Tittle: Velocity based training of lower limb to improve absolute and relative power outputs in concentric phase of half-squat in soccer players.

Brief Running Head: Velocity based training of lower limb power in soccer players.

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ABSTRACT

**Purpose:** The power production is force-velocity related. We hypothesized that speed based training of lower limb using half-squat can lead to absolute and relative power improvement in concentric movement, with a same external load. **Methods:** One group of 19 soccer players (age 24.4 yr, SD = 3.7 yr) participated in a pretest-posttest power training protocol, consistent in 2 training sessions per week during 10 weeks, targeted to work the leg power by performing half-squat with fixed external load (M = 71.7; SD = 5.4), at 65% of 1RM. Measurements of power (absolute -W-, and relative –W/kg-), force (N) and velocity (m/s) (mean and peak) were made from a concentric movement of a half-squat exercise with a fixed external load. **Results:** The training protocol increased relative power (M = 47.5, SD = 47.5; p < .001) and absolute power (M = 169.2; SD = 95.5; p < .001). Also, number of repetitions (M = 2.9; SD = 2.4; p < .01), force (M = 66.6; SD = 36.7; p < .001) and velocity (M = .1; SD = .1; p < .001) were increased. However, only improved velocity was related to changes in absolute (r = .939; p < .001) and relative (r = .757; p < .001) power. **Conclusion:** The speed based training, combined with moderate to high external load can lead to an improvement of absolute and relative power in concentric phases of half-squat in soccer players. This could be important for improving the performance of the players in the field.

**Keywords:** speed, force, leg, exercise.

INTRODUCTION

Running is the predominant activity of soccer players, yet explosive type actions such as sprints, jumps, duels, and kicking are important factors for successful performance (2).
Factors such as acceleration, running, velocity, and capacity to release energy are of major importance (7). Because soccer involves high intensity intermittent exercise, it has been suggested that a high anaerobic power is a desirable feature of competitive soccer players (2, 1). Fitness performance from those who achieved international or professional status shows significant differences for sprint and jump, peak concentric torque, maximal anaerobic power and other qualities in comparison to those who remained amateur (6). This suggests that improvements in fitness performance, such as power outputs, can play an important role in their chances of promoting higher achievement levels. Moreover, anaerobic power may be as important for performance as for injury prevention (12). The better performance of professional soccer players requires the implementation of specific training methods for athletes leading to an increase in strength and power parameters, while taking into account the importance of injury prevention. We approach a critical practical issue of this paper: it is not necessary to lead the muscle to the limit of its strength to improve the power outputs of the soccer players. Furthermore, this orientation would have a beneficial effect on injury prevention. The selection of exercises that will enhance power and reduce injury is thus a key element of program design for coaches working in soccer.

Power is defined as the rate of performing work; the product of force and velocity, the rate of transformation of metabolic potential energy to work or heat (17). Maximal muscular power is obtained at optimal values of force and velocity, since power is the product of these two parameters (19). The ability to generate maximal power during complex motor skills is of paramount importance to successful athletic performance, which is affected by a range of interrelated factors (3), such as heart rate, skin temperature, or blood lactate accumulation (18). Strength, since an individual cannot possess a high level of power without first being relatively strong (4) and velocity are also related to power performance. Maximal muscular
power is determined and limited by the force-velocity relationship and affected by the length-tension relationship.

The effects of speed training methods have been investigated (8), and it appears to be an effective way of improving some segments of power performance in soccer players. However, it is not clear that speed training is more effective than strength training to improve power (20). Different loading schemes can lead to similar improvements in power related abilities, regardless of the load or velocity used (13). Moreover, the combination of a heavy-resistance and running-speed training program on vertical jump performs better than isolated resistance training without speed training (10). During concentric contraction muscle shortens as it contracts. These methods has been shown to be effective in increasing muscle strength, in spite of eccentric training, which seems to be more successful in promoting such muscle strength gains (15). Concentric half-squat exercise is related with functional outcomes when it is performed against external loading within a range of the load, in the case of which the maximal power output is attained (14). In this sense, the combination of moderate to high load with maximum number of repetitions at a given velocity could be more efficient. Traditionally, the training protocols used for increasing power outputs consisted in a set of exercises in which athletes lifted heavy weights (nearly 1RM) with few repetitions. Otherwise, performing a large number of repetitions with low weight was related to the increased endurance. We hypothesized that the combination of both types of training protocols in the same exercise can produce a positive effect on power outputs. This type of power training, in which athletes train for a maximal amount of repetitions above a given velocity threshold with a set load, would lead to prevent a great number of injuries.
The aim of this study is to determine whether performing maximal amount of repetitions above a pre-determined velocity with a pre-determined load would lead to increased absolute and relative concentric leg power in soccer players.

METHODS

Experimental Approach to the Problem

In order to test if velocity based training, with an external load of 65% of 1RM, increases absolute and relative power outputs, a one group pretest-posttest experimental design (O1 X O2) was conducted. Ideally, absolute and relative power increase between pretest and posttest (dependent variables) are due to training protocol. Also measures of force, velocity and number of repetitions were taken into account. This approach allowed us to assess the effect of a combined training of strength and endurance on power outputs of the soccer players.

Subjects

Nineteen healthy male soccer players from a Spanish second division professional team volunteered to participate in a pretest-posttest power training protocol. Before the study, each subject was informed about the nature of the study, reviewing and signing informed consent forms, which was approved by the Institutional Review Board for use of subjects of the School of Medicine of the University of Córdoba. One subject had to leave the training
program due to injury. Finally, eighteen subjects were measured in posttest. The mean age and standard deviation (in brackets) of these eighteen soccer players was 23.4 (3.7) years (range 19-31), weight was 73.4 (3.6) kg and height was 179.3 (6.0) cm.

Procedures

Prior to the implementation of the training program, a structural survey, functional description and ultrasound examination of the participants were conducted, targeted to rule out any malfunctions. Pretest measures were taken in the Medical Sports Centre of the University of Córdoba, on nineteen subjects. A ten week training program protocol with two weekly sessions was applied. Posttest measures were taken on eighteen survivals. The tests were conducted in the week before and the week after the 10-week training period. All the practice and testing took place at the same time of the day to control any circadian variation in performance. The subjects were asked to participate in two training sessions per week (Tuesday and Friday) during ten consecutive weeks before the soccer training session, targeted to work the leg power by performing half-squats with a fixed external load, which was established as 65% of one repetition maximum (1RM). 1RM was assessed following the procedure described by Kraemer and Fry (1996) (11), consisting of a first warm-up set of 8-10 repetitions at 50% of 1RM. A second warm-up of 3-5 repetitions with approximately 75% of 1RM, and third warm-up with 90% of 1RM followed. Finally, the participants performed 1RM exercises by increasing the load during consecutive trials. When participants were unable to correctly perform a half-back squat, 1RM was established (M = 110.38 kg; SD = 17.8), which was ranged between 103-124 kg (M = 118.39; SD = 19.12). The external load to be used in the training program, which was selected based on 65% of 1RM, was ranged
between 65-85 kg (M = 71.7; SD = 5.4), representing 97.7% of body weight (IC95% 94.0-101.4). Athletes participated in each session 4 sets of 10-25 repetitions, according to the maximum power output measured in test. When the power level of two successive repetitions was below the minimum the series ended. The feedback was given on sound and movement speed (±10%). The recovery period between each set was three minutes. Training sessions lasted 45 minutes and began with a standard 15-minute warm-up: five minutes of jogging and three sets of 10, 15 and 20 repetitions respectively of the same test exercise to the 50, 60 and 75% of the corresponding external load. The athletes were instructed to not jump and to keep their heels on the floor.

Measurements

Measurements in pretest and posttest of power (absolute -W-, and relative –W/kg-), force (N) and velocity (m/s) (mean and peak) were made from a concentric movement of a half-squat exercise with a fixed external load. Participants were encouraged to perform as many repetitions as fast as possible. For 15 seconds, subjects performed successive half-squat repetitions at maximum speed. Prior to this, they were informed of the correct leg-thigh angle to effect the displacement. Athletes, before measurement, performed a 15 minute warm-up of jogging (5 minutes) and three sets of 10, 15 and 20 repetitions respectively of the same test exercise to the 50, 60 and 75% of the corresponding external load. For measuring power, force and velocity, a linear encoder connected to Muscle lab-Bosco System® (Ergotest Technology – MA.GI.CA.srl, Roma) was used.
Statistical analysis

Means, standard deviations, maximums and minimums were used to describe all the variables. In order to study the efficacy of the training program, two paired sample comparisons were computed by means of t-test or its non-parametric equivalent, that is, Wilcoxon signed-rank test. Previously, Shapiro-Wilk normality tests were run out for differences between pretest-posttest. Cohen’s effect size was calculated by dividing the mean change and standard deviation baseline. Pearson's product–moment correlation was also calculated to determine the relationship between selected variables. A level of p < 0.05 was selected to indicate statistical significance.

RESULTS

Table 1 shows descriptive statistics (Min, Max, M, SD) in pretest and posttest. From pretest to posttest, the number of repetitions increased 18.6%, relative power improvement was 8.2%, absolute power increased 12.6%, force output increased 4.0% and velocity 12.5%. Results of the sample paired tests showed a significance change between pretest and posttest in all selected variables (table 1). The Shapiro-Wilk normality test was applied to these differences (table 1), showing that ΔRepetitions (z = .834; p = .005) and ΔForce (z = .891; p = .040) do not follow the normal distribution. In these variables, non-parametric Wilcoxon signed-rank tests were run out, and statically significant differences were detected between the initial and the final measurements (ΔRepetitions: z = -3.118; p = .002; Cohen’s d = 1.93; ΔForce: z = -3.636; p = .000; Cohen’s d = .50). The ΔVelocity t-test indicates an
improvement in speed performance between the pretest and the posttest \[t(17) = 5.426; p = .000; \text{Cohen’s d} = 1.00\]. Regarding the mean power in concentric half-squats, there was also an increase in the relative \[t(17) = 7.138; p = .000; \text{Cohen’s d} = 1.00\] and absolute \[t(17) = 7.303; p = .000; \text{Cohen’s d} = .88\] values between the pretest and the posttest. Cohen’s coefficient showed a moderate to large effect size in all variables.

[Table 1 about here]

Linear association between Δvariables by Pearson’s product-moment correlations (table 3) shows that there is a positive correlation between the ΔAbsolute and ΔRelative power \((r = .997, P < .001)\), and between ΔForce and the ΔRepetitions \((r = .832, p < .001)\). Of greater interest is the significant correlation between ΔVelocity and ΔRelative power \((r = .939, P < .001)\) and between ΔVelocity and ΔAbsolute power \((r = .939, p = < .001)\), which indicates that improvements in velocity are highly related to improvements in power in concentric half-squats. However, ΔForce is associated with some of the measures of ΔPower, either relative or absolute.

[Table 2 about here]

DISCUSSION
These results show that a specific velocity training program of lower limbs in concentric half-squats with a fixed external load improves relative and absolute power outputs in healthy male soccer players. Such results match those from Jovanovic et al (8), who conclude that a speed training method appears to be an effective way of improving some segments of power performance in young soccer players. In our study, absolute and relative power outputs in concentric phases of half-squats were improved after the implementation of velocity-based training protocol. In addition, the number of repetitions increased, showing an improvement in resistance output. On the other hand, force values were improved as a consequence of training velocity with an external load. There is a lack of studies regarding the influence of speed training on the strength and power outputs of soccer players. In healthy older persons it has been observed that resistance training focusing on speed of movement substantially improved leg power and maximal strength (5).

We have observed that increased velocity is significantly related to better measurements of relative and absolute power, according to experimental efficacy of speed training, while increased force is related to any measurement of power, which is contradictory to results obtained in other studies (21) where strength is strongly correlated with vertical jump height in elite soccer players. This may be due to the measurements on concentric phase of half-squat, since it is known that eccentric movement is stronger related to strength development that concentric is (16). Force improvement related to a specific training of velocity is greater in eccentric than in a concentric phase of half-squats. In any event, it has been observed that the only parameter related to force improvement is a greater number of repetitions, but not greater velocity. This could seem contradictory, but it is not since it could be argued that a greater number of repetitions is not related with greater velocity, probably due to an undetected statistically inverse relationship between velocity and number of repetitions.
Moreover, since our training program included set velocity and load, in which each athlete trains for a maximal amount of repetitions above a given velocity threshold with a set load, it seems logical that the number of repetitions would be the largest adaptation. Others methods of using velocity/power feedback during training (set load and set repetitions, or set velocity and set repetitions) probably would lead athletes to a larger velocity or force adaptation.

Furthermore, it is likely that the instruction given to the athletes to keep their feet on the floor could lead to the inability to determine changes in velocity, due to that the deceleration of the bar would have prevented from a genuine maximal velocity during each repetition.

However, it is necessary to replicate these results in a randomized clinical trial, since our one group pretest-posttest design doesn´t allow us to conclude that power improvement is specifically due to training. Moreover, some effects could not be detected sufficiently as a consequence of a low statistical power from a small sample size.

Therefore, we conclude that speed training in eccentric half-squats of lower limbs can lead to an improvement of absolute and relative power outputs.
PRACTICAL APPLICATIONS

The results obtained in the present study could be important for a better field performance of soccer players, as speed based training can reach power improvements without an increasing external load nearly 1RM. The running speed, which is a major issue in soccer, is related to the ability to apply more force on the ground. A high proportion of plays involves the need to use the sprint, so increasing the power of the lower limbs will give player a competitive edge. The vertical jumping is another important item for soccer players that could be improved by increasing the power capability of the legs, which in turn is related to more opportunities to dispute certain plays in which the ball is on the air. Also the speed of the shot is associated to a greater leg power. All these performance improvements can be achieved by training lower body power based on a greater concentric contraction speed and a moderate external load. Coaches or practitioners should keep in mind that it is not necessary to increase external load to improve relative and absolute power outputs.
References


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Table 1. Descriptive Statistics, differences (posttest minus pretest), Shapiro-Wilk normality tests of differences and paired samples test with Cohen’s effect size.

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
<th>Dif</th>
<th>SW</th>
<th>St (df)</th>
<th>Cohen’s d</th>
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<tbody>
<tr>
<td><strong>Repetitions</strong></td>
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<td></td>
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<tr>
<td>min-max</td>
<td>13.0 - 18.0</td>
<td>14.0 - 22.0</td>
<td>-4.0 - 6.0</td>
<td></td>
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<td></td>
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<tr>
<td>M (SD)</td>
<td>15.6 (1.5)</td>
<td>18.5 (2.1)</td>
<td>2.9 (2.4)</td>
<td>0.834</td>
<td>-3.118</td>
<td>1.93</td>
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<td><strong>Rel Power</strong></td>
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<tr>
<td>(W/kg)</td>
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<tr>
<td>min-max</td>
<td>14.2 - 24.0</td>
<td>16.7 - 26.2</td>
<td>-0.1 - 5.7</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>M (SD)</td>
<td>18.2 (2.3)</td>
<td>20.5 (2.6)</td>
<td>2.3 (1.4)</td>
<td>0.967</td>
<td>7.138†</td>
<td>1.00</td>
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<td><strong>Abs Power</strong></td>
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<td>(W)</td>
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<tr>
<td>min-max</td>
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<td>1208.0 - 2020.4</td>
<td>-8.0 - 402.6</td>
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<tr>
<td>M (SD)</td>
<td>1338.6 (192.6)</td>
<td>1507.8 (206.1)</td>
<td>169.2 (95.5)</td>
<td>0.967</td>
<td>7.303†</td>
<td>0.88</td>
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<tr>
<td><strong>Force (N)</strong></td>
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<tr>
<td>min-max</td>
<td>1444.0 - 1976.0</td>
<td>1489.4 - 203.8</td>
<td>-36.5 - 113.5</td>
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<tr>
<td>M (SD)</td>
<td>1675.3 (134.5)</td>
<td>1741.9 (127.5)</td>
<td>66.6 (36.7)</td>
<td>0.891</td>
<td>-3.636†</td>
<td>0.50</td>
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<tr>
<td><strong>Velocity</strong></td>
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<tr>
<td>(m/s)</td>
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<tr>
<td>min-max</td>
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<td>0.7 - 1.0</td>
<td>0.0 - 0.2</td>
<td></td>
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<tr>
<td>M (SD)</td>
<td>0.8 (0.1)</td>
<td>0.9 (0.1)</td>
<td>0.1 (0.1)</td>
<td>0.951</td>
<td>5.426†</td>
<td>1.00</td>
</tr>
</tbody>
</table>

M: mean; SD: standard dev.; SW: Shapiro-Wilk normality test; St.: statistic a: Wilcoxon test (z statistic); b: t-test; * p < .05; † p < .01; ‡ p < .001.
Table 2. Pearson’s product-moment correlations.

<table>
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<th>Variables</th>
<th>1</th>
<th>2</th>
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<tbody>
<tr>
<td>2 Δ Rel pow (W/kg)</td>
<td>-.128</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3 Δ Abs pow (W)</td>
<td>-.132</td>
<td>.997†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Δ Force (N)</td>
<td>.832†</td>
<td>.393</td>
<td>.387</td>
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</tr>
<tr>
<td>5 Δ Velocity (m/s)</td>
<td>-.424</td>
<td>.939†</td>
<td>.939†</td>
<td>.081</td>
</tr>
</tbody>
</table>

1. Repetitions; 2. Δ Rel pow (W/kg); 3. Δ Abs pow (W); 4. Δ Force (N); 5. Δ Velocity (m/s)
†: p ≤ 0.001.