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The Effect of a Combined High-Intensity Strength and Speed Training Program on the Running and Jumping Ability of Soccer Players

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Abstract. Kotzamanidis, C., D. Chatzopoulos, C. Michailidis, G. Papaiakovou, and D. Patikas. The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. *J. Strength Cond. Res. 19(2):369–375. 2005.*—The purpose of this study was to investigate the effect of a combined heavy-resistance and running-speed training program performed in the same training session on strength, running velocity (RV), and vertical-jump performance (VJ) of soccer players. Thirty-five individuals were divided into 3 groups. The first group ($n = 12$, COM group) performed a combined resistance and speed training program at the same training session, and the second one ($n = 11$, STR group) performed the same resistance training without speed training. The third group was the control group ($n = 12$, CON group). Three jump tests were used for the evaluation of vertical jump performance: squat jump, countermovement jump, and drop jump. The 30-m dash and 1 repetition maximum (1RM) tests were used for running speed and strength evaluation, respectively. After training, both experimental groups significantly improved their 1RM of all tested exercises. Furthermore, the COM group performed significantly better than the STR and the CON groups in the 30-m dash, squat jump, and countermovement jump. It is concluded that the combined resistance and running-speed program provides better results than the conventional resistance training, regarding the power performance of soccer players.

Key Words. running speed, squat jump, counter movement jump

Introduction

Soccer is a sport that is based on explosive actions such as kicking, jumping, and sprinting (32). Players cover about 10 km during a game (32) and need to sprint repeatedly within irregular intervals during the game. The relevant literature reveals that running velocity (RV) can be improved following several types of training interventions, such as sprint training without external resistance, towing, overspeed (11), and specific plyometric (speed-bound) exercises (33). Furthermore, it has been reported that resistance training does not improve RV, despite the applied intensity (11, 12, 22, 28, 36, 44).

The jumping ability of a soccer player could also be considered crucial for his or her performance. Vertical jump (VJ) is a complex movement that greatly depends on interlimb coordination (8), on muscle fiber type and stiffness (7), and occasionally on maximum strength, depending on the level of the athlete's performance (6). Relevant literature has shown that VJ is improved through various types of training methods, such as resistance training (1, 6, 15), depth jump (41), jumping (stretch-shortening cycle) exercises (1, 6, 15, 28, 44), and a combination of plyometric exercises and electrostimulation (27). It has been demonstrated that explosive-type resistance training is more effective in improving VJ, compared to high-resistance training (28, 44). However, it has also been reported that resistance training does not always result in enhancement of VJ, which is affected by other factors such as learning effect (9), training status (2), and volume of training (24).

Several studies have reported that combined programs including resistance and explosive unloaded tasks, such as throwing, jumping, and karate punching, in the same training session may improve muscular strength and the velocity of execution on the selected task (6, 11, 14, 23, 25, 39, 42, 43). Improvements were attributed either to neural adaptations or to a learning transfer. To our knowledge, there is no information concerning the effectiveness on RV of a combined program including high resistance and repeated multi-articular movement such as running speed. For this reason, the main purpose of this study was to investigate the effect of a combined program including high-resistance running speed training in the same session on RV. The secondary purpose of the study was to investigate the effectiveness of the above mentioned combined program on jumping ability. Part of this study was published previously (31).

Methods

Experimental Approach to the Problem

This study was designed to address 2 questions: (a) Does a combined resistance and running-speed program performed in the same training session affect RV? (b) Is this program superior to a conventional resistance program in terms of vertical-jump performance? However, we must emphasize that our intention was not a comparison with previously used conventional running-speed programs. We concentrated on the possible effect of heavy resistance training on RV. For this reason 2 groups of soccer players followed 2 different training programs, one consisting of conventional resistance training and the other one consisting of combined strength and running-speed training in the same session. Both groups were compared with a control group, which consisted of moderately active individuals of the same age. The effectiveness of the applied training programs was evaluated with pre- and posttraining testing in strength, running velocity, and vertical

TABLE 1. Participants' physical characteristics and training age (mean ± *SD*).

Groups*	*n*	Age (y)	Mass (kg)	Height (m)	Training age (yr)
COM	12	17.0 ± 1.1	73.5 ± 1.2	1.78 ± 0.35	4.0 ± 1.5
STR	11	17.1 ± 1.1	72.5 ± 2.2	1.75 ± 0.25	4.0 ± 1.5
CON	12	17.8 ± 0.3	75.0 ± 1.8	1.76 ± 0.13	—

* COM = combined resistance and speed training program group; STR = resistance training only group; CON = control group.

jump. In the pretraining testing period, participants initially visited our laboratory to be familiarized with the testing procedures, and in a second visit they performed all the selected tests.

Subjects

Thirty-five healthy male volunteers divided among 3 groups (2 experimental groups and 1 control group) participated in this study. The 2 experimental groups consisted of 23 soccer players. The soccer players were separated into 2 experimental groups after drawing lots: a group that followed the combined program (COM group) ($n = 12$) and a group that followed only resistance training (STR group) (n = 11). The control group (CON group) ($n = 12$) consisted of randomly selected physical education students without sport training backgrounds. The students in the CON group were moderately active because of the nature of their studies, including sessions of basketball, soccer, handball, volleyball, artistic gymnastics, and swimming. Physical characteristics and training age of all participants in this study are given in Table 1.

The experimental procedure was performed according to the ethics guidelines of the Aristotle University of Thessaloniki, Greece. All subjects were informed of all the details of the program and all possible risks associated with their involvement in the designed study. They also filled out a medical history questionnaire and signed an informed consent document before any testing. Their parents were also invited before the intervention to be informed about the study, and all gave their verbal consent. All subjects were classified by a physician for their maturation in the fifth stage according to Tanner (38).

Evaluation and Procedures

All subjects participated in 2 introductory sessions before evaluation to eliminate any learning effects and to be informed about the general resistance and running-velocity training instructions. All subjects performed a general warm-up program including 10 minutes of cycling on a Monark cycling ergometer and stretching exercises before evaluation.

Maximal Strength. The 1 repetition maximum (1RM) was determined for each exercise. After the general warm-up program, participants performed a specific warm-up including submaximal intensity performance for all tested exercises, at levels of 50, 75, and 85% of the 1RM for each participant. The relevant repetitions for each selected intensity were 12, 8, and 3 respectively. Two sets were performed for each selected intensity. After that, resistance was gradually increased from a critical value 5% below the expected 1RM. After each successful performance the intensity was gradually increased by 2% until failure in lifting of the same load was observed. The interval between repetitions was 3 minutes. For the final estimation of 1RM, 3–6 trials were used. Failure was defined when participants failed to perform the full range of motion of the selected exercise on at least 2 attempts. The full range of motion was defined by lifting the bar without any additional load. All testing procedures were closely supervised. Uniform encouragement was offered to all participants according to the American College of Sports Medicine guidelines (4). The following exercises were evaluated:

- Back half squat at 90°. Each participant kept an upright position, looking forward and firmly grasping the bar with both hands. The bar was also supported upon the shoulders. Then the participant bent his knees until he reached the limit of 90°. After that the participant raised himself to the upright position with the lower limbs completely extended (Pearson $r = 0.953$, $p < 0.05$).
- Step up on a bench with 1 leg. The participant stood with 1 foot (first foot) on the bench (knee angle = 90°) and the other foot (second foot) on the floor with the leg fully extended. Then the participant stepped onto the bench with the second foot by fully extending the first leg. Afterwards the second foot returned smoothly to the starting point. This task was separately performed for each of the feet (Pearson coefficient $r = 0.927$, $p < 0.05$).
- Leg curls for hamstrings. In the beginning position, the participant lay prone on the bench grasping the handles below the bench with his arms bent. His knees were below the bottom edge of the bench and his lower legs (ankles) were under the roller pad. Then he flexed his knees to bring the ankles as close as possible to the buttocks and then lowered the roller pad slowly and under control to beginning position. The leg curl machine was angled at the user's hip to position the hamstring in a more favorable mechanical position (Pearson coefficient $r = 0.959$, $p < 0.05$)

Running Velocity (RV). The speed was evaluated by using 2 pairs of photocells and reflectors connected with an electronic timer (Tag Heuer, Marin, Switzerland). The photocells were placed at shoulder height and the time was given in hundredths of a second. The photocells were positioned at the start and at the end of a 30-m runway. The standing start position was chosen and each participant performed 2 trials. The best time was used for the evaluation (Pearson coefficient $r = 0.966$, $p < 0.05$).

Jumping Performance. For jumping performance the participants executed 3 different jumping tests:

- Squat jump (SJ). The participant started from a stationary semisquatted position (knee angle = 90°) and jumped upward as high as possible (Pearson coefficient $r = 0.967$, $p < 0.05$).
- Countermovement jump (CMJ). The participant started from an upright standing position and performed a very fast preliminary downward movement, flexing his knees and hip. Immediately after he extended the knees and hips again to jump vertically off the ground (Pearson coefficient $r = 0.969$, $p < 0.05$).
- Drop jump (DJ40). The participant jumped from a bench (height = 40 cm) and performed a maximal jump immediately after landing on the floor (Pearson coefficient $r = 0.972$, $p < 0.05$).

All jumping tests were performed without using the

TABLE 2. Training contents of the periods.*

Periods	COM group	STR group
First period (general)	Endurance, strength endurance, coordination, flexibility	Endurance, strength endurance, coordination, flexibility
Second period (experimental) first subperiod	1. Warm-up (15 min) 2. Resistance training (8RM, 60 min) 3. Active recovery using soccer skills (10 min) 4. Speed program (15 min) 5. Active recovery (10 min)	1. Warm-up (15 min) 2. Resistance training (8RM, 60 min) 3. Technique training with very low intensity (25 min) 4. Active recovery (10 min)
Second period (experimental) second subperiod	1. Warm-up (15 min) 2. Resistance training (6RM, 60 min) 3. Active recovery using soccer skills (10 min) 4. Speed program (15–20 min) 5. Active recovery (10 min)	1. Warm-up (15 min) 2. Resistance training (6M, 60 min) 3. Technique training with very low intensity (25–30 min) 4. Active recovery (10 min)
Second period (experimental) third subperiod	1. Warm-up (15 min) 2. Resistance training (3RM, 60 min) 3. Active recovery using soccer skills (10 min) 4. Speed program (20 min) 5. Active recovery (10 min)	1. Warm-up (15 min) 2. Resistance training (3RM, 60 min) 3. Technique training (30 min) with very low intensity 4. Active recovery (10 min)

* COM = combined resistance and speed training group; STR = resistance training only group; RM = repetition maximum.

arms. For each test the participants performed 3 trials barefoot. The best performance based on height was used for analysis. The force data were collected by using an AMTI force plate with a sampling frequency of 500 Hz connected with a personal computer. The data analysis was performed using customized software.

Training Plan

Both experimental groups followed a training program of 13 weeks, which was divided into general and experimental periods (Table 2). The first (general) period lasted 4 weeks and was the same for both groups. Training frequency was 3 sessions per week. The training program for this period included endurance, strength endurance, flexibility, and coordination. This training period served as a preparatory phase to prevent possible injuries from the high-intensity program, which would be applied during the experimental period (16).

The second (experimental) period lasted 9 weeks and was divided into 3 subperiods (Table 2). The first 2 subperiods lasted 4 weeks each (microcycles) and the third subperiod lasted 1 week (microcycle). The training frequency of the 2 experimental groups was twice per week. During this period the COM group performed a combined resistance and speed program in the same training session. The STR group performed only the same resistance training as the COM group.

The periodic model was used for the resistance training (36). The intensities for each subperiod were 8RM, 6RM, and 3RM respectively. For each selected intensity, 4 sets were performed with 3-minute intervals between them. Loads were increased when subjects were able to perform more than the targeted number of repetitions with the current workload. This testing procedure was performed during the first training session of the week. Supplementary exercises included abdominal and back exercises and toe raises for the plantar flexor muscles.

Immediately after the resistance training, the COM group performed a short speed program with 4, 5, and 6 maximal intensity repetitions of 30 m in the first, second, and third subperiod respectively. A 3-minute interval was given between each repetition. The number of running trials was determined after a pilot measurement. For each subperiod, the criterion for the selected trials was that the performance time of each trial should be kept constant. This was tested during the first session of the first microcycle of each subperiod. There was an interval of 10 minutes between the resistance and speed programs. The duration of the interval was determined based on previous studies (10), which reported that a 10-minute interval after resistance training is an optimal time period for speed potentiation.

All selected tests were performed at the beginning and the end of the second (experimental) period

Statistical Analyses

Separate analyses of variance (ANOVAs) were conducted to test the differences between the 3 groups in the beginning of the intervention (pretraining status). Separate analyses of covariance (ANCOVAs) were conducted to test the differences between the 3 groups after the intervention (COM, STR, and CON groups). The final results of the tests (running speed, squat, countermovement, and drop jump) were the dependent variables, and the respective initial results were the covariates. The Scheffe post hoc procedure was used to determine which groups differed significantly. The paired samples t-test was applied for tracking down the differences between the initial and final values of a variable in the same group. The significance level was set at $p \leq 0.05$.

RESULTS

Pretraining Status

The ANOVAs with the pretraining values of the variables revealed no significant differences among the 3 groups.

Strength

Means and standard deviations of strength variables for the 3 groups in the beginning and in the end of the programs are reported in Table 3.

The paired t-tests revealed that the COM group (Half Squat $t = 9.298$, Step Up $t = 8.074$, and Leg Curls $t = 11.000$, in all cases $p < 0.01$) and the STR group (Half

TABLE 3. Mean ± *SD* of strength variables in pre and post measures for the 3 groups.†

Variable	Test	COM group	STR group	CON group
Half squat	Pre	139.58 ± 18.14	140.45 ± 15.56	138.33 ± 13.87
	Post	151.66 ± 20.59*	154.54 ± 15.72*	140.41 ± 13.39
Step up	Pre	64.16 ± 6.33	65.45 ± 7.56	69.16 ± 5.14
	Post	75.41 ± 8.38*	76.36 ± 7.10*	71.25 ± 4.33
Leg curls	Pre	50.41 ± 5.41	53.63 ± 6.74	51.25 ± 4.33
	Post	59.58 ± 5.82*	62.27 ± 5.64*	52.50 ± 5.43

* Significant difference from pretest within the group ($p < 0.01$).
† COM = combined resistance and speed training program group; STR = resistance training only group; CON = control group.

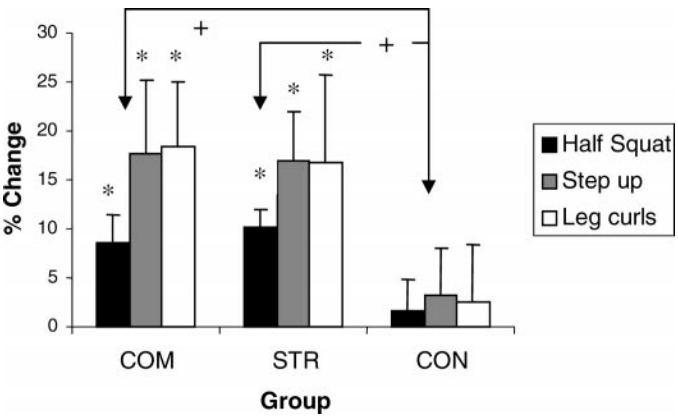

FIGURE 1. Percentage change in strength variables from pretest to posttest. * Significant difference from pretest to posttest within group. + Significant difference between groups.

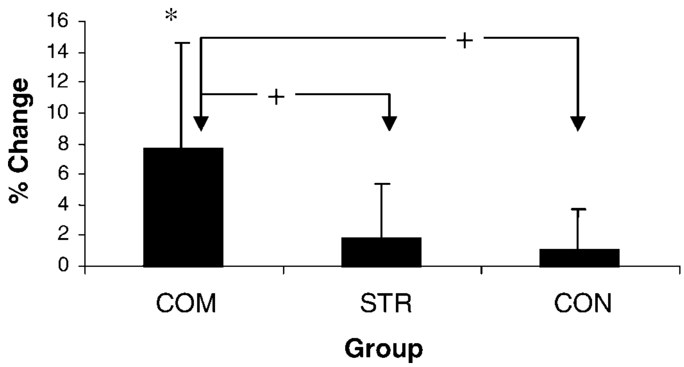

FIGURE 2. Percentage change in squat jump from pretest to posttest. * Significant difference within group. + Significant difference between groups.

Squat $t = 23.106$, Step Up $t = 17.889$, and Leg Curls $t = 7.286$, in all cases $p < 0.01$) improved significantly from pretest to posttest on all strength variables (Table 3). There were no significant changes in the CON group.

The 3 separate ANCOVAs with the strength variables indicated that there were significant differences between the 3 groups (Half Squat $F_{2,31} = 30.950$, Step Up $F_{2,31} = 19.798$, and Leg Curls $F_{2,31} = 22.568$, in all cases $p < 0.01$). The Scheffe post hoc analyses showed that the COM group and the STR group performed significantly better than the CON group on all strength variables. There were no significant differences between the COM group and the STR group (Figure 1).

Jump Performance

Means and standard deviations of squat, drop, and countermovement jumps for the 3 groups in the beginning and in the end of the programs are reported in Table 4.

Squat Jump

The results of the *t*-test indicated a significant improvement only for the COM group ($t = 3.963$, $p < 0.01$). There were no significant changes from pretest to posttest in the STR and CON groups (Figure 2).

A covariance analysis with the final values of the squat-jump test as the dependent variable and the respective initial values as the covariate revealed significant differences among the 3 groups ($F_{2,31} = 7.251$, $p < 0.01$). The Scheffe post hoc analysis showed that the COM group performed significantly better than the STR and the CON groups. There were no other significant differences among the 3 groups (Figure 2).

Drop Jump

The results of the *t*-test did not show any significant changes in any of the 3 groups from pre- to postmeasurement (Table 4). The covariance analysis for the drop jump indicated no significant differences among the 3 groups.

Countermovement Jump

The paired-samples *t*-test revealed significant improvement in the countermovement from pre- to posttest in the COM group ($t = 4.201$, $p < 0.01$). There were no significant changes in the STR and CON groups (Figure 3).

TABLE 4. Mean ± *SD* of squat-, drop- and countermovement jump in the pre and post tests for the 3 groups.†

Test		COM	STR	CON
Squat jump	Pre	25.51 ± 2.51	25.71 ± 3.14	25.80 ± 2.46
	Post	27.50 ± 3.36*	26.19 ± 3.45	26.06 ± 2.56
Drop jump	Pre	20.07 ± 3.96	18.40 ± 5.45	20.65 ± 2.94
	Post	21.18 ± 3.65*	18.88 ± 5.47	21.34 ± 4.11
Countermovement	Pre	27.83 ± 2.80	27.24 ± 3.41	28.32 ± 2.79
	Post	29.69 ± 3.55	27.48 ± 3.33	28.26 ± 2.83

* Significant difference from pretest within the group ($p < 0.01$).
† COM = combined resistance and speed training program group; STR = resistance training only group; CON = control group.

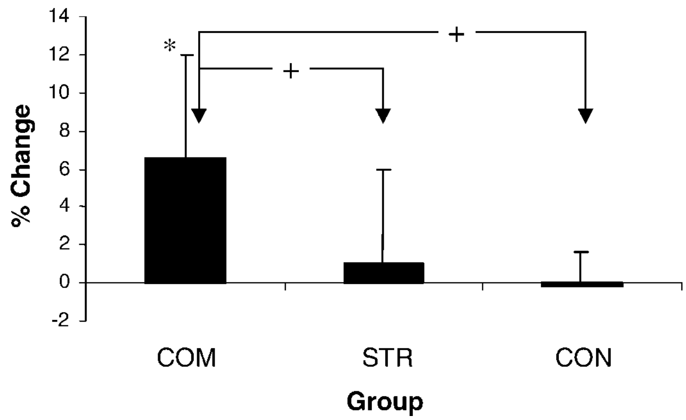

FIGURE 3. Percentage changes in countermovement jump from pretest to posttest. * Significant difference within group. + Significant difference between groups.

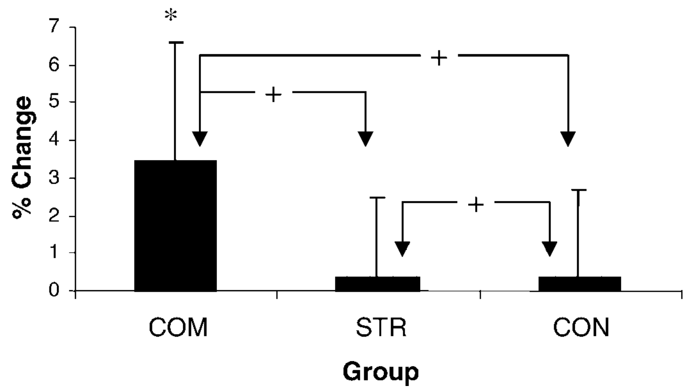

FIGURE 4. Percentage changes in 30-m running speed from pretest to posttest. * Significant difference from pretest to posttest for that group. + Significant difference between the 2 groups.

TABLE 5. Mean ± *SD* of 30-m running speed in pre and post measures for the 3 groups.†

	COM-group	STR-group	CON-group
Pre	4.34 ± 0.17	4.33 ± 0.17	4.50 ± 0.21
Post	4.19 ± 0.14*	4.31 ± 0.16	4.48 ± 0.20

* Significant difference from pretest within the group ($p < 0.01$).

† COM = combined resistance and speed training program group; STR = resistance training only group; CON = control group.

The covariance analysis for the countermovement jump indicated significant differences among the 3 groups ($F_{2,31} = 12.685$, $p < 0.01$). The Scheffe post hoc procedure revealed that the COM group performed significantly better than the STR group and the CON group. There was no significant difference between the STR group and the CON group.

Running Speed 30-m Dash

Means and standard deviations of the 30-m running speed for the 3 groups in the beginning and at the end of the programs are reported in Table 5.

The paired samples *t*-test revealed significant improvement in running speed from pre- to posttest only in the COM group ($t = 3.776$, $p < 0.01$). There were no significant changes in STR group or CON group (Figure 4).

The covariance analysis for running speed indicated significant differences among the 3 groups ($F_{2,31} = 8.458$, $p < 0.01$). The Scheffe post hoc procedure revealed that the COM and STR groups performed significantly better than the CON group. Furthermore, the COM group performed significantly better than the STR group.

DISCUSSION

The results of the study indicate that a combined high-resistance and running-velocity training program in the same training session influence positively the strength, the RV, the SJ, and the CMJ of soccer players. In contrast, the conventional resistance program improved only the strength ability. Performance of the DJ40 did not increase in either of the 2 groups.

The strength gain in both experimental groups of the current study confirm earlier studies (12) showing that strength is enhanced after a short-term high-resistance program of 9 weeks with a frequency of 2 training sessions per week. To what extent the reported strength gain of both experimental groups was attributable to morphological or neuronal factors (34) was beyond the target of this study, which is why this case was not analyzed furthermore.

The absence of running-velocity enhancement observed after resistance training in the STR group is supported by previous studies, which reported that strength training does not improve running velocity (11, 12, 22, 28, 36, 44). The basic explanation for this phenomenon is based on the fact that the resistance-training gain cannot be transferred (learning effect) to RV performance (11, 12, 35) because the nervous system cannot learn and control the acquired level of strength or muscle mass in very fast movements. This is especially true for RV because it consists of very fast repetitive movements requiring a high level of interlimb coordination, and it has kinematic and dynamic parameters that continuously change during different phases of speed performance (29, 30).

Another possible explanation for the lack of transfer is the relationship between RV performance and the exercises selected for the resistance training. Previous studies (35) have reported that heavy resistance training improved velocity of those tasks whose structure was identical with the exercises used for resistance training. Consequently it could be speculated that the reported RV improvement of the COM group was due to the immediate transfer of the acquired strength to the running technique due to the speed performance after the resistance training. This explanation is supported by previous studies, which have pointed out that training programs in which heavy resistance training and a motor task were combined in the same training session enhance task velocity (5, 39, 43). Indirect evidence for the transfer of the resistance training gain to RV was based on the design of the program, with heavy resistance training and sprint training on alternative days of the same microcycle (12).

Additional factors which probably explain the obtained results (RV improvement) of the COM group include the influence of neuronal factors and, especially, the case of postactivation potentiation (22). It has been found that after a high-intensity electrical or resistance stimulus, an inhibition of neuromuscular performance is observed initially and then a phase of high facilitation follows (3, 21, 40). Based on this concept, it has been reported (10) that the optimal time period for velocity enhancement is 5 minutes after a high-intensity resistance stimulus, and this facilitation is completely diminished 20 minutes later. The period of 10 minutes that elapsed between the resistance training and the RV program in the current study lies within the previously reported optimal intervals (10). Similar results related to the beneficial effect of resistance-training stimulus on subsequent motor tasks have also been reported for the vertical jump (18, 19).

Many studies have examined the effect of resistance training on vertical-jump performance, in many cases reporting conflicting results. Specifically it has been reported that resistance training increases VJ performance in untrained population independently of its intensity (1, 6, 15), indicating that this increase could be attributed to various factors such as the strength gain per se, neuronal involvement, rate of force development, and muscle stiffness.

However other studies (2, 9, 17) have reported that heavy resistance training does not increase VJ performance (SJ and CMJ). Analyzing these studies further, it seems that one reason for the absence of VJ increase after strength gain is the learning effect (9). Bobbert and Van Soest (9) reported that after heavy resistance training the nervous system must learn to control and transfer the additional obtained force to increase the VJ. Other studies (2, 20) found that resistance training did not improve VJ performance in well-trained athletes. Surprisingly this result was also observed in junior athletes having an intermediate level of training background (17), supporting the results obtained with the STR group in the current study. Another possible reason for the lack of VJ increase is the amount of applied training overload. Hofman et al. (24) reported that the enhancement of VJ depends on the frequency of resistance training sessions per week. They pointed out that low-frequency training caused minimal development of VJ. Taking into consideration that in Gorostiaga et al (17) and in our study, 2 training sessions per week were performed, it could be supported that the results of the STR group could be attributed to the amount of the applied training program.

The superiority of the COM-group program on VJ could be attributed to the additional load of running performance. Running performance consists of continuous repetitions of stretch-shortening cycle movements that are performed with maximum intensity exceeding the muscle activation of the maximum isometric contraction (13). Consequently it could be speculated that the combination of resistance training with RV performance affected the VJ in the same way as the combined resistance training with plyometric (stretch-shortening cycle) exercise (1, 6, 15).

Concerning the results obtained for the drop jump, it is well known that this performance depends mainly on muscle stiffness (45). It is also known that resistance training increases the muscle stiffness, as well (26). The fact that the results obtained from the 2 experimental groups did not show any increase in the drop jump from 40 cm could be attributed to the fact that neither program was sufficient to cause the adequate adaptations on the muscle-tendon unit.

To summarize, our findings support the idea that combining resistance- and speed-training programs in the same training session is more effective than the conventional resistance program for running-speed and jumping-ability enhancement. These adaptations could be attributed either to neuronal factors or to the optimal transfer of the strength gain to running performance.

Practical Applications

Previous studies demonstrated that conventional high-resistance training does not increase running velocity. The results of this study provide support for combining high-resistance training and running performance in the same training session to enhance strength, running velocity, and jumping performance, simultaneously. However, further research is required to compare the effectiveness of the combined strength and speed training program to other training methods related to running enhancement.

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