TRADITIONAL FREE-WEIGHT VERSUS VARIABLE RESISTANCE TRAINING APPLIED TO ELITE YOUNG SOCCER PLAYERS DURING A SHORT PRESEASON: EFFECTS ON STRENGTH, SPEED, AND POWER PERFORMANCE

Running head: *Variable vs traditional strength-training in soccer players*

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ABSTRACT

Maximizing the neuromuscular capacities of players is a critical challenge during short soccer preseasons. This study compared the effects of two strength-power training regimes, on the strength, speed, and power performance of elite young soccer players during a 4-week preseason. Twenty-five under-20 players from the same club were pair-matched in two training groups as follows: traditional training group (TTG) (n=13), athletes performed half-squat (HS) and jump-squat (JS) exercises as traditionally prescribed; and EB group (EBG) (n=12), athletes performed HS and JS with EB attached to the barbell. Vertical jump height, 20-m sprint velocity, change-of-direction (COD) speed, HS and JS power, and one-repetition maximum (1RM) in the HS were assessed pre, post 2-week, and post 4-week of training. An ANOVA two-way with repeated measures was used to assess the effects of both training protocols over the experimental period. Both strategies were effective for significantly improving HS and JS power (effect sizes [ES] 1.00 - 1.77), HS 1RM (ES = 1.68 and 1.51 for TTG and EBG, respectively), vertical jumping ability (ES 0.37 - 0.65), and COD speed (ES = 0.81 and 0.39 for TTG and EBG, respectively), when comparing pre- and post-measures. In contrast, both TTG and EBG failed to increase 20-m sprint velocity (ES ranging between -0.54 and 0.23). In conclusion, both training schemes were able to improve the strength and power performance, but not the sprint capacity of young soccer players. To accelerate strength gains over very-short time periods (i.e., 2-week), variable resistance training may be advantageous. Conversely, to optimize power adaptations in ballistic exercises across a similar time period, traditional FW training may be preferred.

Key words: team sports, football, ballistic exercises, free weights, neuromuscular adaptation.

INTRODUCTION

Maximizing strength, speed, and power capacities during short soccer preseasons is a critical challenge for coaches and sport scientists (26, 30, 35, 37).It is recognized that the high volumes of aerobic-based training (e.g., technical-tactical sessions) performed throughout these phases may compromise the proper development of neuromuscular abilities, due to the well-established interference training effects (30, 53). From an applied perspective, this can be considered a key paradox, as modern soccer increasingly requires faster and more powerful players to effectively deal with the high-intensity (and crucial) game situations (5, 11, 17). Moreover, higher levels of strength and power developed in a balanced manner (i.e., between agonist and antagonist muscles) have been consistently associated with decreased risks of injury occurrence and recurrence (4, 8, 16, 38, 54). As a consequence, practitioners are constantly seeking more efficient strategies to improve these physical qualities in elite soccer players.

For instance, half-squat (HS) or jump-squat (JS) exercises performed at the optimum power load (OPL) (i.e., load that maximizes power output) were effective at counteracting the speed and power decrements which commonly occur over short soccer preseasons (i.e., 4-6 weeks) (30).Correspondingly, in a 4-week intervention, Loturco et al. (31) reported meaningful improvements in speed and power-related abilities in under-20 (U20) players who executed JS using loads 20% higher or lower than the OPL (i.e., ~ 2% increases in vertical jump height and 5-m sprint speed). In fact, greater changes in neuromechanical capacities and kinematic indices during soccer preseasons have only been observed in longer studies (i.e., 8-12 weeks), when young or senior athletes were exposed to a higher number of resistance training sessions (i.e., ~ 5.5% increases in both jump and short sprint performance and ~ 16% increases in both linear and angular knee velocities assessed during a maximal kicking instep test) (32, 52, 53). Nonetheless, in several tournaments around the world, the preseason training phase lasts between 4 and 6 weeks (6, 40, 49). Hence, there is a need to develop methods able to improve neuromuscular performance in shorter periods of time.

More recently, the concomitant utilization of elastic bands (EB) and free-weights (FW) has been suggested as an alternative way to maximize strength gains in resistance trained subjects (48). In summary, this training combination can provide higher external resistance at the final phase of the movement (when the EB is overstretched) and relatively lower resistance during its initial concentric phase (compared with traditional FW training) (23, 44, 45). Accordingly, Saeterbakken et al. (44) reported increases of 117, 105, and 93% in the upper, middle, and lower positions in squats with EB, respectively, compared to constant FW exercise using a six-repetition maximum load (i.e., 6RM). This additional resistance might offer an extra training stimulus, thereby optimizing the neuromuscular adaptations in the latter stages of the movement (3, 7, 20, 48). In contrast, this load increment will also provoke an increased deceleration rate at the upper portion of the lifting which, in theory, could negatively affect power development (13, 39).This effect may be even more pronounced in ballistic exercises (e.g., JS), which allow for continued and progressive acceleration over the entire range of motion (12, 13, 39). Therefore, it would be interesting to examine the effects of traditional (e.g., HS) and ballistic exercises separately after training phases exclusively composed of these exercises. This is crucial to determine whether the influence of variable resistance training on athletic performance may also be impacted by the exercise selection.

Furthermore, even in a short period of time, it would be important to assess the effectiveness of a more mixed resistance training scheme, which implements different exercises and loading intensities, with or without the concomitant utilization of EB. This multifaceted approach may allow coaches to select and use more efficient training strategies, especially during very congested training periods, such as soccer preseasons (30, 35, 37). The aim of the present study was to compare the effects of a traditional versus variable strength-power training regime on strength, speed, and power performance of U20 players during a 4-week soccer preseason. Based on the above-mentioned factors, we hypothesized that training with EB would elicit greater adaptations in strength-related capabilities (e.g., maximum strength), whereas FW training would produce higher improvements in speed and power performances.

METHODS

Experimental Approach to the Problem

A two-group, randomized, longitudinal design was conducted to test the effectiveness of two distinct training programs on the strength, speed, and power performance of elite young soccer players during a 4-week preseason training period. Players were ordered, from the lowest to the highest 1RM values in the HS, in a customized spreadsheet, and grouped in pairs according to their baseline results. Subsequently, the group allocation of each pair was performed by tossing a coin. All athletes had been previously familiarized with the training and testing routines. The performance tests were performed in the following order: squat and countermovement jump (SJ and CMJ), sprinting speed at 5-, 10-, and 20-m, Zigzag change of direction (COD) speed, HS and JS maximum power outputs assessment, and 1RM test in the HS exercise. The physical tests were performed at the same day, in three distinct phases: pre, post 2-week, and at the end of the training period (4-week). Prior to all testing sessions, a general and specific warm-up routine was performed, involving light running (5-min at a self-selected pace) and submaximal attempts at each testing exercise (e.g., submaximal sprints and vertical jumps).

Subjects

Twenty-five male U20 players (age: 18.5 ± 0.6 years; age range: 18-20 years old); height: 179.2 ± 6.2 cm; body-mass [BM]: 71.7 ± 5.7 kg) from the same soccer club with at least six years of experience in a professional training program and regularly competing in the São Paulo State Championship, the most important regional Brazilian youth tournament, took part in this study. Athletes were pair-matched in two training groups as follows: traditional training group (TTG; n = 13), athletes who performed HS and JS exercises as traditionally prescribed; and EB group (EBG; n = 12), athletes who performed HS and JS exercises adding EB to the bar as described elsewhere (23). The study protocol took place during a 4-week preseason training phase. The study was approved by the local Ethics Committee and the participants signed an informed consent form prior to research commencement.

Procedures

Vertical jumping tests

Vertical jump height was assessed using the SJ and CMJ. In the SJ, athletes were required to remain in a static position with a 90° knee flexion angle for ~ 2-s before jumping, without any preparatory movement. In the CMJ, athletes were instructed to execute a downward movement followed by complete extension of the legs and were free to determine the countermovement amplitude to avoid changes in jumping coordination. All jumps were executed with the hands on the hips and the athletes were instructed to jump as high as possible. The jumps were performed on a contact platform (Elite Jump®, S2 Sports, São Paulo, Brazil) and jump height was automatically calculated based on the flight-time. A total of five attempts were allowed for each jump, interspersed by 15-s intervals. The best attempts for the SJ and CMJ were used for subsequent analyses.

Sprinting speed

Four pairs of photocells (Smart Speed, Fusion Sport, Brisbane, Australia) were positioned at the starting line and at the distances of 5-, 10-, and 20-m. Soccer players sprinted twice, starting from a standing position 0.3-m behind the starting line. The sprint tests were performed on an indoor running track. Sprint velocity (VEL) was calculated as the distance travelled over a measured time interval. A 5-min rest interval was allowed between the two attempts and the fastest time was retained for analyses.

Zigzag change of direction speed test

The COD course consisted of four 5-m sections marked with cones set at 100° angles performed on an indoor court (24). Athletes were required to decelerate and accelerate as fast as possible without losing body stability. Two maximal attempts were completed with a 5-min rest interval between attempts. Starting from a standing position with the front foot placed 0.3-m behind the first pair of photocells (Smart Speed, Fusion Sport, Brisbane, Australia) (i.e., starting line), players ran and changed direction as quickly as possible, until crossing the second pair of photocells, placed 20-m from the starting line. The fastest time from the two attempts was retained for analyses.

Bar power outputs in half-squat and jump squat exercises

Maximum mean propulsive power (MPP) outputs were assessed in HS and JS, all performed on a Smith machine (Hammer Strength Equipment, Rosemont, IL, USA) as previously described (27, 28, 46). To determine the MPP, a linear velocity transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine barbell and values were automatically derived by the custom-designed software. The bar position data were sampled at 1,000 Hz. The maximum MPP values obtained in each exercise were used for analysis. Values were normalized by dividing the absolute power by the athletes' body mass (i.e., relative power = $W \cdot kg^{-1}$). In addition to the MPP values, the loads corresponding to bar-velocities ranging from 0.90 to 0.40 $m \cdot s^{-1}$ in the HS and ranging from 1.2to 1.0 $m \cdot s^{-1}$ in the JS in both traditional and EB modes were also assessed in each respective group to determine the training loads during the distinct training phases. Importantly, in the traditional mode, only weight plates were used to generate resistance, while in the EB mode, the resistance was simultaneously generated by the EB and the weight plates. The length of EB was individually adjusted before each exercise set, according to the players' heights (23). On average, the EBG used loads 20 and 24% lower than the TTG to achieve the same bar-velocities in the HS and JS exercises, respectively.

Maximum dynamic strength test in the half-squat exercise

Maximum dynamic strength was assessed using the 1RM HS test as previously described (10). Prior to the test, subjects executed two warm-up sets, as follows: 1) five repetitions at 50% of the estimated 1RM, and 2) three repetitions at 70% of the estimated 1RM. A 3-min rest interval was provided between all sets. After 3 minutes, athletes started the test and were allowed up to five attempts to achieve their 1RM (i.e., maximum weight that could be lifted once using proper technique), which was measured to the nearest 1 kg (10). The test was performed using a Smith-machine device (Hammer-Strength Equipment, Rosemont, IL, USA). Values were normalized by dividing the 1RM by the athletes' BM (i.e., relative strength).

Training Program

During the experimental period, all soccer players performed 12 resistance training sessions. The players involved in this study participated in all prescribed training sessions during the preseason training period. The typical weekly training schedule is presented in Table 1. A velocity-based training (VBT) program (41) was employed to ensure that all athletes trained at similar movement velocities (hence, intensities) during every training session, independent of their respective training groups (Figure 1). Under this approach, athletes from both groups executed the exercises at the same bar-velocities. The unique difference between the training protocols was the use (or not) of the EB as an alternative way to add resistance to the barbell in conjunction with the weight plates. As a result, we completely isolated the potential effects of using or not using EB during ballistic and non-ballistic exercises. This is the first study to use a VBT strategy to balance and match the movement velocity between variable and traditional resistance training programs.

Training sessions

Athletes were asked to move the bar as fast as possible during all sets and repetitions throughout the training sessions. The bar-velocities were progressively assessed with EB (EBG) and without EB (TTG) every 3 training sessions, in order to accurately determine the exact training load for each specific training session. The EBG used an adapted variable resistance device, composed of two EBs of "moderate" intensity (Pro-Action Sports Ltda., São Paulo, Brazil) attached to the Smith-Machine structure (Figure 2). This mechanical adaptation was directly made by the soccer team technical staff, and all players were accustomed to performing traditional and ballistic exercises using this apparatus. The training sessions consisted of performing 6 training sessions in 2 weeks using the HS exercise (strength foundation phase) and 6 subsequent training sessions in the other 2 weeks using the JS exercise (power-oriented training phase). The detailed training prescription including volume and intensity are presented in the figure 1.

*****INSERT TABLE 1 HERE*****

*****INSERT FIGURE 1 HERE*****

*****INSERT FIGURE 2 HERE*****

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Data normality was confirmed using the Shapiro-Wilk test. To examine the differences in the performance tests among the three assessments performed in the two intervention groups, an ANOVA two-way with repeated measures (group x time interaction) followed by the Bonferroni's *post-hoc* (using IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY, USA) was performed. The statistical level of significance was set as $P < 0.05$. Additionally, to determine the magnitude of the differences between the groups pre- and post-training and delta changes, effect sizes (ES) were calculated and interpreted using the thresholds proposed by Rhea (42) for highly trained subjects, as follows: <0.25, 0.25-0.50, 0.50-1.00, and >1.00 for trivial, small, moderate, and large, respectively. All performance tests used herein demonstrated small errors of measurement, as evidenced by their high levels of accuracy and reproducibility (coefficient of variation <5% and intraclass correlation coefficient [using an alpha two-way mixed model] >0.90 for all assessments) based on previously described criterion (19).

RESULTS

Both training groups had similar performances at baseline (pre-measurements) in all physical tests ($P > 0.05$). Table 2 shows comparisons of the vertical jump heights, HS and JS power, and HS 1RM between both groups of training over the three distinct assessments. Both TTG and EBG groups exhibited similar significant increases in JS and HS power, as well as in HS 1RM when comparing pre and 2nd week tests ($P < 0.05$). In addition, both training groups displayed similar significant improvements in vertical jump height, HS and JS power, and HS 1RM, at the 4th week (in comparison to pre- measurements; $P < 0.05$). A group x time interaction was only observed for the JS power, in which the TTG showed a significantly higher increase than the EBG at all periods of assessment ($P < 0.05$).

*****INSERT TABLE 2 HERE*****

Figure 3 depicts the comparisons of the linear and COD sprint velocities between the TTG and EBG across the assessment periods. Overall, the linear sprint velocities in the three distances tested were significantly impaired after 2 weeks of training and returned to baseline values at the 4th week in both groups of training (ES ranging from 0.82 and 1.52 for TTG and ES ranging from 1.07 and 1.87 for EBG, in all distances tested comparing pre vs 2nd week and 2nd week vs 4th week; $P < 0.05$). No significant difference was observed when comparing pre vs 4th week for the linear sprint tests in both groups (ES ranging from 0.02 to 0.23 for TTG and ES ranging from 0.36 to 0.68 for EBG, in all distances tested; $P > 0.05$). No group x time interaction was observed for the linear sprint tests ($P > 0.05$).

*****INSERT FIGURE 3 HERE*****

For the Zigzag COD test, TTG presented a significantly superior performance in the final assessment (4th week) compared to the previous measurements (pre and 2nd week; ES = 0.81 and 0.86, respectively; $P < 0.05$; within-group main effect of time). No significant difference was observed in the COD test between pre and 2nd week for the TTG (ES = 0.05; $P > 0.05$; within-group main effect of time). For the EBG, a significantly higher COD velocity was observed in the 4th week compared to the 2nd week of training (ES = 0.82; $P < 0.05$; within-group main effect of time), while no significant differences were observed when comparing pre vs 2nd week and pre vs 4th week measures (ES = 0.42 and 0.39, respectively; $P > 0.05$; within-group main effect of time). Finally, no group x time interaction was observed for the COD test performance ($P > 0.05$).

DISCUSSION

The purpose of this study was to examine and compare the effects of sequentially performing HS and JS exercises at similar velocities, with or without the concomitant use of EB, on the strength, speed, and power performance of elite young soccer players during a 4-week soccer preseason. The main findings were: (1) throughout the intervention, both strategies were able to significantly improve JS power, HS power, HS 1RM, and vertical jumping ability; (2) both training protocols failed to increase linear sprint velocity and only TTG elicited significant improvements in COD speed (within-group difference). In general, the magnitude and time course of these changes varied throughout the 4-week training intervention.

Although significant and consistent from pre- to post-measurement, the increases in strength-power capacities occurred at different rates across the study. Regarding maximum dynamic strength, both groups presented significant and large improvements (ES $\geq$ 1.51) after the 4-week training period. Nonetheless, the evolution and magnitude of these changes were distinct between the groups, with the EBG displaying a higher increment in the first two weeks, as demonstrated by the larger ES at this time-point (Table 2). In contrast, from week 2-4, the TTG continued to show a progressive increase in HS 1RM, which was confirmed by the significant within-group difference (and *moderate* ES) observed in this group over this period. This agrees with the notion that variable resistance components may provide a superior stimulus for enhancing force production and muscle activity, by offering a gradual increase in the external load throughout the range of motion, especially in the upper portion of the movement (1, 2, 43, 44). Thus, despite the absence of significant differences between both training schemes, the larger ES displayed by EBG for 1RM gains (ES = 1.46 versus ES = 0.92 for TTG) suggests that the elastic overload accelerated the strength adaptations in this group, allowing players to achieve greater gains in a shorter period of time (i.e., 2-week). Anderson et al. (3) reported similar findings when comparing the effects of "combined" (EB+FW) and "traditional" FW training during a 7-week intervention on 44 young athletes from 3 sports. In that study, both groups improved bench-press and squat 1RM, but the combined group presented an improvement nearly two and three times greater for bench-press and squat, respectively. Based on this, the authors concluded that variable resistance can work as an effective adjunct to training, which might be related to the alterations in contractile machinery (i.e., neuromuscular structures) provoked by the concomitant utilization of EB and FW when raising or lowering loads. Nevertheless, longer studies (i.e., from 10 to 12 weeks) found no significant differences in strength gains between groups who trained with or without the simultaneous use of bungee cords (2, 36). Therefore, it is possible that the additional effect of variable resistances on strength development occurs mainly at shorter time periods, being gradually reduced as the training progresses. This could explain why the TTG continued to improve (and the EBG stopped improving) strength capacity from the 2^{nd} to 4^{th} week, thereby equating the total increase of the EBG in HS 1RM at post-assessment. In practical terms, the accentuated impact of EB on strength performance may have special importance in elite soccer settings (e.g., very-short pre-seasons, inter-seasons, and intensive competitions), where strength-power training time is extremely limited (30). These effects should be investigated in long-term experiments, in order to provide a better understanding of the chronic use of variable loads on maximum strength.

For the first time, we tested the effects of sequentially combining non-ballistic and ballistic exercises in a variable resistance training program. This aspect, added to the fact that participants were assessed at the end of each specific training phase, allowed us to make more accurate inferences about the effects of using EB under different exercise conditions, and its possible implications for power development. For instance, after the non-ballistic phase (between pre and 2^{nd} week), the power adaptations were quite similar in both groups, with significant (and at least moderate) increases for both HS and JS power (Table 2). The only noticeable difference between these changes was related to the superior increases in JS power observed in the TTG, as revealed by the significant between-group differences detected for all time points and the greater ES observed at the 2nd week for this group (i.e., large, versus moderate ES in EBG). The same holds true for the changes detected between the 2nd and 4th weeks (ballistic phase), where only the TTG presented a moderate ES for the increases in JS power (whereas the remaining ES for power variations ranged between trivial and small). From these data it is possible to conclude that: (1) overall, both training strategies were able to improve power production in young soccer players, and (2) these increases were superior in the TTG, but were only related to the performance obtained in ballistic exercises, being higher over a very-short period of time (i.e., 2 weeks) and after a training phase comprising traditional resistance exercises performed at heavier intensities (i.e., strength-oriented phase; bar-velocities ranging between 0.4 and 0.9 $m \cdot s^{-1}$). Thus, it is possible to speculate that the combination between heavy loads and EB may reduce the enhancement in power output over shorter time periods; however, these effects seem to be mitigated at lighter loading conditions (i.e., power-oriented phase; bar-velocities ranging between 1.0 and 1.2 $m \cdot s^{-1}$). These findings are in line with previous research showing similar improvements in power-related performance in both upper- (i.e., bench press) and lower-limb exercises (i.e., back squat and split squat) executed at moderate and heavy loading conditions (i.e., training intensities ranging from 70 to 92% 1RM; with EB providing a fixed resistance of ~ 20% 1RM [for bench press] and between 27 and 58% of the total resistance [for back and split squats]) in elite young athletes and other populations after comparing the chronic effects of variable and constant resistance training programs (2, 43). This is the first study to demonstrate these effects under a mixed training scheme, which simultaneously combined non-ballistic and ballistic exercises over a 4-week training period.

In general, the functional abilities (sprinting and jumping) also presented a similar evolution throughout the training period. Regarding sprint speed, neither group showed significant differences from pre to 4th week, but curiously exhibited an impaired performance at the mid-test point (2nd week). These results are similar to those observed in numerous studies performed during soccer pre-seasons where, as aforementioned, the high volume of aerobic-based training sessions (i.e., technical-tactical training) seems to hamper the adequate development of speed performance (30, 31, 53), regardless of the resistance training approach used. Added to this, these negative effects may have been potentiated by the use of heavy loads across the strength foundation phase, as the loads prescribed during this phase were within a velocity range of 0.4 to 0.9 $m.s^{-1}$. This means that the players started this period using a HS load corresponding to ~ 85% 1RM (0.4 $m.s^{-1}$) and continued to use heavy loads (≥ 75% 1RM, ~0.5 $m.s^{-1}$) for a substantial period of time (33). Indeed, the adverse effects and "reduced levels of transference" of strength training with heavy loads to maximum sprint speed have been extensively reported in the literature, and these effects may be even more pronounced in soccer players (9, 22, 25, 34).Conversely, between the 7th and 12th training sessions (week 2-4), the strength training intensity decreased considerably, with the JS being performed at velocities ≥1.0 $m.s^{-1}$ (~ 45-50% 1RM), a velocity range recognized for maximizing the power output in this exercise (27, 31). Finally, after this training phase, which comprised only ballistic movements executed at moderate loads, the athletes recuperated their initial levels of sprint velocity over 5-, 10-, and 20-m (compared to their pre values). As such, it is possible that the significant decrements in maximum sprint velocity detected at mid-testing were not related to the training strategies *per se,* but stem from the use of heavy loads during the strength foundation phase (25, 34).

With respect to COD speed, both groups displayed an equivalent performance level at the mid-test point; nevertheless, at the 4th week, only the TTG presented a significant improvement in comparison to the pre-measurements (within-group difference). Thus, it can be concluded that: (1) heavy strength training does not affect (i.e., improve or impair) COD performance over very-short time periods (i.e., 2-week), and (2) ballistic JS performed at moderate loads may induce positive changes in COD speed. Our findings indicate that these effects may be optimized when this exercise is executed without the simultaneous use of EB, and within a range of loads able to maximize power output. Likewise, Cronin et al. (14) did not find a significant gain in multidirectional agility in sport-trained subjects who performed a resistance training program including “bungy jump squats”. The same occurred in the “non-bungy jump squat condition”, although this group demonstrated a trend towards greater improvement in agility (an increase of 1.4% versus an increase of 0.7% detected in the “bungy condition”). However, in that study, both groups completed the “conditioning programme” performing JS at heavy loads (i.e., 8-RM; ~ 80% 1RM), which may have affected the transference of strength and power gains to functional performance (25, 47, 51). From these data, it might be suggested that traditional strength training is superior to variable resistance training for improving COD speed; nonetheless, this theoretical superiority is only obtained under certain circumstances, specifically when athletes train at moderate loading conditions. This agrees with previous observations and confirms the critical role played by vertical force production in the COD performance of elite soccer players (15, 21, 25, 47). Therefore, soccer coaches are recommended to frequently include vertically oriented exercises (e.g., squat and JS) at moderate loads in their resistance training routines, in order to enhance vertical force production and, hence, COD speed. Specifically, for this purpose, the exercises should preferably be performed without the concomitant use of EB.

Both TTG and EBG significantly improved vertical jump performance (SJ and CMJ) at post-testing (Table 2). Nevertheless, our findings suggest that these increases may occur to a greater extent in the EBG (moderate ES versus a small ES observed in the TTG, in both SJ and CMJ tests). Our results are in accordance with previous research, which also demonstrated the superiority of variable over traditional FW resistance training programs in improving vertical jumping ability, regardless of the intervention time (5 or 7 weeks) or subjects' training background (i.e., strength-trained athletes, wrestlers, and team-sport players) (3, 20). The authors of these studies suggest that the greater adaptations in jumping capacity observed in the EB groups may be related to the higher magnitude of neuromuscular adaptations induced by the increased and progressive rate of elastic tension generated throughout the entire range of motion, which requires athletes to continuously accelerate during the concentric portion of the lifting (3, 20, 48). On the other hand, in traditional FW training, the load is only accelerated until the "sticking period" (i.e., the phase of minimal leverage, where there is a temporary reduction in movement velocity) (50). From this period, the implement (e.g., weighted barbell) will decelerate in order to stop the movement at the end of the upward phase of the lifting (48). It may be that during the whole training period (including during the non-ballistic HS training phase), the EBG executed exercises which allowed for continued acceleration throughout the range of motion, thus allowing for greater transference to sport-specific performance (13). This is especially true in vertical jumps, as higher acceleration rates will result in higher take-off velocities and, hence, in higher jump heights (18, 29). Therefore, the cumulative effect of sequentially performing two different types of continuously accelerative movements across the 4 weeks of the study may explain the apparent superiority exhibited by the EBG in the post SJ and CMJ tests. Practitioners should consider this specific and particular mechanical aspect when selecting the optimal training approaches to maximize vertical jump performance in soccer players.

In summary, we showed that both traditional and variable resistance training strategies comprising traditional HS and ballistic JS exercises are effective in improving the strength and power capacities of elite young soccer players during a short soccer preseason. These significant enhancements occurred at different magnitudes over the entire training period. On the contrary, neither EBG nor TTG achieved meaningful improvements in linear sprint ability, and only TTG displayed significant increases in COD speed in relation to the pre-measurements. This study is limited by its short duration, as it was performed during an actual 4-week soccer preseason. However, this is a real and frequent scenario in modern soccer, which requires researchers and coaches to identify and select more effective methods for enhancing the physical performance of their athletes during this critical training phase. Future studies should examine the long-term adaptations to variable and combined (e.g., EB + FW) resistance training programs as well as to test the effectiveness of different training methods (e.g., resisted sprints and assisted jumps) on the neuromuscular performance of elite young and senior soccer players.

PRACTICAL APPLICATIONS

This study has important implications for coaches, especially with respect to the effective development of strength, power, and speed-related abilities during short soccer preseasons. To accelerate strength gains over very-short time periods (i.e., 2-week), variable resistance training might be preferred over traditional FW training. Conversely, to optimize power adaptations in ballistic conditions at light and moderate loads across a similar time period, traditional FW training may be advantageous. Importantly, these respective differences in power increases appear to be mitigated after longer training periods (i.e., 4-week), specifically after a ballistic training phase. According to previous studies on these topics, linear sprint velocity did not increase at post-testing (30, 35, 37), but presented a significant decrease at mid-testing, after the “strength foundation phase” (25, 34). Thus, it seems that the use of heavy loads may compromise the proper development of sprint capacity during soccer preseasons, regardless of the training strategy employed (i.e., EBG or TTG). Finally, COD speed improved significantly only in the TTG, which seems to be a direct consequence of the increases in vertical force production through the use of a moderate range of loads without the concomitant utilization of EB. Practitioners should be aware of these potential factors when designing training programs to improve athletic performance in the context of congested soccer preseasons.

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FIGURE CAPTIONS

Figure 1. A schematic presentation of the study design.

Figure 2. Adapted variable resistance device with elastic bands attached to the Smith-machine barbell.

Figure 3. Comparisons of the linear and change of direction (Zigzag) sprint velocity (VEL) between the traditional training group (TTG) and elastic bands group (EBG) across the distinct periods of assessment. *Within-group difference in relation to pre, $P < 0.05$; $^{\#}$within-group difference in relation to 2nd week, $P < 0.05$.

Table 1. Weekly training program for the soccer players during the 4 weeks of preseason.

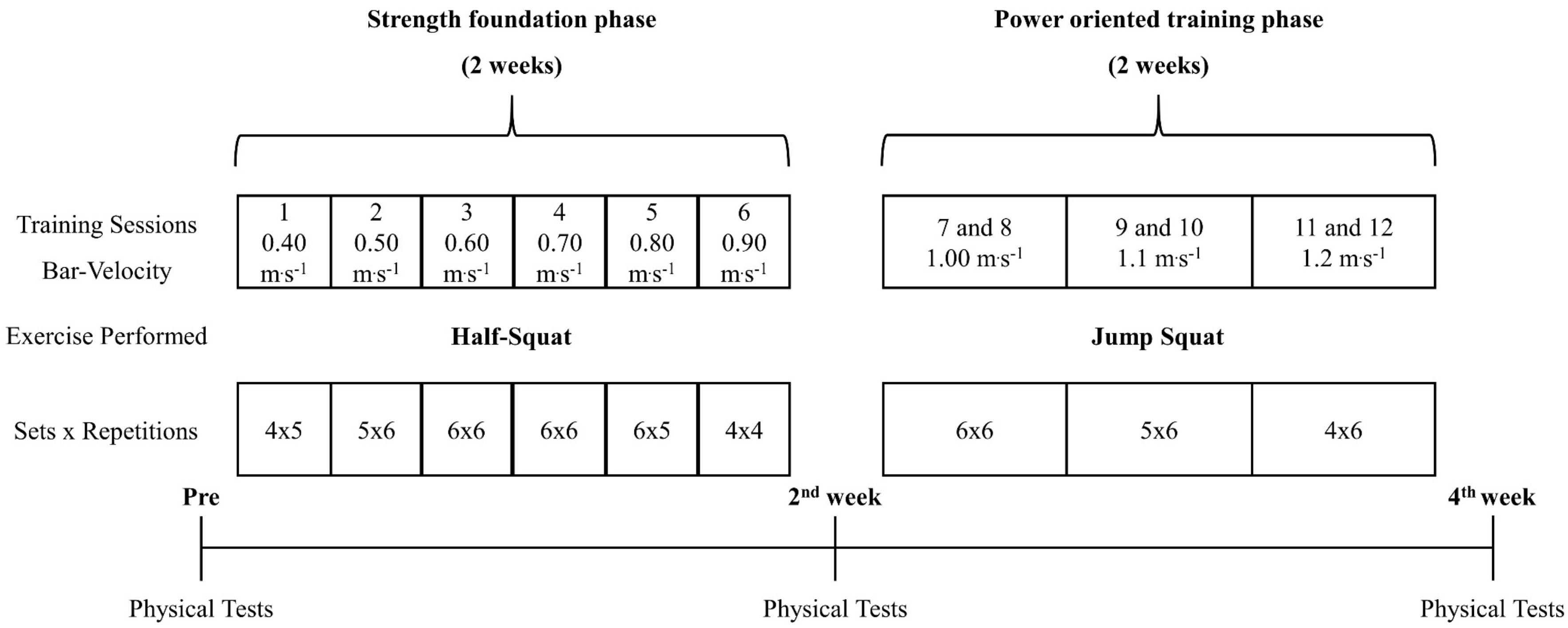
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Morning	S/PT 30’	TEC/TAC 70’	S/PT 30’	TEC 40’	S/PT 30’	TEC 50’
Afternoon	TEC/TAC 80’	TEC 50’	TEC/TAC 80’	TEC/TAC 90’	TEC/TAC 90’	Rest

Note: TEC = Technical Training; TAC = Tactical Training; S/PT = Strength and Power Training; The numbers after the training sessions represent the volume in minutes. TEC/TAC training involved different formats of small-sided games and specific technical actions (e.g., goal shooting, corner kick situations).

Table 2. Comparisons of the vertical jump heights, relative bar power outputs, and relative maximum strength between groups.

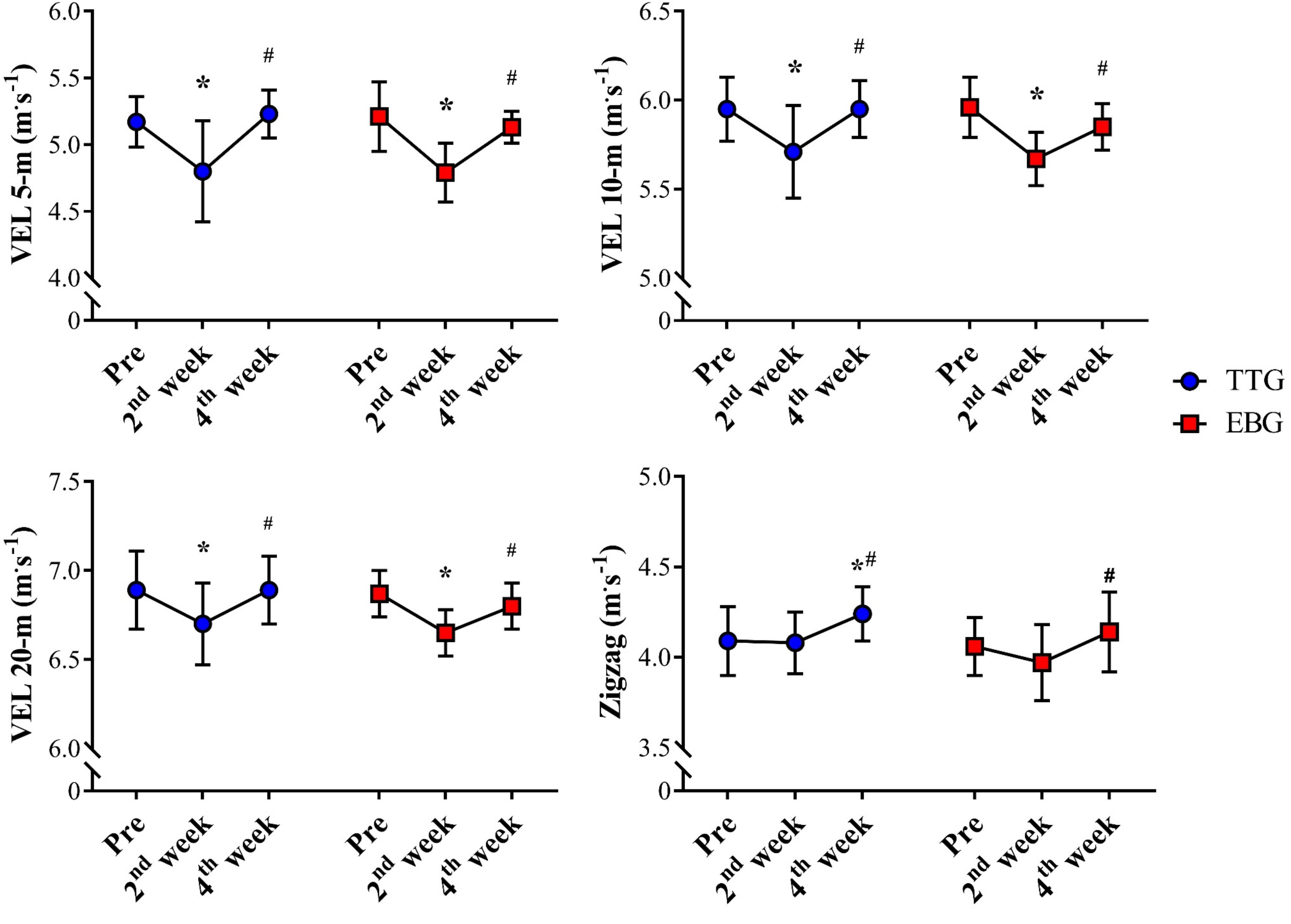
		Pre	**2nd Week**	**4th Week**	**Effect Sizes (*rating*)**		
					Pre *vs* 2nd	**Pre *vs* 4th**	**2nd *vs* 4th**
SJ (cm)	TTG	40.7 ± 5.2	41.7 ± 5.3	42.9 ± 5.9*#	0.16 (*trivial*)	0.37 (*small*)	0.21 (*trivial*)
	EBG	38.9 ± 4.1	39.9 ± 3.8	41.6 ± 4.3*	0.23 (*trivial*)	0.62 (*moderate*)	0.39 (*small*)
CMJ (cm)	TTG	43.3 ± 5.4	44.5 ± 5.7	46.0 ± 6.1*#	0.20 (*trivial*)	0.44 (*small*)	0.25 (*small*)
	EBG	42.4 ± 3.5	43.7 ± 3.3	45.0 ± 4.1*#	0.34 (*small*)	0.65 (*moderate*)	0.31 (*small*)
JS Power ($W \cdot kg^{-1}$)	TTG	10.60 ± 1.05	12.59 ± 1.83*	13.38 ± 1.43*#+	1.27 (*large*)	1.77 (*large*)	0.50 (*moderate*)
	EBG	10.69 ± 1.45	11.74 ± 1.25*	12.36 ± 1.31*	0.73 (*moderate*)	1.16 (*large*)	0.43 (*small*)
HS Power ($W \cdot kg^{-1}$)	TTG	8.32 ± 1.13	9.56 ± 1.35*	9.91 ± 1.78*	0.80 (*moderate*)	1.03 (*large*)	0.22 (*trivial*)
	EBG	8.13 ± 1.14	8.99 ± 1.26*	9.48 ± 1.33*	0.64 (*moderate*)	1.00 (*large*)	0.36 (*small*)
HS 1RM	TTG	1.79 ± 0.29	2.08 ± 0.44*	2.32 ± 0.39*#	0.92 (*moderate*)	1.68 (*large*)	0.76 (*moderate*)
	EBG	1.71 ± 0.30	2.18 ± 0.36*	2.20 ± 0.36*	1.46 (*large*)	1.51 (*large*)	0.05 (*trivial*)

SJ: squat jump; CMJ: countermovement jump; JS: jump squat; HS: half-squat; 1RM: one repetition maximum; TTG: traditional training group; EBG: elastic band group; *Within group difference in relation to pre, $P < 0.05$; #within group difference in relation to 2nd week, $P < 0.05$; +Group x time interaction for all time points (greater improvements in this variable in comparison to the other group), $P < 0.05$.



Strength foundation phase
(2 weeks)
Power oriented training phase
(2 weeks)
Training Sessions
Bar-Velocity
1 0.40 m·s-1
2 0.50 m·s-1
3 0.60 m·s-1
4 0.70 m·s-1
5 0.80 m·s-1
6 0.90 m·s-1
7 and 8 1.00 m·s-1
9 and 10 1.1 m·s-1
11 and 12 1.2 m·s-1
Exercise Performed
Half-Squat
Jump Squat
Sets x Repetitions
4x5
5x6
6x6
6x6
6x5
4x4
6x6
5x6
4x6
Pre
2nd week
4th week
Physical Tests
Physical Tests
Physical Tests


5
10



VEL 5-m (m·s-1)
6.0
5.5
5.0
4.5
4.0
0
VEL 10-m (m·s-1)
6.5
6.0
5.5
5.0
0
VEL 20-m (m·s-1)
7.5
7.0
6.5
6.0
0
Zigzag (m·s-1)
5.0
4.5
4.0
3.5
0
*
#
*#
Pre
2nd week
4th week
TTG
EBG