Short – Term Effects of Strength and Plyometric Training on sprint and jump performance in Professional Soccer Players

Running head: *“**Strength and plyometric training in professional soccer players**”*

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ABSTRACT

The purpose of this study was to compare the effects of combined strength and plyometric training with strength training alone on power related measurements in professional soccer players. Subjects in the intervention team were randomly divided into two groups. Group ST (n = 6) performed heavy strength training twice a week during seven weeks in addition to 6-8 soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control (C) group (n = 7) performed 6-8 soccer sessions a week. Pre and post tests were 1RM half squat, counter movement jump (CMJ), squat jump (SJ), 4-bound test (4BT), peak power in half squat with 20kg, 35kg, and 50 kg (PP_{20}, PP_{35}, PP_{50}, respectively), sprint acceleration, peak sprint velocity and total time 40m sprint. There were no significant difference between the ST+P group and ST group, thus we pooled the groups into one intervention group. The intervention group significantly improved in all measurements except CMJ, while the C group only showed significant improvements in PP_{20}. There was significant difference in relative improvement between the intervention group and C group in 1RM half squat, 4BT, and SJ. However, significant difference between groups was not observed in PP_{20}, and PP_{35}, sprint acceleration, peak sprinting velocity and total time on 40m sprint. The results suggest that there is no significant performance enhancing effects of combining strength and plyometric training in professional soccer players concurrently performing 6-8 soccer sessions a week compared to strength training alone. However, heavy strength training leads to significant gains in strength and power related measurements in professional soccer players.

Key Words: Combined training, running speed, 1RM half squat, squat jump, power.

INTRODUCTION

During a 90-minute soccer match, professional soccer players makes numerous explosive bursts, like kicking, tackling, jumping, turning, sprinting, and changing pace (5). Speed strength, also known as power, is crucial for the performance in sports where changes of direction, accelerations, and jumps are of importance (27). Hence, strength and power in leg muscles are important for professional soccer players.

Maximal strength is an important quality for power performance, because power is the product of force (strength) and velocity (speed). Thus, an increase in 1RM is usually related to improved power abilities (34). In professional soccer players, heavy strength training twice per week on leg extensor muscles has been shown to improve 1RM, vertical jump height, 10m, and 20m sprint time (18). However, the study was conducted during the preparation phase, and since there was no control group it is not possible to conclude whether the improvements were caused by seasonal changes in the concurrent soccer training (technical, tactical, and endurance) or by the strength training per se. In general, heavy strength training on leg extensor muscles is reported to improve power, jumping height and sprint performance (e.g. 11, 24, 26). Consequently a wide variety of strength training modes and training protocols have been used to develop lower extremity strength and power.

Plyometric training involves exercises where the active muscles are stretched prior to its shortening. Plyometric exercises can be done both with or without external load, and both modalities have been shown to increase power, jumping height and sprint performance (e.g. 26, 30, 39). However, contradictory results exist regarding the effects of plyometric training on speed-power measurements (23, 39) as well as for the effect of heavy strength training (17, 20, 39). Heavy strength training and plyometric training may affect different aspects of power related skills. Consequently, it has been suggested that combining heavy strength training and plyometric training improves power and power related skills to greater extent than any of the two training modalities alone (3). In the majority of studies in this field, data supports the hypothesis that combining heavy strength training and plyometric exercises is superior to only training one of the training modalities (3, 11, 17, 20, 36). The reason for this could be that these two training modes enhance two important qualities for high power production: Maximum force and rapid force development.

An 8-week combined strength, ballistic and on-court (including plyometric actions) training program in elite volleyball players resulted in superior jump performance compared to strength or on-court training only (28). We are not aware of any controlled studies in professional soccer players which focus on effects of heavy strength training with or without plyometric exercises on important skills in soccer like maximum power, jump and sprint performances. Therefore, the purpose of this study was to compare the effects of combined strength and plyometric training with strength training alone on power related skills in professional soccer players. The intervention (7-weeks) took place in the preseason preparation phase including 6-8 soccer sessions a week. We hypothesized that the combined training would be superior to strength training alone.

METHODS

Approach to the Problem

The current study was designed to address two questions: (a) Does the addition of a 7-week heavy strength training period improve strength, jumping abilities, sprint performance, and peak power production in professional soccer players during the preparation phase with concurrent soccer sessions? (b) Does a combination of heavy strength training and plyometric training result in superior improvements compared to heavy strength training alone on the abovementioned test parameters? To investigate these questions, two groups of professional soccer players conducted the same heavy strength training regime during their preparation phase and the only difference was that one group performed plyometric training while the other group conducted low-intensity core exercises. The control group consisted of professional soccer players who instead of heavy strength training performed core exercises during their preparation period. Changes in the selected variables were tested in the intervention group and control group before and after the 7-week intervention.

Subjects

Twenty-one Norwegian professional male soccer players (Premier League, see table 1 for descriptive data) volunteered to participate in this study. They had performed in average 5-7 training sessions a week during the last 3 years. The study was approved by the Regional Ethics Committee of Norway.

Subjects in the intervention team were randomly divided into 2 groups. Group ST (n = 6) performed the heavy strength training regime and no extra plyometric training in addition to 6-8 soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control (C) group (n = 7) performed 6-8 soccer sessions a week in addition to a core training program lasting approximately the same time as the abovementioned strength training program. There were no differences between groups in anthropometric parameters or the testvariables before the intervention period (Table 1 and 3).

(Table 1 about here)

Procedures

Although all subjects had experience with strength training and the half squat exercise, the intervention groups participated in two weekly strength-training sessions (12-15RM) the last three weeks before initiation of the study to make sure they used a proper lifting technique. This was a part of the transition phase leading to the preseason phase. All subjects performed both their pre and post-tests in one day with the same test order. The pre- and post-testing was done on the same equipment with identical subject-equipment positioning overseen by the same trained investigator. The post-tests were accomplished at approximately the same time of the day as the pre-tests, and 3-5 days after the last strength-training session.

All subjects performed a standardized warm-up prior to the sprint test. Subjects jogged for a 15-minute period at a moderate pace. The warm up was concluded by 4-5 40-meter submaximal runs. Subjects performed 3-4 maximal effort sprints over a distance of 40 meters. The subjects in the intervention group performed their pre and post sprints on a hard even surface in an indoor facility, while control subjects performed all their sprints on an indoor sprint track. All subjects used adapted indoor shoes. Due to different running surface, it is important to carefully interpret the absolute values in the C group and intervention group. The sprints were separated by approximately 3 minutes to ensure fully recovery between sprints. Subjects commenced each sprint from a standing (static) position in which they positioned their front foot 50 cm behind the start line. Subjects decided themselves when to start each run with the time being recorded when the subject intercepted the photocell beam. Subjects were instructed to sprint as fast as possible through the distance. Times were recorded by photocells (*JBL Systems, Oslo, Norway*) placed at the start line, after 10m, 30m, and 40m. Sprint acceleration was measured as the time to complete the first 10m, and peak sprint velocity was measured as mean velocity between 30m and 40m. The trial with the best 40m sprint time was chosen for analysis of the sprint times after 10m, 30m and 40m (CV < 3%).

Jumping measurement

After five minutes of rest, subjects performed a specific warm up consisting of 3-5 submaximal series of horizontal jumps with alternating between right and left leg. Horizontal jumping performance was evaluated by a 4-bound test (4BT), where the horizontal distance covered after a series of four forward jumps with alternate left and right foot contacts was measured with a tape. The 4BT started from a standing position, and the subjects was encouraged to cover the longest distance. The best result out of 4-6 trials was used in statistical analysis (CV<1.5%). The maximal vertical jump ability was tested on a force plate (SG-9, Advanced Mechanical Technologies, Newton, Mass., USA). Subjects performed CMJ and SJ with the hands kept on the hips throughout the jumps. During SJ, with knees at 90º of flexion, the subjects were instructed to execute a maximal vertical jump and were not allowed to use any downward movement prior to the maximal vertical jump. The force curves were inspected to verify no downwards movements prior to the vertical jump. During CMJ, the angular displacement of the knees was standardized so that the subjects were required to bend their knees to approximately 90° and then rebound upward in a maximal vertical jump. Force data were sampled at 1000 Hz for 5 seconds using an external A/D converter (USB-1408FS, Measurement Computing Corporation USA), and all data was calculated using Matlab. Jumping height was determined as the centre of mass displacement calculated from force development and measured body mass. Each subject had four attempts interspersed with approximately 1,5 minute rest between each jumps, in both SJ and CMJ and the best jump from each subject was used in data analysis (CV<3%).

Peak power measurement

Peak power was assed during loaded barbell squat jump. The test procedure was identical to SJ procedure except the increased loading of a barbell and the hands were positioned on the barbell. Subjects performed SJ against absolute loads of 20 kg, 35 kg, and 50 kg (PP_{20}, PP_{35}, and PP_{50}, respectively), on a force plate. Subjects performed two SJ at each load with two minutes rest between each attempt. The highest score of each load was recorded. Mechanical power was continuously calculated as the instantaneous product of vertical force and velocity. Peak power corresponded to the highest instantaneous power output before take-off at each load (CV<3%).

1RM measurement

Maximal strength in leg extensors was measured as 1RM in squat. Before the 1RM squat test, subjects performed a standardized specific warm-up consisting of 3 sets with gradually increasing load (40-75-85% of expected 1RM) and decreasing number of reps (12-7-3). The depth of squat in the 1RM was set to a knee-angle of 90°. To assure similar knee angle in the pre- and post-test for all the subjects, the subjects' squat depth was individually marked at the pre-test depth of the buttock on a list. Thus the subject had to reach his individually depth (touch his list with the buttock) in the post-test to get the lift accepted. The first attempt in the test was performed with a load approximately 5% below the expected 1RM load. After each successful attempt, the load was increased by 2-5% until failure in lifting the same load in 2-3 following attempts. The rest period between each attempt was 3 minutes. The coefficient of variation for test-retest reliability for this test has been found to be less than 2% (29).

Training

The 7 weeks intervention period consisted of 2 strength workouts per week on non-consecutive days. Each workout consisted of a half squat and a hip flexion exercise. The hip flexion exercise was included because it has been indicated that this exercise is important for improvement in sprinting performance (8). After a 15-minute warm-up with light jogging or cycling, subjects performed 2-3 warm-up sets of squat with gradually increased weight. All subjects were supervised by one of the investigators at all strength training sessions during the entire training period. The training intensity was 4-6RM and similar for the two groups. Subjects were encouraged to continuously increase their RM loads during the intervention. Subjects were allowed assistance on the last rep. Based on the assumption that it is the intended rather than actual velocity that determines the velocity-specific training response (6), strength training was conducted with emphasizing maximal mobilization in concentric phase, while the eccentric phase had a slower speed (approximately 2-3 sec). Training volume (number of sets) was altered similar for the two groups. During the first two weeks both groups trained with 3 sets, during the third, fourth and fifth training weeks they increased the volume to 4 sets, and during the final 2 weeks they trained with 5 sets (table 2).

(Table 2 about here)

The plyometric program for the ST+P group consisted of double arm single-leg forward jumps, single-arm alternate-leg forward bound, and double leg hurdle jump. Progressive overload principles were incorporated into the programme by increasing the number of foot contacts. Number of sets and foot contacts in each drill was between 2-4 and 5-10, respectively and rest between sets was approximately one minute (table 2). Subjects were encouraged to perform each drill with maximum intensity, emphasizing a fast switch from eccentric to concentric contraction for optimum quickness off the ground. The C group performed a core training program lasting approximately the same time as the abovementioned strength training program. The core training program focused on the deepest abdominal muscle (m. transversus abdominis) and included various balance, abdominal and back exercises with and without a fitness ball.

A regular training week for both control and intervention groups consisted of 6-8 soccer sessions lasting between 90 and 120 minutes focusing on physical conditioning, technical, and tactical aspects of the game (see figure 2 for further details).

Statistical Analyses

All values given in the text, figures, and tables are mean ± SE. A one-way analysis of variance (ANOVA) was used to determine significant differences between the ST+P, ST and C group in percentage change. After we had pooled the two intervention groups, unpaired *t*-tests were used to compare relative changes from before to after training between the intervention group and C group. Paired *t*-tests were used to test for significant changes within groups from before to after training. Pearson correlation coefficients were determined for selected variables. The level of significance was set at $p \leq 0.05$.

RESULTS

The one-way analysis of variance (ANOVA) detected no significant differences between the ST+P group and ST group in percentage change in any of the testvariables from pre to post. However, both groups increased significantly from pre to post test in 1RM half squat, 4BT, and PP_{20}, and PP_{50} ($p < 0.05$; Table 3). Neither the ST+P group nor the ST group significantly improved in CMJ performance.

(Table 3 about here)

Since there were no significant difference between the ST+P group and ST group, the two groups were pooled into one intervention group. We then found that the increase in 1RM squat from pre to post was significantly higher in the intervention group than in the C group (25% vs. 2,5%; $p < 0.001$; Figure 1), while no significant change took place in the C group.

(Figure 1 about here)

There were no differences between groups in total training volume or training intensity in soccer sessions during the intervention period (Figure 2). Of course there were difference in the amount of heavy strength training between the intervention group and C group.

(Figure 2 about here)

The horizontal jumping performance in the 4BT was significantly improved in the intervention group ($p < 0.001$). Furthermore, the relative improvement in the intervention group was superior to the C group, 4% vs. 0%, respectively ($p = 0.01$; Figure 3).

(Figure 3 about here)

Regarding vertical jump performance, there were no significant changes in either group in the CMJ test (Table 3), while the intervention group increased significantly 8.5% in the SJ (p = 0.02). This increase was significantly different from the C group (p = 0.03), which had no improvements in the SJ (Figure 4).

(Figure 4 about here)

The intervention group increased significantly in all measurements of peak power (PP_{20}, PP_{35}, and PP_{50}; $p < 0.01$). In the C group there was observed a significant increase in PP_{20} (p = 0.02), otherwise there were no changes in peak power (Table 3). There were no significant differences between groups in any peak power measurements, although there was a tendency in PP_{50} (p= 0.058).

The intervention group significantly increased running performance in the acceleration phase (the first 10m of the 40m sprint; $p < 0.02$), peak running velocity (time between 30m and 40m in the 40m sprint; $p < 0.02$), and total time during the 40m sprint test ($p < 0.02$), while there were no significant changes in the C group or between groups (Table 3).

There were significant correlations between relative strength in squat (1RM/body weight) and jump performance (r=0.5, p<0.05) and sprint performance (10 and 40 m time, r=0.4, p<0.05) at baseline. The only significant correlations between changes in 1 RM squat and changes in the power related measurements where with change in 4BT (r=0.61, p<0.01).

DISCUSSION

Both ST+P group and ST group significantly improved strength, jump, and sprint performance, but there were no significant difference between the two groups. Therefore the groups were pooled into one intervention group to increase statistical power, and compared with the C group. The intervention group significantly improved in all measurements except CMJ, while the C group only showed significant improvements in PP_{20}. After the intervention period there were significant difference between the intervention group and C group in relative changes in 1RM half squat, 4BT, SJ and a trend towards difference in PP_{50}.

In contrast to our findings superior adaptations in power related measurements are reported when traditional strength training are combined with explosive plyometric exercises in both untrained subjects (11, 36) and trained subjects (3, 7, 17). A point of interest is the fact that none of the combined studies on trained subjects performed additional training, such that the weekly amount of training sessions (2-4) was quite normal (3, 7, 17). Interestingly, in the study of Clutch et al. (7), subjects who combined strength and plyometric training was a weight training class and the other was a volleyball team with additional volleyball training five days a week during the intervention. There was only significant difference between the combined training and strength training in the group with no additional training. Whether this lack of difference is due to the jumping performed during the volleyball practice, a state of overtraining, or other possible causes remains unclear. Simmilar findings have been reported in French handball players (37). The subjects performed standard handball training three times a week during the six-week intervention period in addition to four sessions a week of combined strength and plyometric training or only strength training. No significant differences between the two intervention groups were observed in jump performance. The similarity of the studies with additionally training sessions including plyometric and explosive movements (handball, volleyball and soccer) makes it tempting to suggest that when the total amount of plyometric stimulus is large during the regular team sessions, you do not get any further advantages of combining a heavy strength training regime with plyometric exercises compared to strength training alone. The latter is further supported by the findings that strength training enhances speed of an unloaded movement only when combined with specific training of that movement (38).

The increase in 1RM half squat is fairly in line with another study on male soccer players from the Norwegian Premier League with similar heavy strength training regime (18). It is interesting to note this relative large increase in maximum strength (about 2% per training session) despite concurrent endurance, technical, and tactical soccer training. There are studies indicating that concurrent strength and endurance training impairs the strength training adaptations in some, but not all tested exercises, when the total training volume of both factors is large (19, 21). Interestingly, of the studies mentioned above, Kraemer et al. (21) measured the response of concurrent training on peak power, and Hennessy & Watson (19) measured 20m sprint and vertical jump performance and found that concurrent training impaired these adaptations.

The lack of significant difference between training group and control group in some of the parameters may be related to possible effects of overtraining. In a 6-week long study on adolescent handball players, the subjects which performed heavy strength training in addition to handball training got a compromised testosterone:cortisol ratio during the last four weeks (14). It has also been suggested that the lack of direct correspondence between increased strength and other types of performances is at least partially due to a lag time (2, 10, 35). Lag time is the period of time in which an athlete learns to use the increased strength in various sport skills. This is in line with the findings of no improvement immediately after a plyometric training period, but after a recovery period significant improvement in CMJ was found (22). Unfortunately, we were not able to perform any tests after a recovery period, so whether this is the case in our study is impossible to say.

Like in the current study, previously strength-trained subjects may experience no significant increase in their CMJ performance after a short-term strength training period and improvement in maximal strength (32, 37). In agreement with the latter, improving strength does not automatically result in more powerful movements and improved performance (20, 25, 33**)**. Improvements in exercises that include stretch-shortening cycles (SSC) are often explained through changes in the stretch reflex or increased capacity to store and reuse elastic energy (37). Consequently, it is possible that the intervention program failed to stimulate these factors significantly. However, there was a significant increase in the 4BT, which consists of several SSC. Therefore, the reason (s) for no improvements in CMJ during the current study remains unclear. Whether the findings can be explained by the above mentioned lag time, lack of recovery period, overtraining, too short intervention period or low statistical power remains unknown.

The results of this study indicate that substantial increase in 1RM can be made with little or no increase in body weight. The increase in 1RM values observed may be due to alterations in neural factors caused by the intensity of training (15). There is also a possibility that hypertrophy in leg muscles may account for the increase in 1RM because changes in body composition (reduced fat mass) is likely in this phase of the training cycle (pre-season). It has also been suggested that a possible response to strength training may be consolidation of the tissue as the muscle fibres increase in girth at the expense of extracellular spaces (13). However, we do not have data to discriminate between changes in muscle cross sectional area or neural activity as the mechanism (s) behind increased leg strength.

Furthermore, it has been stated that maximal strength is the overall most important factor in power output when movement duration is longer than 250 milliseconds (34). There are several possible reasons why the observed increase in maximum strength may increase peak power and performance in power related measurements: (A) An absolute weight would represent a smaller percentage of maximum strength, thus this weight would be easier to accelerate. (B) Increased strength is often associated with preferred hypertrophy of type II fibres (e.g. 4, 31) and thereby increasing the type II/I cross-sectional area ratio. Type II fibres are the primary motor units that contribute to high power output (16). (C) Enhanced neural drive (1). It is also likely that power production for moving light loads also depends on other force-related components such as initial rate of force development and peak rate of force development (34). Heavy strength training regimes normally results in large improvements of rate of force development (1).

Fry et al. (12) and Wilson et al. (39) reported no significant increase in sprint acceleration or velocity after training programs involving essentially vertical plyometric exercises and weight training in trained subjects. This may be related to the lack of specific sprint training during the intervention period. Furthermore, it has been reported that strength training not always improves 20m-100m sprint time (9, 17, 20, 26, 39). Interestingly, the group in the study of Kotzamanidis et al. (20), which performed sprint training in addidtion to strength training, improved their 30m-sprint performance, while the group who had no specific sprint training did not improve. Similarly, in the study of Delecluse et al. (9) there was a significant increase in sprint acceleration when strength and sprint training was combined. Thus, it seems that the concurrent sprint training (performed during the regularly soccer practices) in the present study may be important for sprint adaptations. This is in line with another study on professional soccer players, which found that concurrent heavy strength training and soccer sessions increased the sprint performance (18). Another possible explanation for the improved sprint performance in the current study may be the inclusion of a specific hip flexor exercise in the strength training program, shown to relate to improvements in sprint performance (9).

Previous studies indicates that heavy strength training and increased maximum strength generally results in greater improvements at the high force end of the force-velocity curve and that high velocity/high power training leads to superior improvements towards the high velocity end (9, 17, 26). The current study indicate that heavy strength training significantly increases performance in professional soccer players at both the high force end (1RM and sprint acceleration) and the high velocity end (peak sprint velocity and 4BT) as long as the subjects is performing concurrent plyometric and explosive exercises during their soccer sessions. We did not find any significant difference between the group which combined heavy strength training and plyometric exercises in addition to their regular soccer sessions and the group, which conducted only the heavy strength training in addition to the regular soccer sessions.

PRACTICAL APPLICATIONS

Our data indicate that professional soccer players can achieve improvements in strength and power related measurements as a result of a 7-week heavy strength training period. When professional soccer players conducts a 7-week heavy strength training regime during their preseason preparation phase with an addition of a weekly amount of 6-8 soccer sessions, there seems to be no further improvements by including a specific plyometric training program. However, the specific mechanisms responsible for the observed findings cannot be determined from the current study. Furthermore, we cannot conclude on any long-term consequences of the two training modalities.

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Legends to Figures

Figure 1. Relative changes in 1RM half squat during the 7-week training in the intervention group and control group. *Significant different from baseline ($p < 0.001$). #Significant differences between groups ($p < 0.001$).

Figure 2. Training volume (hours) and distribution of training volume amonge the intervention group and the C group.

Figure 3. Relative changes in 4BT (4 bounce test) during the 7-week training in the intervention group and control group. *Significant different from baseline ($p < 0.001$). #Significant differences between groups ($p = 0.01$).

Figure 4. Relative changes in counter movement jump (CMJ) and squat jump (SJ) during the 7-week training in the intervention group and control group. *Significant different from baseline ($p = 0.02$). #Significant differences between groups ($p = 0.03$).

FIGURES

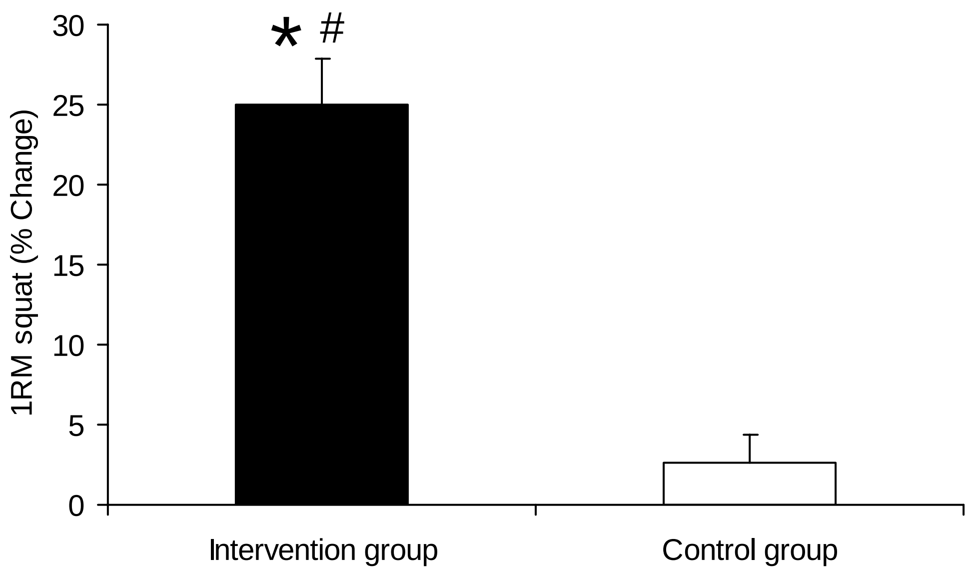


Figure 1. Relative changes in 1RM half squat during the 7-week training in the intervention group and control group. *Significant different from baseline ($p < 0.001$). #Significant differences between groups ($p < 0.001$).

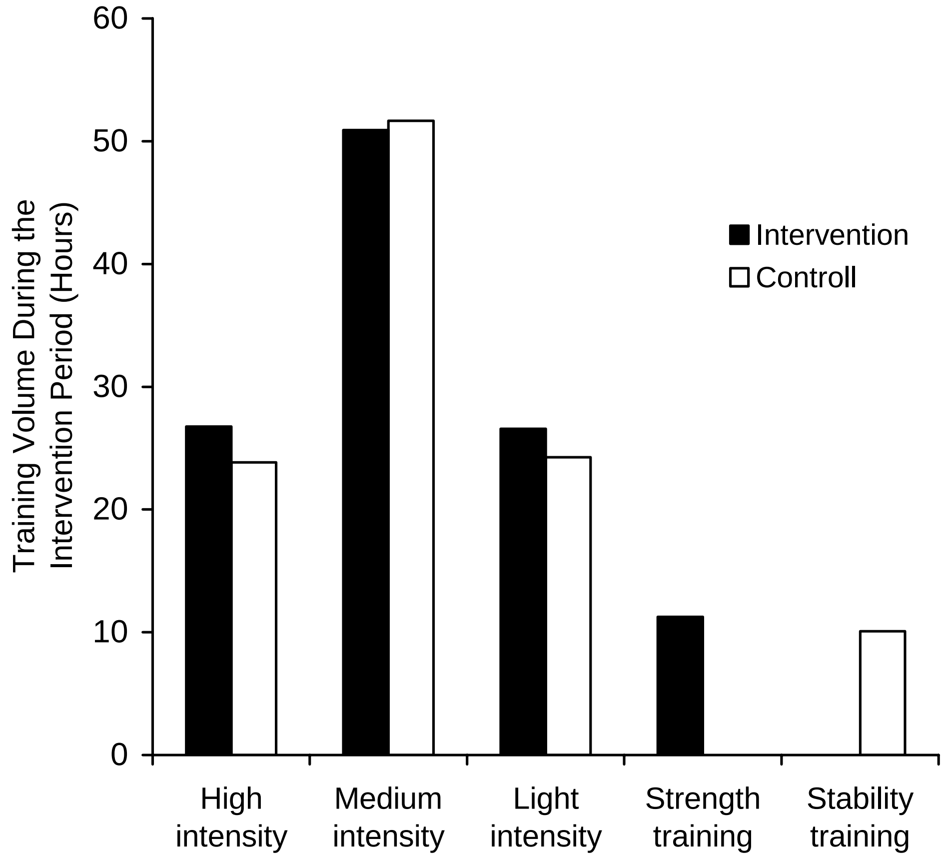
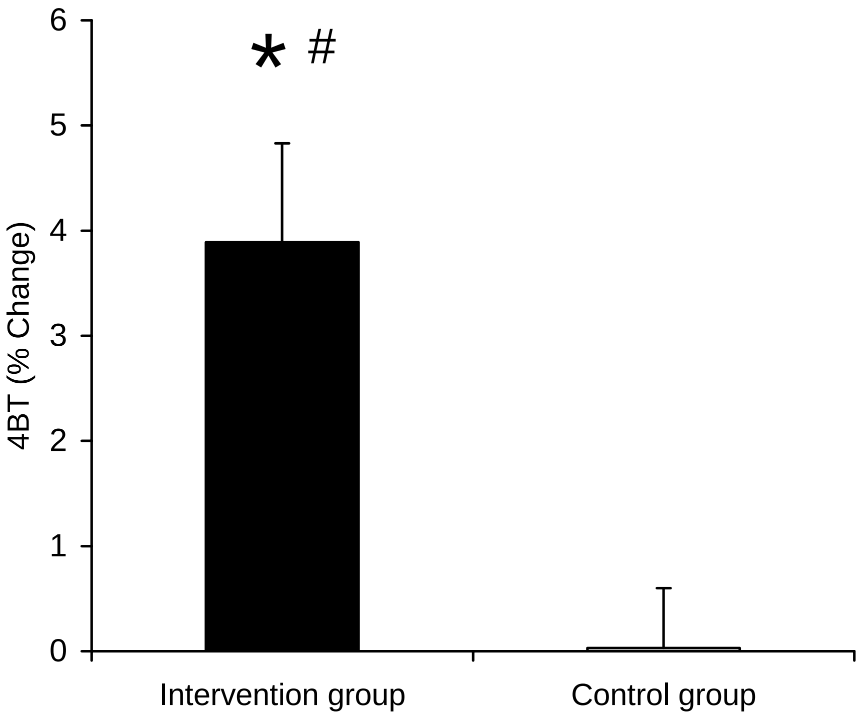


Figure 2. Training volume (hours) and distribution of training volume amonge the intervention group and the C group.



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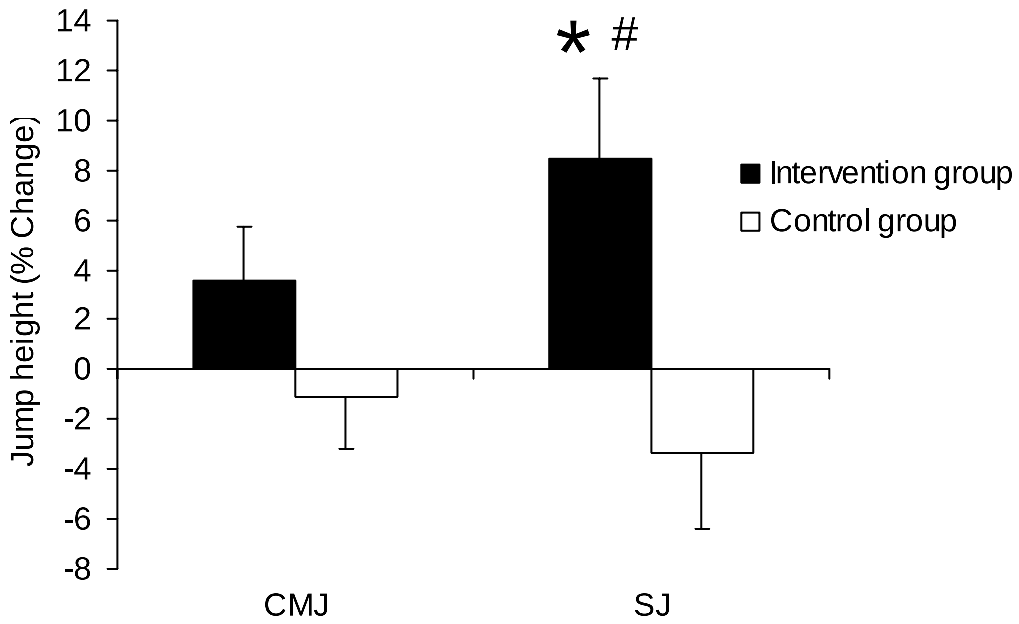

Figure 4. Relative changes in counter movement jump (CMJ) and squat jump (SJ) during the 7-week training in the intervention group and control group. *Significant different from baseline (p = 0.02). #Significant differences between groups (p = 0.03).

TABLES

Table 1. Subjects' age and height characteristics at baseline and pre and post values for their bodyweight. Values are means ± SE

Variable	Test	ST+P group	ST group	Pooled interv. group	Control group
Age (years)	Pre	23±2	22±2.5	23±1.5	24±1.5
Height (cm)	Pre	180±2.2	186±2.6	183±1.8	186±2
Weight (kg)	Pre	73.5±3.5	79.5±2.5	76.0±2.5	81.0±1.5
	Post	74.5±3.0	79.0±2.0	76.5±2.0	81.0±2.0

ST+P group = performed heavy strength training and plyometric exercises in addition to regular soccer training. ST group = performed only heavy strength training in addition to regular soccer training. Pooled intervention group = consists of the two intervention groups. Control group = performed stabilization exercises in addition to regular soccer training.

Table 2: Strength training regime for both the ST and ST+P group. Only the ST+P group performed the plyometric training in the same bout as strength training.

Week	1. Bout	2. Bout	Alternate leg bound†	Double leg hurdle jump†	Single leg forward hop†
1	3 x 6RM	3 x 6RM	2 x 8	2 x 5	2 x 5
2	3 x 6RM	3 x 6RM	2 x 8	2 x 5	2 x 5
3	4 x 5RM	4 x 5RM	3 x 8	2 x 5	2 x 5
4	4 x 5RM	4 x 5RM	3 x 10	2 x 5	2 x 5
5	4 x 5RM	4 x 5RM	3 x 10	2 x 5	2 x 5
6	5 x 4RM	5 x 4RM	4 x 10	2 x 5	2 x 5
7	5 x 4RM	5 x 4RM	4 x 10	2 x 5	2 x 5

†Only the ST+P group performed the plyometric training program.

Table 3. Pre- and posttraining values for 1RM, jumping-, sprint-, and peak power measurements. Values are means ± SE.

Variable	Test	ST+P group	ST group	Pooled interv. group	Control group
1RM half-squat (kg)	Pre	179±6	166±5	173±4	178±6
	Post	220±3*	209±7*	215±4*	183±2
4BT (m)	Pre	9.77±0.41	10.19±0.19	9.95±0.2	10.14±0.09
	Post	10.16±0.28*	10.56±0.27*	10.33±0.2*	10.14±0.12
CMJ (cm)	Pre	36.0±2	32.3±0.8	34.4±1.3	36±0.9
	Post	36.7±1.9	33.9±0.6	35.5±1.2	35.7±1.4
SJ (cm)	Pre	29.6±1.4	29.0±0.9	29.3±0.9	30.3±1.2
	Post	32.3±1.7*	31.0±1.7	31.7±1.2*	29.2±1.1
PP_{20} (w)	Pre	3197±135	3414±123	3290±95	3690±124
	Post	3515±115*	3752±53*	3616±75*	3923±163*
PP_{35} (w)	Pre	3165±131	3486±101	3303±94	3708±108
	Post	3418±126*	3745±73	3558±88*	3840±201
PP_{50} (w)	Pre	3153±147	3399±77	3266±91	3677±119
	Post	3454±164*	3775±80*	3602±103*	3820±153
Sprint time 0-10m (s)	Pre	1.76±0.02	1.79±0.03	1.78±0.02	1.74±0.01
	Post	1.74±0.02	1.76±0.02	1.75±0.01*	1.74±0.02
Sprint time 30-40m (s)	Pre	1.18±0.02	1.18±0.02	1.18±0.01	1.18±0.01
	Post	1.17±0.02*	1.17±0.01	1.17±0.01*	1.16±0.01
Sprint time 0- 40m (s)	Pre	5.43±0.06	5.44±0.08	5.43±0.05	5.35±0.02
	Post	5.37±0.07*	5.37±0.06	5.37±0.05*	5.30±0.04

4BT = 4 bound test, CMJ = counter movement jump, SJ = squat jump, PP_{20} = peak power with external load of 20 kg, PP_{35} = peak power with external load of 35 kg, PP_{50} = peak power with external load of 50 kg, PRV = peak running velocity. * Significant difference from pretest within the group ($p \leq 0.05$).