between-group analyses, the COD ability and 30 m sprint performances were *possibly* (small ES:0.30; 90%CI:-0.20-0.81; Δ=+1.88%) and *likely* (moderate ES:0.81; 90%CI:-0.16-1.78; Δ=+2.38%) more improved in the OPL than in the PT intervention, respectively. **Conclusions**: The two different training programs improved physical performance outcomes during the in-season period. However, the combination of vertically-and horizontally-based training exercises (squat+hip thrust) at optimum power zone led to superior gains in COD and 30 m linear sprint performances.

Keywords: Stretch-shortening cycle, optimum power load, jumping, speed, change of direction, soccer.

INTRODUCTION

Soccer is the most widely sport practiced in the world. It is considered an intermittent activity in which an increased demand in high-intensity explosive actions (such as jumping, sprinting or multidirectional movements) have been observed during official matches[1]. Consequently, this leads to the growing interest in developing training programs that specifically enhance performance during these powerful activities.

Several strength-power training strategies result in significant soccer-specific physical performance changes, typically assessed by vertical jump, straight-line sprint and change of direction (COD) speed tests[2]. The efficacy of resistance and plyometric training modes is so extensively recognized that some authors argue that "further studies comparing the effect of different conditioning programs against a control group that only perform soccer training are not needed[2]. Currently, it seems more valuable to compare the effects of different neuromuscular training interventions using parallel matched-group designs and determine the most effective method, considering the players' initial characteristics and targeted performance parameters.

Lower extremity plyometric training (PT) mostly comprises jumping exercises using the stretch-shortening cycle muscle action. Using both the natural components of the muscle and tendon and the stretch reflex, PT enhances the ability to produce the maximal force in the shortest amount of time[3]. PT have been shown to induce improvement in several neuromuscular factors (e.g., muscle activation patterns and eccentric strength) that, in combination, lead to enhanced performance in jump, sprint and COD tests in soccer players of both sexes[4]. Still, simpler and low-volume training drills comprising only bilateral horizontal or vertical jumps are related to neuromechanical training responses which are specific to the training-axis[5, 6] , according to force-vector theory which supports the importance of applying training exercises in the same movement direction as the targeted sport-specific movement to enhance the transfer effect. Therefore, it is clear that a comprehensive but time-efficient PT program can be added to soccer players' preparation, ensuing enhancement of key physical capacities.

Training at optimum power load ([OPL] i.e., the load capable of maximizing the muscle power output) seems to be an effective and practical alternative for enhancing the physical fitness of soccer players. Indeed, jump squats, performed at OPL have shown to significantly increase performance in soccer-specific tasks (sprinting, jumping, changing of direction)[7, 8]. Similarly, half-squats under OPL condition were effective in counteracting power and speed decrements in soccer players[9]. Apart from these vertically oriented drills, it was recently suggested that performing 12 to 6 RM in the barbell hip thrust (loaded bridging exercise used to target the hip extensor musculature in anteroposterior force vector movement [horizontally-directed exercise, taking into consideration the athlete in the upright position]) resulted in potential beneficial effects on 10- and 20-m sprint times in adolescent athletes[10]. These benefits were greater than those elicited by front squat, supporting the force-vector theory. It remains to be determined whether a combination of squat and hip thrust exercises performed at the OPL will result in positive changes to physical performance in highly trained soccer players. This training strategy is time-efficient and avoids the ground impact typical of PT that in some instances cannot be tolerated by injured or under-recovered athletes (e.g., feeling delayed onset muscle soreness effects)[11].

The aim of this study was to compare the effects of squat + hip thrust training performed at the OPL vs. PT on jump, sprint and COD performances measured in young elite-level soccer players. It was hypothesized that similar gains in jump performance would occur after both the PT and OPL training modes[4-6, 12], but the OPL-based approach would be a more effective training method to induce superior gains in sprint and COD performances[9, 10] than the PT intervention.

METHODS

Participants

At the beginning of the control period, the study sample consisted of 26 Portuguese elite male soccer players (age, 18.4±0.49 years, height 1.76.13±0.07 m, weight 70.2.4±5.67 kg; body fat 8.8±0.72%) from the same team. Due to injury, illness, or National team commitments, only 16 of the initial players completed the intervention period, randomly belonging to one of the two groups: PT (n = 8; age, 18.6±0.52 years, height 1.73.13±0.06 m, weight 66.4±5.51 kg; body fat 8.5±0.55%) and OPL (n = 8; age 18.4 ±0.52 years, height 1.77±0.07 m, weight 71.8±4.55; body fat 9.0±0.69%). All subjects had been involved in competitive soccer for at least 7 years, were training five 1.5-hour sessions per week, and were competing at junior national level at time of the study. The data collection formed part of the team routines in which players are frequently assessed across the seasonal periods. Therefore, the normal ethics committee clearance was not required[13]

Experimental design

The study started with the control/familiarization period (9 weeks) in which the participants followed their soccer training routine only and were instructed on all technical aspects related to strength and plyometric exercises (performed further in the intervention period). This stage served as reference to attest if eventual changes in the intervention period could be attributed to the applied training programs. After the control period, a parallel two-group, longitudinal design was conducted to test the effectiveness of the PT and OPL training programs, consisting of 12 training sessions, performed before soccer training, over 7 weeks (on separate days, twice-weekly with the exception of the two last weeks, [Figure 1]). The players were matched by playing position (defenders, midfielders and attackers) and allocated to one of two training programs by tossing a coin.

The experimental procedures took place during the second half of the competitive season after 5 months of uninterrupted training.

Throughout the intervention period, all participants were also instructed to continue with their routine activities, irrespective of group allocation (strength-power at optimum power load *vs.* plyometric training). The microcyle planning was similar during the familiarization and intervention periods (five training sessions and one match). Soccer training was prescribed by the coaching staff and consisted mainly of technical (e.g. ball conduction, pass, dribbling, kicking, and heading) and tactical drills (e.g. defending and attacking drills, corner and penalty situations), and small-sided games.

The effects of control and training interventions were assessed using a number of field tests (Figure 1; moments 1, 2 and 3) that have been previously reported as relevant to soccer[14].

In two testing sessions the vertical jumps (session 1), and the 30 m sprint followed by the T test (session 2) were performed. The interval between the latter was 20 min. The two sessions were performed with 24h recovery period. During the intervention period the players performed strength or plyometric training.

After the 7-week experimental period, both testing sessions were repeated. All testing sessions were scheduled >48 hours following a competition or hard physical training to minimize the influence of fatigue.

Optimum power load in half-squat and hip-thrust exercises

Bar mean propulsive power (MPP) was assessed in the half-squat and hip-thrust exercises. The subjects were instructed to execute 3 repetitions at maximal velocity against progressive loads, starting at 60% of their body mass. In the half-squat exercise, the athletes executed a knee flexion until the thigh was parallel to the ground and, afterwards, moved the bar up as fast as possible, without their shoulder losing contact with the bar. In the hip thrust exercise subjects had the upper backs on a bench and were instructed to thrust the bar upward, as fast as possible, while maintaining a neutral spine and pelvis positions. [15] For both exercises, a load of 10% of body mass was gradually added in each set until a decrease in MPP was observed (after five to six sets on average). A 5-min interval was provided between sets. To determine MMP, a valid and reliable small accelerometer (Beast sensor, Brescia, Italy) [16], operating at 50 Hz, was attached to the bar. The MPP (W) of each repetition was transferred in real time via Bluetooth to the Beast app for iOS v.2.2.3, which was installed on an Ipad 3 with iOS 10.2 operative system. The maximum MPP value was retained for data analysis purposes.

Linear sprint and change of direction (COD)

After a standardized warm-up (10-minute including low- intensity forward, sideways, and backward running; several acceleration runs; and jumping at a progressively increased intensity), the participants performed two trials of maximal 30-m sprints, with 10-m lap (10 m: [ICC: 0.91; CV: 2.26%]; 30 m: [ICC: 0.96; CV: 2.18%]). The efforts were separated by a 3-minute of passive rest period.

Afterwards, players performed two maximal T-test bouts (ICC: 0.92, CV: 1.99%) interspersed with 10 minutes of passive recovery, used to determine speed with directional changes such as forward sprinting, right and left side shuffling, and backpedalling. The participants were required to run as fast as possible forward to the center cone (10 m), turn to the left cone (5 m), then turn and run back to the right cone (10 m), and then turn and run back to center cone (5 m) and then run straight back (backpedalling) through the start/finish gate.

Both the 30 m sprint and T-test were performed on an outdoor field with natural grass and single beam infrared timing gates (Brower, Wireless TC Timing System, Draper, UT, USA) were used to record test times. Subjects started in their own time from a standing start position 0.2 m behind the start line timing gates and the fastest trial achieved, in each one of the tests, was retained for data analysis.

Vertical jump measurements

Vertical jump performance was assessed using a contact platform (Ergojump, Globus, Codogne, Italy) in which players performed squat (SJ) and countermovement (CMJ) jumps. In the SJ, a static position with a 90° knee flexion angle was maintained for 3s before a jump attempt without any downward movement before extension of the lower limbs (visually checked by an experienced researcher). In the CMJ, the subjects were instructed to perform a downward movement followed by a complete extension of the lower limbs.

Before testing, the players warmed up with 2-to-3 self-administered submaximal CMJs and SJs repetitions. During the testing, the players positioned arms akimbo and performed 3 trials of each test (SJ: [ICC: 0.95; CV:3.6%]; CMJ: [ICC: 0.93, CV:3.5%]) with approximately 2 and 3 minutes recovery time between trials and in-between tests (SJ or CMJ), respectively. The players were asked to jump as high as possible and the highest jump (cm) was recorded for further analysis.

Training interventions

Strength training at optimum power load

Prior to the beginning of the experimental period, the players' optimum power loads in both the half-squat and hip-thrust were determined and were used as load-references (ranging from 66 to 90 kg). The power training sessions began with a 10-minute warm-up (submaximal loaded squat and hip-thrust repetitions) and lasted for ~40 minutes. Soccer players from this group performed 12 strength-oriented training sessions: (Sessions 1–4) 4 × 8 using the optimum power load; (Sessions 5–8) 4 x 6 using 1.05 × the optimum power load; (sessions 9–12) 4×4 using 1.10 × the optimum power load. All power-exercises were performed interspersed by 2-

min intervals. This progress was included considering the training-induced changes in the optimum power load[9], which could not be individually adjusted due to the tight schedule of the team during the in-season phase.

Plyometric training

All plyometric sessions (lasting ~35 in first sessions to 45 minutes in last sessions) were performed just after a standardized warm-up, consisting of a series of squats, lunges and submaximal jump actions.

Participants performed the plyometric sessions, in a gymnasium type floor, at 100% of their maximal individual effort (i.e., maximal height or distance). A resting period of ~10s was considered between non-continuous plyometric drills and all sets were interspersed by 2-min intervals. Taking into consideration the stress of the plyometric training on the musculotendon unit, exercise volume was progressively increased following a plyometric progression model categorized by the total number of ground contacts (from 56 to 126; Table 1).[3]

During the training sessions of both interventions, all subjects were under direct supervision (2 coaches in OPL and 1 coach in PT) and were instructed on how to perform each exercise (general posture, movement kinematics [OPL and PT] and landing ["quietly" with soft ground impact, PT]).

Statistical analyses

Data in the text and tables/figures are presented as means ± standard deviations (± SD) or ± 90% confidence interval (± 90%CI). All data were first log-transformed to reduce bias arising from non-uniformity error. Data were then assessed for practical meaningfulness using magnitude-based inference (MBI) approaches[17]. We used this qualitative approach because traditional statistical approaches often do not indicate the magnitude of an effect, which is typically more relevant to athletic performance than any statistically significant effect. To examine the effects of the type of intervention (PT and OPL) on neuromuscular performance outcomes, differences between groups (PT vs. OPL) and differences over time (pre-training *vs.* post-training in both moments: control and intervention period) for all dependent variables were calculated. The smallest worthwhile change (SWC) was calculated (0.2 × SD) and 90% CI were also determined. Quantitative chances of beneficial/higher or harmful/lower effect were assessed qualitatively as follows: 25% to 75%, possibly; 75% to 95%, likely; 95% to 99%, very likely; and >99%, almost certain. If the chance of having beneficial/higher or harmful/lower performances was both >5%, the true difference was assessed as unclear[17]. In addition, the Cohen's *d* effect size (ES) of changes in neuromuscular performance measures was calculated. Threshold values for Cohen's *d* ES statistics were 0.20, 0.60, 1.20, 2.0 and 4.0 for small, moderate, large, very large and extremely large, respectively. In addition, to provide information about individual responsiveness to training, we showed the number of individuals who made changes greater than the SWC for each dependent variable, with the SWC being used as criteria to inform individuals who made a "positive response" in performance. Thus, the SWC was also expressed as a percentage of the group mean. All inference-based analyses were conducted using a publicly available spreadsheet (http://sportsci.org/2017/wghxls.htm).

The field tests reliability was assessed by intraclass correlation coefficient (ICC) and coefficient of variation (CV).

RESULTS

Control Period

With exception of CMJ height, in which no substantial effect (trivial ES: -0.03; 90%CI: -0.38 to 0.31) was detected, all the other physical performance measures were slightly impaired throughout the control period (9-weeks). There were *very likely* and *likely* harmful changes for SJ height (small ES: -0.51; 90%CI: -0.82 to -0.21) and COD performance (small ES: -0.50;

90%CI: -0.88 to -0.12), respectively. After the 9-week control period, 10 m (small ES: -0.21; 90%CI: -0.51 to 0.10) and 30 m (small ES: -0.23; 90%CI: -0.46 to 0.00) sprint speed were *possibly* decreased, indicating that players became slower after the control period (Table 2).

Intervention Period

Baseline

Between-groups differences at baseline for CMJ, SJ, 10 m and 30 m sprint speeds were rated as *unclear* (trivial to small ESs) (Table 3). In contrast, there was a meaningful difference between groups for COD performance at baseline. The players belonging to the PT group were *very likely* faster (better COD ability) than those in OPL group.

Within-Groups Changes

The individual percentage improvements for each participant in CMJ, SJ, 10 m sprint, 30 m sprint and COD are shown in Figure 2.

The number of individual athletes who showed improved performance for each variable were as follows: CMJ (OPL: 7 out of 8; PT: 6 out of 8), SJ (OPL: 7 out of 8; PT: 6 out of 8), 10 m sprint (OPL: 6 out of 8; PT: 4 out 7), 30 m sprint (OPL: 6 out of 8; PT: 4 out of 7) and COD (OPL: 7 out 8; PT: 5 out 7).

Raw values, relative changes and qualitative outcomes derived from MBI analyses for all performance outputs are presented in Table 3. Changes in CMJ height were *likely* (moderate ES: 0.62; 90%CI: 0.18 to 1.06) and *very likely* (moderate ES: 1.02; 90%CI: 0.46 to 1.57) positive for both PT and OPL groups, respectively. The improvements in SJ height were *very likely* (moderate ES: 0.97; 90%CI: 0.32 to 1.61) and *almost certainly* (moderate ES: 1.08; 90%CI: 0.66 to 1.51) beneficial after PT and OPL training regimes, respectively. For 10 m sprint speed, there was a *possibly* (62/37/01%) improvement in the PT group (small ES: 0.25; 90% CI: -0.05 to 0.54)), while no substantial gain (*unclear* effect: 65/25/10%; small ES: 0.36;

90% CI: -0.40 to 1.13) was noticed for OPL group. From pre- to post-training period, 30 m sprint speed was only *possibly* (54/45/01%; small ES: 0.21; 90%CI: -0.02 to 0.45) improved in the PT group, but was *likely* (93/05/02%; moderate ES: 1.02; 90%CI: 0.09; 1.95) enhanced after OPL training intervention. COD performance was also *very likely* enhanced after both PT (small ES: 0.53; 90%CI: 0.24; 0.81) and OPL (moderate ES: 0.93; 90%CI: 0.50; 1.36) training strategies.

Between-Groups Changes

Between-group changes for all performance outputs are illustrated in Figure 3.

Due to the differences between groups for COD performance at baseline, the pre-training value was inserted as covariate in the analysis. After adjusting the changes in COD performance for baseline values, OPL-based exercises induced *possibly* (small ES: 0.30; 90%CI: -0.20 to 0.81) larger gains in COD performance than PT intervention. After OPL-based training approach, changes in 30 m sprint speed were *likely* (moderate ES: 0.81; 90%CI: -0.16 to 1.78) greater than after PT intervention. Finally, there were no substantial differences (*unclear* effects) for the changes in 10 m sprint speed (trivial ES: 0.13; 90% CI: -0.73 to 0.99), CMJ (trivial ES: 0.15; 90% CI: -0.53 to 0.83) and SJ height (trivial ES: -0.01; 90% CI: -0.81 to 0.78) between both PT and OPL training groups.

DISCUSSION

This study aimed to compare the effects of 12 training sessions of plyometric vs. strength training at OPL on physical fitness of elite young soccer players. An original feature of this study was the inclusion of combined vertically (half-squat) and horizontally (hip thrust) based exercises performed at the respective optimum power zones; indeed, to our knowledge, this is the first study that has directly compared this strength-power training combination with PT. The results showed that despite both training interventions were effective in improving the lower limb performance, the OPL training was the most effective method to improve accelerated linear sprint and COD abilities. Due to its effectiveness to increase physical performance and easy applicability, not requiring maximal lifts and time-consuming or complex measures (e.g., 1RM), the implementation of the OPL method is recommended. From a practical standpoint, the very first assessment of OPL in a given exercise would require measuring barbell velocity (by using different affordable technologies[16]) at five/six different loads, but afterwards the training load can be rectified/tested with less attempts at certain predetermined periods. This might be a suitable approach when dealing with limited time and several players.

During the "control" period included in this study before starting the intervention, the regular soccer training was not sufficient to improve the physical performance measures; in fact, some of the physical abilities were impaired in this specific in-season phase. This fact might corroborate the assumption that improvements observed during the training intervention phase can be attributed to the additional conditioning programs (PT and OPL), and not to soccer training alone [2]. In fact, in some instances, even the inclusion of strength-power training is not capable to counteract the loss of power-speed capacities in soccer players due to the predominance of aerobic technical-tactical training in their programs [9].

The majority of players showed a performance improvement after both interventions, indicating the advantage of including strength power and/or plyometric sessions in the regular training schedule of youth soccer players. Nevertheless, there were some individual cases in which the performance seemed to be maintained or impaired. In fact, adaptations to strength-power training strategies is often suggested to present inter-individual variability[18, 19]. Several factors (e.g., genetics, training status, individual recovery rates, and motivation, among others) may justify this phenomenon, underlying the importance of regular monitoring to optimize training interventions.

A considerable number of jumps are executed during training and official matches (e.g. headings), which makes essential the assessment and development of jump performance in soccer players. In the current investigation, both training protocols were effective in promoting improvements in vertical jump capacity which is consistent with some recent studies in which exclusively strength-power [20, 21] or plyometric [21-23] training schemes were effective in improving jumping ability in young soccer players. Since no differences were observed between programs, it seems reasonable to assume that both interventions induced positive and similar neuromuscular adaptations related to jump ability. Potential adaptations might include increased neural drive to the agonist muscles, improved intermuscular coordination and changes in mechanical characteristics of the muscle-tendon complex[11, 24]. This is contrary to the theoretical assumption that improvements in jump height are merely achieved when executing exercises that comprise the use of the stretch-shortening cycle [25]. In fact, it has been reported that training programs that follow a biomechanical similarity between jump and strength exercise (e.g., vertical jump and half-squat, both of which are performed with emphasis on force produced along the vertical axis) are similarly efficient in improving jump performance. [24] In addition, the substantial utilization of the quadriceps in half-squat and vertical jump also establishes a possible causal mechanism (muscle size and function) for beneficial vertical jump adaptations in both interventions.[26] In this sense, the emphasis on one or the other training strategy (PT or OPL) to develop jump capability should also consider other contextual factors such as age-category, player's injury background, training level and force/power qualities, among others.

Soccer players are also required to develop their speed-related abilities to cope with the demands related to their involvement in high-intensity match and training activities [1]. Both interventional programs were successful in enhancing the sprint performance, agreeing with previous studies (with similar approaches) conducted on the topic [21, 22, 27, 28]. Indeed, both OPL and PT interventions comprised exercises with an anteroposterior force vector relative to the body (e.g., hip thrust vs horizontal jumps) that seems to be a key component in sprint performance.[29] However, it is important to emphasize that more forceful horizontal jumps (e.g., loaded bilateral horizontal jump training eliciting maximal anteroposterior amplitude per repetition[30]) were not included in our study. These exercises could have improved more sprint and COD abilities and need to be compared with OPL strategy in future studies.

Nevertheless, in the current study, the training scheme using OPL was *likely* (86% chances of a greater effect, Figure 3) more effective in translating the positive neuromuscular adaptations into 30 m sprint performance improvements than PT intervention. To some extent, these results corroborate earlier findings that loaded squat and hip-thrust exercises seemed to allow greater improvements in the later phase of a linear sprint in comparison to exercises of a more ballistic nature [21, 27, 29, 31]. The higher transfer to 30 m rather than 10 m lap sprint performance could be related to the fact that only exercises comprising heavy-loads seem to enhance the earlier phases of sprint performance (acceleration phase) [32]. In fact, as previously reported, light/moderate loads, similar to the ones used in the current study, might be less effective to increase the speed build up phase performance in comparison the maximum sprint phase [21], in which the ability to produce greater horizontal-to-vertical force ratio might be more relevant than the overall force production itself.[33] Satisfying this drill specificity principle, the hip thrust exercise, used in the OPL, seems to be very beneficial for developing the end-range hip extension strength that is of great importance during maximal sprinting[34].

Apart from this, it should also be argued that an eventual variability of the starting position could bias the 10 m performance. Despite in the present study the participants were required to start each trial in a staggered stance with their preferred foot leading, no other kinematic variables were controlled. Considering that sprint bouts during a soccer game are shorter than 30 m, with 49% being shorter than 10 m [35], training interventions to enhance the initial sprint acceleration should be contemplated.

In addition to linear sprinting, soccer players perform many CODs during a soccer training/game. Both training interventions were effective in improving COD ability probably due to general improvement in muscle power and concentric and eccentric muscle strength.[36] Nevertheless, the gains were more evident in the OPL group (63% chances of a greater effect, Figure 3). Among the several factors that influence COD (e.g., running technique, anthropometrical features, leg-muscle qualities), the straight-sprinting speeds should also be considered relevant to enhance this capability [37]. In this context, this might partially explain the higher gains in COD performance in OPL intervention, consequent to the larger improvement in accelerated running (30 m sprint) in comparison to PT scheme. Complementarily, it can also be argued that the hip thrust exercise used in the OPL group might have added a specific positive transfer to COD performance considering that the application of horizontal propulsive forces (prominent in this kind of exercise[10]) could explain more than 35% of COD performance [38].

Some limitations should be taken in consideration when interpreting the results of this study: (i) MBI analyses used in this investigation has been criticized because it inflates the Type-I error rate, resulting in a proliferation of false positive results[39], (ii) sprint and COD performances were tested using a single-beam photocell timing system that tends to present less accurate and reliable results in comparison to other systems (e.g. dual-beam, full automatic timing systems),[40] (iii) the training stimulus of each intervention (PL vs OPL) could not be directly compared considering the differences in load application between programs and, (iv) a short-term training intervention was implemented not examining the maintenance of the training effects in each group.

PRACTICAL APPLICATIONS

It may be suggested that in order to maximize the development of lower limb physical performance among elite young soccer players during the in-season phase, the use of exercises in the optimal power range load of hip-knee-ankle extensor muscles could be an effective option. Nevertheless, PT can be also concurrently included in the soccer training program to provide variation in training stimuli that effectively improve neuromuscular capacities of players. This information certainly helps coaches and sport scientists to develop better and more effective performance enhancement training programs.

CONCLUSIONS

This investigation showed that 12 sessions of two different training programs improved physical performance outcomes during the in-season period, with best results achieved with the combination of vertically- and horizontally-based training exercises at optimum power zones for the 30 m linear sprint and COD ability.

Acknowledgements:

The authors would like to acknowledge soccer players and coaches for their participation and professionalism throughout the duration of the study. There are no funding sources and no conflicts of interest surrounding this scientific investigation.

REFERENCES

1. Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med.* 2014;35(13):1095-1100.

2. García-Ramos A, Haff GG, Feriche B, Jaric S. Effects of different conditioning programmes on the performance of high-velocity soccer-related tasks: Systematic review and meta-analysis of controlled trials. *Int J Sports Sci Coaching.* 2018;13(1):129-151.

3. Bedoya AA, Miltenberger MR, Lopez RM. Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review. *J Strength Cond Res.* 2015;29(8):2351-2360.

4. Ramirez-Campillo R, Vergara-Pedreros M, Henriquez-Olguin C, et al. Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. *J Sports Sci.* 2016;34(8):687-693.

5. Loturco I, Pereira LA, Kobal R, et al. Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players. *J Sports Sci.* 2015;33(20):2182-2191.

6. Gonzalo-Skok O, Sanchez-Sabate J, Izquierdo-Lupon L, Saez de Villarreal E. Influence of force-vector and force application plyometric training in young elite basketball players. *Eur J Sport Sci.* Jul 28 2018:1-10.

7. Loturco I, Nakamura FY, Kobal R, et al. Traditional Periodization versus Optimum Training Load Applied to Soccer Players: Effects on Neuromuscular Abilities. *Int J Sports Med.* 2016;37(13):1051-1059.

8. Loturco I, Pereira LA, Kobal R, et al. Improving Sprint Performance in Soccer: Effectiveness of Jump Squat and Olympic Push Press Exercises. *PLoS One.* 2016;11(4):e0153958.

9. Loturco I, Pereira LA, Kobal R, et al. Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. *J Sports Sci.* 2015;33(12):1283-1292.

10. Contreras B, Vigotsky AD, Schoenfeld BJ, et al. Effects of a Six-Week Hip Thrust vs. Front Squat Resistance Training Program on Performance in Adolescent Males: A Randomized Controlled Trial. *J Strength Cond Res.* 2017;31(4):999-1008.

11. Davies G, Riemann BL, Manske R. Current concepts of plyometric exercise. *Int J Sports Phys Ther.* Nov 2015;10(6):760-786.

12. Ramirez-Campillo R, Alvarez C, Garcia-Hermoso A, et al. Methodological Characteristics and Future Directions for Plyometric Jump Training Research: A Scoping Review. *Sports Med.* May 2018;48(5):1059-1081.

13. Winter EM, Maughan RJ. Requirements for ethics approvals. *J Sports Sci.* Aug 2009;27(10):985.

14. Hulse MA, Morris JG, Hawkins RD, Hodson A, Nevill AM, Nevill ME. A field-test battery for elite, young soccer players. *Int J Sports Med.* 2013;34(4):302-311.

15. Contreras B, Cronin J, Schoenfeld B. Barbell hip thrust. *Strength Cond J.* 2011;33(5):58-61.

16. Balsalobre-Fernandez C, Marchante D, Baz-Valle E, Alonso-Molero I, Jimenez SL, Munoz-Lopez M. Analysis of Wearable and Smartphone-Based Technologies for the Measurement of Barbell Velocity in Different Resistance Training Exercises. *Front Physiol.* 2017;8:649.

17. 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):3-13.

18. Freitas TT, Martinez-Rodriguez A, Calleja-González J, Alcaraz PE. Short-term adaptations following Complex Training in team-sports: A meta-analysis. *PLoS ONE.* 2017;12(6):e0180223.

19. Ramirez-Campillo R, Alvarez C, Gentil P, et al. Inter-individual Variability in Responses to 7 Weeks of Plyometric Jump Training in Male Youth Soccer Players. *Front Physiol.* 2018;9(1156).

20. Hammami M, Negra Y, Billaut F, Hermassi S, Shephard RJ, Chelly MS. Effects of lower-limb strength training on agility, repeated sprinting with changes of direction, leg peak power, and neuromuscular adaptations of soccer players. *J Strength Cond Res.* 2017.

21. de Hoyo M, Gonzalo-Skok O, Sanudo B, et al. Comparative Effects of In-Season Full-Back Squat, Resisted Sprint Training, and Plyometric Training on Explosive Performance in U-19 Elite Soccer Players. *J Strength Cond Res.* 2016;30(2):368-377.

22. Loturco I, Kobal R, Maldonado T, et al. Jump Squat is More Related to Sprinting and Jumping Abilities than Olympic Push Press. *Int J Sports Med.* 2017;38(8):604-612.

23. Chtara M, Rouissi M, Haddad M, et al. Specific physical trainability in elite young soccer players: efficiency over 6 weeks' in-season training. *Biol Sport.* 2017;34(2):137-148.

24. Hammami M, Gaamouri N, Shephard RJ, Chelly MS. Effects of Contrast Strength vs. Plyometric Training on Lower Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. *J Strength Cond Res.* 2018;doi: 10.1519/JSC.0000000000002425.

25. Baker D. Improving Vertical Jump Performance Through General, Special, and Specific Strength Training: A Brief Review. *J Strength Cond Res.* 1996;10(2):131-136.

26. Bloomquist K, Langberg H, Karlsen S, Madsgaard S, Boesen M, Raastad T. Effect of range of motion in heavy load squatting on muscle and tendon adaptations. *Eur J Appl Physiol.* Aug 2013;113(8):2133-2142.

27. Dello Iacono A, Seitz LB. Hip thrust-based PAP effects on sprint performance of soccer players: heavy-loaded versus optimum-power development protocols. *J Sports Sci.* 2018;36(20):2375-2382.

28. Kobal R, Pereira LA, Zanetti V, Ramirez-Campillo R, Loturco I. Effects of Unloaded vs. Loaded Plyometrics on Speed and Power Performance of Elite Young Soccer Players. *Front Physiol.* 2017;8:742.

29. Seitz LB, Reyes A, Tran TT, Saez de Villarreal E, Haff GG. Increases in lower-body strength transfer positively to sprint performance: a systematic review with meta-analysis. *Sports Med.* 2014;44(12):1693-1702.

30. 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.* Dec 2016;37(13):1060-1065.

31. Wilson GJ, Newton RU, Murphy AJ, Humphries BJ. The optimal training load for the development of dynamic athletic performance. *Med Sci Sports Exerc.* 1993;25(11):1279-1286.

32. Chelly MS, Fathloun M, Cherif N, Ben Amar M, Tabka Z, Van Praagh E. Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *J Strength Cond Res.* 2009;23(8):2241-2249.

33. Los Arcos A, Yanci J, Mendiguchia J, Salinero JJ, Brughelli M, Castagna C. Short-term training effects of vertically and horizontally oriented exercises on neuromuscular performance in professional soccer players. *Int J Sports Physiol Perform.* May 2014;9(3):480-488.

34. Schache AG, Blanch PD, Dorn TW, Brown NA, Rosemond D, Pandy MG. Effect of running speed on lower limb joint kinetics. *Med Sci Sports Exerc.* Jul 2011;43(7):1260-1271.

35. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. *Sports Med.* 2005;35(6):501-536.

36. Young WB, Dawson B, Henry GJ. Agility and Change-of-Direction Speed are Independent Skills: Implications for Training for Agility in Invasion Sports. *International Journal of Sports Science & Coaching.* 2015;10(1):159-169.

37. Sheppard JM, Young WB. Agility literature review: classifications, training and testing. *J Sports Sci.* 2006;24(9):919-932.

38. Dos'Santos T, Thomas C, Jones PA, Comfort P. Mechanical Determinants of Faster Change of Direction Speed Performance in Male Athletes. *J Strength Cond Res.* 2017;31(3):696-705.

39. Sainani KL. The Problem with "Magnitude-based Inference". *Med Sci Sports Exerc.* Oct 2018;50(10):2166-2176.

40. Haugen T, Buchheit M. Sprint Running Performance Monitoring: Methodological and Practical Considerations. *Sports Med.* May 2016;46(5):641-656.

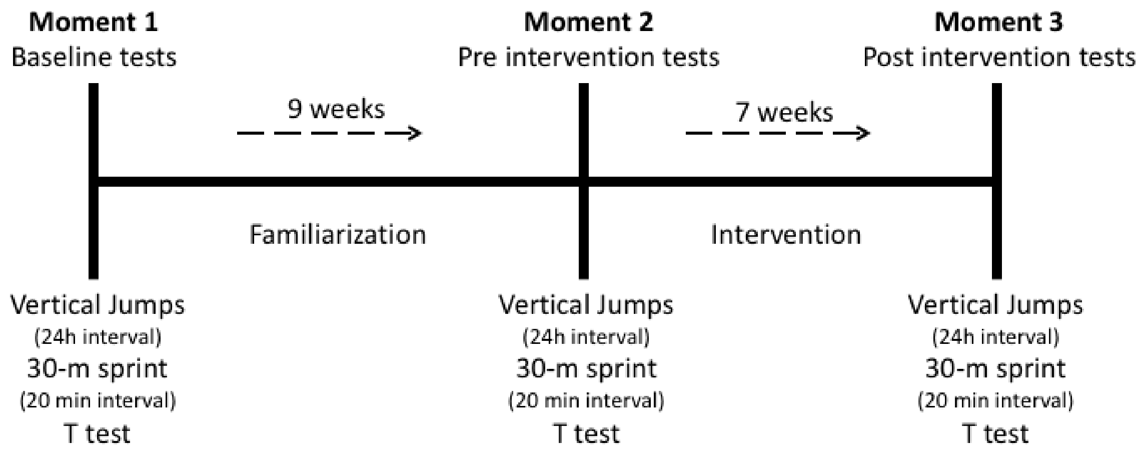

Figure 1. Experimental design

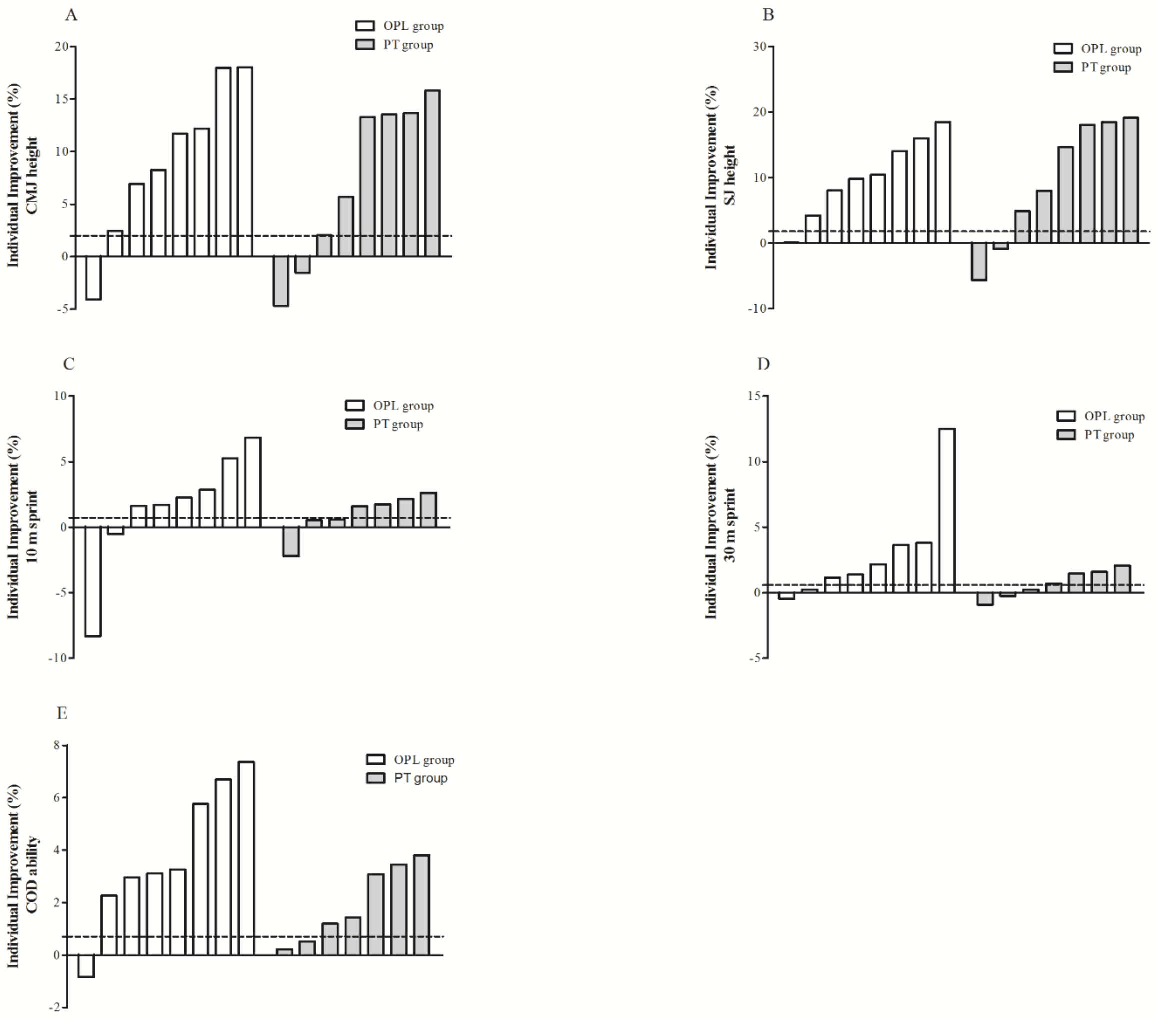

Figure 2. Individual responses to plyometric or optimum power load training for each participant in countermovement (CMJ), and squat jump, (SJ), 10 and 30 m sprint, and COD performance

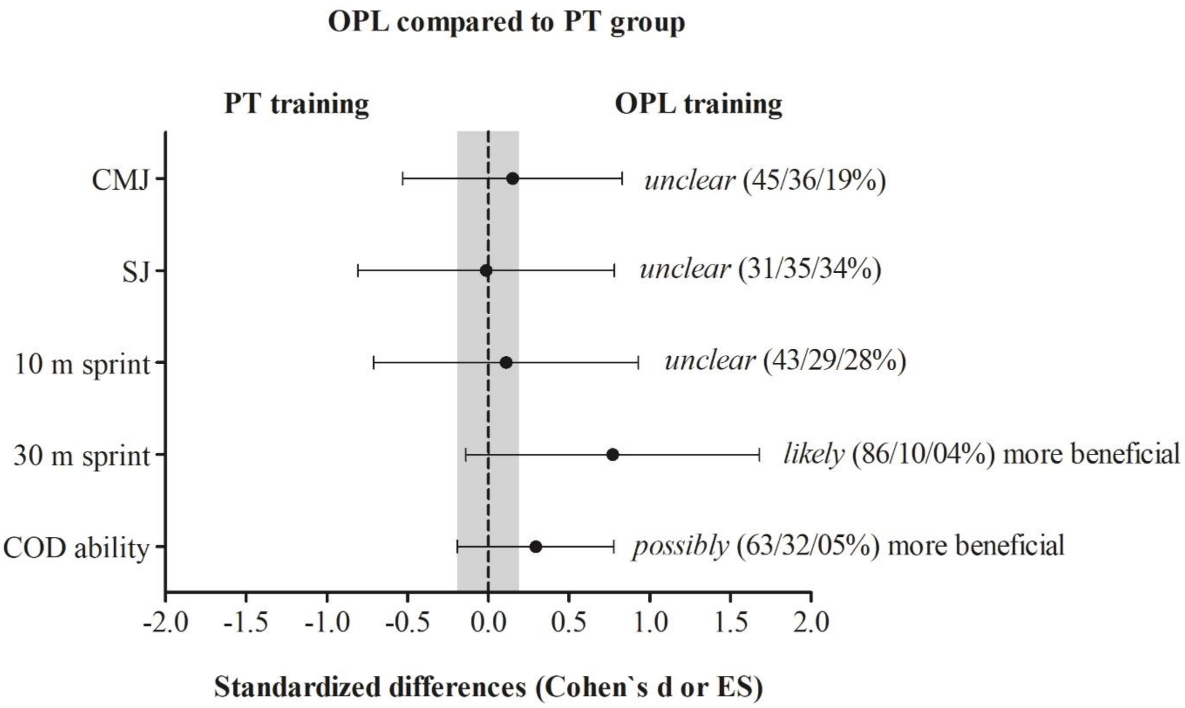

Figure 3. Efficiency of Optimum power load (OPL) compared to Plyometric training (PT) to improve countermovement (CMJ), and squat jump, (SJ), 10 and 30 m sprint, and COD performance. Bars indicate uncertainty in the true mean changes (with 90% confidence limits). Grey area represents the smallest worthwhile change

Table 1. Plyometric training program

	Sets (reps)	Nº Contacts
SESSIONS 1-2		
Frontal hops	1 (8)	8
Backward hops	1 (8)	8
Lateral hops	2 (8)	16
Power skips	3 (8)	24
	Total Impacts	56
SESSIONS 3-6		
Forward hops over 15 cm cone	2 (8)	16
Lateral hops	3 (12)	36
Single leg forward hop (right leg)	2 (8)	16
Single leg forward hop (left leg)	2 (8)	16
	Total Impacts	84
SESSIONS 7-8		
On and off box jumps (30 cm)	2 (10)	20
Lateral hops over 25 cm hurdle	3 (6)	18
Power skips	4 (8)	32
Toe taps on soccer ball	2 (12)	24
	Total Impacts	94
SESSIONS 9-12		
On and off box jumps (45 cm)	2 (12)	24
Box drop jumps for height (55 cm)	3 (10)	30
Single leg forward hop (right leg)	2 (8)	16
Single leg forward hop (left leg)	2 (8)	16
High knees over 25 cm hurdles	4 (10)	40
	Total Impacts	126

Table 2. Descriptive statistics (mean ± SD) and changes (with 90% confidence interval) in physical performance after control period.

	Before Training	**After Training**	**%Change (90%CI)**	**Cohen's d (90%CI)**	**Chances (B/T/H)**	**Outcomes**
CMJ (cm)	38.56 ± 2.42	38.48 ± 2.78	-0.22 (-2.54; 2.09)	-0.03 (-0.38; 0.31)	13/67/20%	Unclear
SJ (cm)	36.46 ± 3.88	34.34 ± 3.20	-5.82 (-9.28; -2.36)	-0.51 (-0.82; -0.21)	00/05/95%	Very Likely ↓
10 m ($m \cdot s^{-1}$)	5.49 ± 0.24	5.44 ± 0.20	-0.98 (-2.43; 0.46)	-0.21 (-0.51; 0.10)	02/46/52%	Possibly ↓
30 m ($m \cdot s^{-1}$)	7.01 ± 0.24	6.95 ± 0.21	-0.85 (-1.70; -0.01)	-0.23 (-0.46; 0.00)	00/40/60%	Possibly ↓
COD ability ($m \cdot s^{-1}$)	4.27 ± 0.11	4.21 ± 0.13	-1.35 (-2.37; -0.33)	-0.50 (-0.88; -0.12)	00/09/91%	Likely ↓

↓: indicates reduced performance; CMJ: countermovement jump; SJ: squat jump; COD: change of direction ability; B: chance of a beneficial change; T: trivial change; H: chance of a harmful change

“Effects of Plyometric vs Optimum Power Training on Components of Physical Fitness in Young Male Soccer Players”
by Ribeiro J et al.
International Journal of Sports Physiology and Performance

Table 3. Descriptive statistics (mean ± SD) and changes (with 90% confidence interval) in physical performance after plyometric (PT) or optimum power load (OPL) training.

		Before Training	**After Training**	**Magnitude-Based Inference**			
	Training Group	Mean ± SD	Mean ± SD	% Change (90%CI)	ES (90%CI)	Chances (B/T/H)	Outcomes
CMJ (cm)	PT	39.76 ± 4.37	42.80 ± 5.23	7.64 (2.17; 13.10)	0.62 (0.18; 1.06)	94/05/01%	Likely ↑
	OPL	38.10 ± 3.19	41.74 ± 3.1	9.55 (4.30; 14.80)	1.02 (0.46; 1.57)	99/01/00%	Very Likely ↑
SJ (cm)	PT	35.93 ± 3.38	39.60 ± 4.64	10.23 (3.40; 17.06)	0.97 (0.32; 1.61)	97/02/01%	Very Likely ↑
	OPL	34.94 ± 2.97	38.56 ± 1.52	10.37 (6.34; 14.42)	1.08 (0.66; 1.51)	100/00/00%	Almost Certainly ↑
10 m ($m \cdot s^{-1}$)	PT	5.43 ± 0.19	5.48 ± 0.17	1.00 (-0.19; 2.19)	0.25 (-0.05; 0.54)	62/37/01%	Possibly ↑
	OPL	5.50 ± 0.20	5.58 ± 0.22	1.48 (-1.61; 4.56)	0.36 (-0.40; 1.13)	65/25/10%	Unclear
30 m ($m \cdot s^{-1}$)	PT	7.01 ± 0.20	7.06 ± 0.20	0.71 (-0.07; 1.48)	0.21 (-0.02; 0.45)	54/45/01%	Possibly ↑
	OPL	6.92 ± 0.19	7.14 ± 0.29	3.14 (0.28; 5.99)	1.02 (0.09; 1.95)	93/05/02%	Likely ↑
COD ability ($m \cdot s^{-1}$)	PT	4.25 ± 0.14	4.34 ± 0.11	1.96 (0.90; 3.03)	0.53 (0.24; 0.81)	97/03/00%	Very Likely ↑
	OPL	4.16 ± 0.15	4.33 ± 0.13	3.88 (2.08; 5.68)	0.93 (0.50; 1.36)	99/01/00%	Very Likely ↑

↑: indicates improved performance. CMJ: countermovement jump; SJ: squat jump; COD: change of direction ability; B: chance of a beneficial change; T: trivial change; H: chance of a harmful change.