Effects of strength training on squat and sprint performance in soccer players

Original Investigation

William J. Styles[1,2], Martyn J. Matthews[2] & Paul Comfort[2#]

[1]Glasgow Celtic Football Club, Medical Department, 95 Kerrydale Street, Glasgow. G40 3RE
[2]Human Performance Laboratory, Directorate of Sport, Exercise, and Physiotherapy, University of Salford, Greater Manchester, M6 6PU. United Kingdom

[#]Corresponding Author: Paul Comfort – p.comfort@salford.ac.uk

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Abstract

Researchers have demonstrated that increases in strength result in increases in athletic performance, although the development of strength is still neglected in some sports. Our aim was to determine whether a simple in-season strength training program would result in increases in maximal squat strength and short sprint performance, in professional soccer players. Professional soccer players (n=17, age = 18.3 ± 1.2 years, height = 1.79 ± 0.06 m, body mass (BM) = 75.5 ± 6.1 kg) completed one repetition maximum (1RM) back squat and sprint tests (5-, 10-, 20 m) before and after a six-week (2 x week) in-season strength training (85-90% 1RM) intervention. Strength training resulted in significant improvements in absolute and relative strength (pre: 125.4 ± 13.8 kg, post 149.3 ± 16.2 kg, $p < 0.001$, Cohen's $d = 0.62$; 1RM/BM pre: 1.66 ± 0.24 $kg.kg^{-1}$, post 1.96 ± 0.29 $kg.kg^{-1}$, $p < 0.001$, Cohen's $d = 0.45$; respectively). Similarly, there were small yet significant improvements in sprint performance over 5 m (pre 1.11 ± 0.04 s, post 1.05 ± 0.05 s, $p < 0.001$, Cohen's $d = 0.55$) 10 m (pre 1.83 ± 0.05 s, post 1.78 ± 0.05 s, $p < 0.001$, Cohen's $d = 0.45$) and 20 m (pre 3.09 ± 0.07 s, post 3.05 ± 0.05 s, $p < 0.001$, Cohen's $d = 0.31$). Changes in maximal squat strength appear to be reflected in improvements in short sprint performance highlighting the importance of developing maximal strength to improve short sprint performance. Moreover this demonstrates that these improvements can be achieved during the competitive season in professional soccer players.

KEY WORDS: Sprint times; Back squat; Acceleration; In-season

Introduction

Whilst the total distance covered in an elite soccer match can total as much as 8-12 km (5, 15), it is the short high-intensity sprints that represent the crucial game-changing moments. These sprints typically last from 2-4 seconds over distances of 10 – 30 m, with players performing 17-81 sprints per game, accounting for up to 11% of the total distance covered during a match (5, 15, 27, 31). Moreover sprinting ability (both acceleration and maximum sprint speed) are able to distinguish soccer players from different standards of play, in both adult (27) and youth soccer (9).

Strong correlations have been reported between short sprint performance and lower body strength, assessed using free weight back squats (7, 10, 18, 21, 25, 35). Wisloff et al. (35) reported a very strong relationship (r = -0.94) between absolute back squat strength and sprint performance in soccer players, while McBride et al. (21), Meir et al. (25), and Comfort et al. (7) reported good relationships between short sprint performance and relative strength (1RM / body mass). Authors of a recent meta-analysis concluded that improvements in lower body strength transfer to improvements in sprint performance (<30 m) (30). This is likely due to stronger athletes developing higher peak ground reaction force and impulse, which have been shown to be strong determinants of sprint performance (11, 32, 33). Good associations are also reported between maximum ground reaction force and maximal sprinting velocity (r = 0.60) (32), suggesting that increasing strength, or maximal force production, may also improve acceleration and maximal sprinting velocity.

During sprinting, contact times of ≥ 200 ms (222 ± 18 ms) have been observed during the initial acceleration phase, reducing to <200 ms (169 ± 7.9 ms) during the maximal velocity phase (12), illustrating that high rates of force development (RFD) are essential for effective acceleration during sprinting. Importantly, maximal strength is reported to be the most important factor in maximizing power output when ground contact time or movement duration is >200 ms (11, 32, 33). When increasing maximal strength, an athlete's body mass will normally show minimal change, therefore if a higher force is applied to a similar mass acceleration increases. Additionally higher strength levels are associated with higher RFD (3, 22, 23, 37). This is likely to be the case for team sport specific sprint distances of ≤20 m, however, the relationship between maximum strength and sprint performances is likely to diminish as the distance increases. As the sprint distance increases it has been proposed that performance is affected more by the stretch shorten cycle and that the relationship between maximal strength and sprint performance is less apparent (4).

Despite these factors there is limited research documenting whether changes in strength are associated with changes in sprint performance (6, 8, 29). Chelly et al., (6) observed an improvement in back squat strength, jump and sprint performance in junior soccer players following a 2-month back-squat training protocol. Similarly, a study by Ronnestad et al. (29) reported significant improvements ($p < 0.05$) in half squat strength (pre: 173 ± 4 kg, post: 215 ± 4 kg), 10m (pre: 1.78 ± 0.02 s, post 1.75 ± 0.01 s) and 40m (pre: 5.43 ± 0.05 s, post 5.37 ± 0.05 s) sprint performances, after 7 weeks of combined strength and plyometric training. More recently Comfort et al. (8) investigated whether changes in maximal squat strength were reflected in changes in sprint performance. Preseason training resulted in 17.7% improvement in maximal squat strength from pre-training (170.6 ± 21.4 kg) to post-training (200.8 ± 19.0 kg), as well as decreases in sprint times over 5m (7.6%), 10m (7.3%), and 20m (5.9%).

With numerous studies reporting that stronger athletes perform better during short sprint performances (4, 7, 10, 11, 18, 21, 25, 35, 37), it may be that increasing lower body strength, through a simple training intervention, is likely to result in improved performance during short sprints and may therefore enhance soccer performance (5), as recently concluded in a meta-analysis (30). To date, while studies have reported associations between squat strength and short sprint performance in soccer (10, 35), only one study has reported that pre-season strength training improved short sprint performance (29). The aim of the investigation, therefore, was to implement a basic in-season strength training program and determine if any resultant increase in maximal squat strength is accompanied by an improvement in short sprint performance. It was therefore hypothesized that the training program would improve subjects' absolute and relative 1RM back squat performance, which would be reflected by a concurrent increase in sprint performance over 5- 10- and 20 m.

Methods

Experimental Approach to the Problem

To determine if a basic in-season strength training program results in an increase in 1RM back squat performance and whether these increases are reflected in a concurrent improvement in sprint performance, a squad of professional soccer players were tested (1RM squat and 5, 10 and 20 m sprint) before and after a 6 week in-season strength training intervention using a repeated measures experimental design.

Due to the fact that this was an in-season intervention in a professional team sport environment it is acknowledged that other sessions over the intervention period (agility, speed) may have influenced sprint performance. It would not have been practical to remove such sessions from the training week of this group of professional athletes; however this increases the ecological validity of the study.

Subjects

Seventeen, elite level professional soccer players (age = 18.3 ± 1.2 years (range 16-20 years), height = 1.79 ± 0.06 m, body mass (BM) = 75.5 ± 6.1 kg, 1RM Back Squat = 125.4 ± 13.8 kg and 1RM/BM = 1.66 ± 0.24 $kg.kg^{-1}$), participated in the study. The Institutional Review Board approved the project and all the participants provided written informed consent and parental or guardian consent where required. The subjects were considered to be moderately trained in regard to maximal strength training interventions and relative strength levels, with an experience of resistance training of approximately 1 year, with a primary focus on strength endurance. The subjects had not been exposed to a strength training intervention of this nature (high intensity and low volume), having previously completed a general preparation phase that focused on muscle hypertrophy and strength endurance. All participants were accustomed with the testing methods, as they formed part of the on-going assessment and evaluation of their athletic development. All participants were free from injury and undertook a standardized warm up prior to each testing session.

Procedures

Maximal strength and sprint performances were assessed on separate days, 72 hours apart. Participants abstained from training for 24 hours prior to testing. Due to testing being conducted on different days all assessments were conducted at the same time of day and the participants asked to standardize their food and fluid intake prior to each testing session.

Maximal Strength Testing

One repetition maximum back squat was assessed via a standardized protocol, with warm up loads approximated via individual training loads (3). During all attempts, the participants were required to squat to a depth where a 90° knee angle was achieved. This angle was gauged prior to the warm up sets using a goniometer, with a bungee cord fixed at a height where it contacted the buttocks while the subject was in this position, which was also reinforced via verbal command. All the participants achieved their 1RM within 4 attempts. Strength performances were reported as both absolute and relative (1RM / body mass) strength.

Sprint Performance

Following a standardized warm up, the participants performed two 20-m sprints on an indoor artificial synthetic grass surface, wearing standard training shoes. Sprints were interspersed with a one minute rest period in accordance with McBride et al. (21). Time to 5, 10 and 20 m was assessed using infrared timing gates (Brower, Speed Trap 2 Wireless Timing System, UT, USA). All the subjects began from a two point start, with their front foot positioned 0.5 m behind the start line and were instructed to perform all the sprints with a maximal effort. Within session reliability of sprint performances was assessed using the data from the two trials, during the pre-intervention assessments; while the best performances were used compare pre to post intervention changes in performance.

Training Intervention

All subjects completed an individualized strength training program twice per week for six weeks (12 sessions in total) (Table 1). Loads were set as a percentage of the pre-test values. The volume load of sessions was manipulated through the repetitions and sets performed to divide the sessions into a high volume and low volume day throughout the week, based on the competition schedule. This intervention formed part of the athlete's in-season conditioning program. Back squats were selected due to the strong associations with maximal strength in this exercise and short sprint performances (4, 7, 10, 11, 18, 21, 25, 35, 37). Romanian deadlifts and Nordic lowers were implemented in light of the high incidence of hamstring strain injuries reported within soccer (36) and the injury prevention benefits of such strengthening exercises (1, 2, 26). In addition the subjects were also familiar with these exercises.

******Insert Table 1 here******

Both maximal strength and sprint performances were reassessed at the end of the 6 week training intervention using the same protocols. Participants were asked to standardize their dietary intake and activity levels for the 24 hours prior to each testing session. All testing was performed at the same time of day to minimize the effect of circadian rhythms.

Statistical Analyses

Intraclass correlation coefficients (ICC's) were conducted to determine reliability of sprint testing methods within sessions. Paired sample t-tests were performed to identify the differences in sprint performances and 1RM back squat performance pre and post 6 weeks of training. Effect sizes were determined using the Cohen *d* method, and interpreted based on the recommendations of Rhea (28) who defines <0.35, 0.35-0.80, 0.80-1.5 and >1.5 as trivial, small, moderate and large respectively.

Additionally, Pearson's product moment correlations were performed to determine associations between the percentage change in sprint performances and the percentage change in relative strength. Correlation coefficients were interpreted as being weak (0.1-0.3), moderate (0.4-0.6) and strong (>0.7) in line with previous recommendations (17). Statistical analyses were performed using SPSS software (Version 20.0, SPSS, Inc., IL, USA). G-Power statistical software (version 3.1.9.2; University of Dusseldorf, Dusseldorf, Germany) (13), was used determined that a minimum sample size of $n = 14$ was required for a statistical power ≥ 0.90 at an alpha level of $p \leq 0.05$.

Results

Examination of ICC's revealed varied but high within session reliability for the 5, 10 and 20 m sprints during testing ($r = 0.86$; $r = 0.89$; $r = 0.92$).

Body mass was increased over the 6-week training period, although the effect size was trivial (pre: 75.5 ± 6.1 kg, post 76.3 ± 5.9 kg, $p < 0.001$, Cohen's $d = 0.07$). Similarly both absolute and relative strength increased significant ($p < 0.001$) between baseline and post the 6 week in season strength training protocol although the effect sizes were small (Table 2). Small but significant ($p < 0.001$) increases in sprint performance, were also observed over each distance (Table 2) between pre and post the 6 week strength training program.

Insert Table 2 here

Strong correlations were also observed between the percentage change in relative 1RM and 5-, 10- and 20 m sprint times ($r = 0.62, 0.78, 0.60$, $p<0.001$, respectively) (Figure 1).

Insert Figure 1 here

Discussion

We have demonstrated that a simple, in-season, strength training program resulted in an improvement in maximal back squat performance which was reflected in improvements in short sprint performance, as identified by a decrease in sprint time over 5-, 10- and 20 m, in professional soccer players, in line with the hypotheses. Furthermore, the changes in relative 1RM squat strength demonstrate strong associations with the changes in 5- ($r = 0.62$), 10- ($r = 0.78$) and 20 m ($r = 0.60$) sprint performances.

The in-season strength training intervention resulted in significant and moderate, improvements in both absolute (19%) and relative (16%) strength. There were also significant ($p < 0.001$), yet small improvements in sprint performance over 5 m (~5%), 10 m (~3%) and 20 m (~1%) (Table 2). Despite moderate increases in squat strength, the effect sizes demonstrate that 5 m sprint performance showed small improvements, with progressively smaller effect sizes and percentage improvements as sprint distance increased, despite being statistically significant. The greater changes in short sprint performance is likely due to the requirement to overcome inertia during the initial 5 m, with the rate of force development rather than maximal force production becoming more important as distance and running velocity increase. The absolute 1RM squat performances (pre 125.4 ± 13.78 kg; post 149.29 ± 16.2 kg) pre training are comparable to values previously reported in soccer players participating in a similar level of competition (129.1 ± 11.4 kg) (24).

The previous study by Comfort et al. (8), which compared changes in back squat and short sprint performances across pre-season training in rugby league players, demonstrated similar increases in relative strength (Pre = 1.78 ± 0.27 $kg.kg^{-1}$ vs. Post = 2.05 ± 0.21 $kg.kg^{-1}$) when compared to the present study (Pre = 1.70 ± 0.24 $kg.kg^{-1}$ vs. Post = 1.97 ± 0.29 $kg.kg^{-1}$). Similarly, changes in 5 m sprint performance were comparable, although the increases in 10 m and 20 m sprint performances were greater in the previous study (8), which could be due to the differences in duration (6 vs. 8 weeks) and the time in the season (pre-season vs. in-season). Similar changes in back squat strength were also observed by Ronnestad et al. (29), after a 7 week strength training intervention in youth soccer players, although they observed minimal changes in 10 m sprint performance.

The current study was an in-season intervention with a group of elite level soccer players that was incorporated into the existing training and competition schedule of a professional club. As such, due to the concurrent focus on multiple fitness attributes, it is possible that changes in maximum strength were less than would be achieved in a program where this was the primary focus. The incompatibility between strength and endurance training has long been recognized, with concurrent training resulting in reduced improvements in strength and power (14, 19). Whilst other research has reported little to no decrements in strength training gains with the addition of endurance training (16), it appears that concurrent training when compared to solely strength training, compromises strength-related adaptations. Indeed the conflicting findings may be explained by the study design, training status of the participants, the strength and endurance stimuli and the recovery between bouts of exercise (20, 34). A key point to consider is that in many of the highlighted studies the participants had little or no strength training history and as such made performance improvements as a result of this novel stimulus. This could explain the results of the current study, in that another group of athletes with a longer training history may require a greater level of overload to stimulate adaptation and the improvements in strength (19% increase in 1RM), which may affect the overall training volume.

While 1RM back squat performance has previously been correlated with sprint performance (7, 10, 18, 21, 25, 35), it has been suggested that assessment of peak force or peak power during squat jumps or countermovement jumps may be a better predictor of sprint performances over distances specific to soccer (11). With jumps divided into slow and fast stretch-shorten cycle (SSC) performance, the countermovement jump is a measure of slow (>250 ms) SSC performance and the drop jump is a measure of fast (<250 ms) SSC performance (37, 38). Cronin & Hansen (11) highlighted that measures of slow SSC performance (countermovement and loaded jump squats) resulted in the highest correlations (r = -0.43 to -0.64) with sprint performance. It is suggested that in the initial phases of sprinting, where ground contact times are longer, measures of slow SSC are more important, whereas measures of fast SSC are more important during the maximal speed phase (11). Indeed the relationship between first-step quickness (5 m time) and maximal speed is weaker than that of first step quickness and acceleration. That is 5 m time accounts for less than 53% of the explained variance associated with maximal speed (30 m time). Jump analysis, therefore, may offer greater insight into the determinants of soccer-specific speed and allow for greater individualization in terms of assessment and exercise prescription. Future research may benefit from investigating if 1RM back squats or assessment of jump performances are more closely related to short sprint performance, with regular assessment of jump performance easier to implement in-season. Additionally, as this study was only 6 weeks in duration, assessment of periodized strength and power training throughout the season is recommended.

Practical Application

The findings of this study are that a simple, low volume, in season strength training intervention in trained professional soccer players can increase maximal squat strength, which is reflected in improvements in sprint performance, albeit to a lower magnitude. This highlights not only the association between strength and performance in short sprints over distances regularly performed in competition, but also that relatively simple interventions can produce meaningful improvements in a population that, although elite, is relatively untrained in strength. It is recommended therefore that strength and conditioning coaches not only try to maintain, but increase strength in season in competitive soccer players, with low volume strength training which should not negatively affect match performance.

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Table legends

Table 1: Example training program during the strength intervention

Table 2: Descriptive statistics (means ± standard deviations and 90% confidence intervals) for performance variables pre and post training

Figure 1: Relationship between change in relative strength and change in 10 m sprint performance

Table 1: Example training program during the strength training intervention

Exercise	High Volume (Sets / Rep's / Load)	Low Volume (Sets / Rep's / Load)
Back Squat	4 / 5 / 85-90%	3 / 3 / 85-90%
Romanian Deadlift	4 / 5 / 85-90%	3 / 3 / 85-90%
Nordic lowers	3 / 4-6*	3 / 3*
***Body mass (no external load)**		

Table 2: Descriptive statistics (means ± standard deviations and 90% confidence intervals) for performance variables pre and post training

Performance Variable	Pre	Post	Effect Size
5 m Sprint (s)	1.11 ± 0.04 (1.09-1.13)	1.05 ± 0.03* (1.04-1.06)	$d = 0.55$
10 m Sprint (s)	1.83 ± 0.05 (1.81-1.85)	1.78 ± 0.05* (1.76-1.80)	$d = 0.45$
20 m Sprint (s)	3.09 ± 0.07 (3.06-3.12)	3.05 ± 0.05* (3.03-3.07)	$d = 0.31$
Absolute (kg)	125.4 ± 13.78 (119.9-130.9)	149.3 ± 16.62* (142.7-155.9)	$d = 0.62$
Relative (kg.kg^{-1})	1.66 ± 0.24 (1.56-1.76)	1.96 ± 0.29* (1.84-2.08)	$d = 0.45$
***$p < 0.001$**			

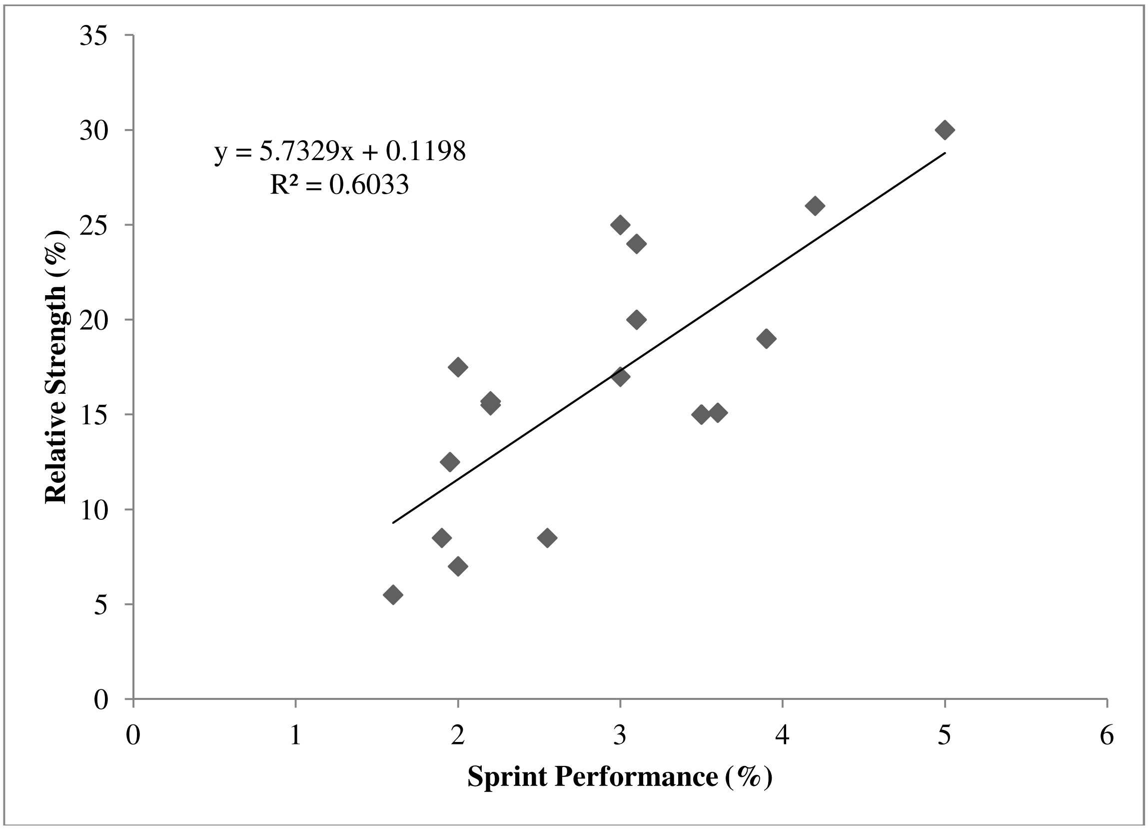

Figure 1: Relationship between change in relative strength and change in 10 m sprint performance