Short Communication

Six weeks of knee extensor isometric training improves soccer related skills in female soccer players

Leah Bimson, Louis Langdown, James P. Fisher, James Steele

Objectives: Resistance training (RT) programs are often utilized to improve strength and power and thus enhance soccer performance. However, there is little research examining isometric knee extensor RTs effects upon soccer related skills.

Design: The aim of this study was to examine the effects of knee extensor isometric training in female soccer athletes.

Method: Sixteen female, university level, amateur soccer players (age 20.5 ± 1.1 years) were assigned to either a control or experimental group. The experimental group trained 1x/week for 6-weeks performing repeated maximal voluntary isometric contractions (MVIC) for the knee extensors alongside regular soccer training and the control group participated in soccer training alone. Knee extension MVICs were performed at seven joint angles and peak torque measured.

Results: Outcome measures included, countermovement jump (CMJ), kicking distance (KD), straight sprint speed and zigzag sprint speed, with (SSB and ZSB, respectively) and without (SS and ZS, respectively) a ball. Significant increases ($p < 0.05$) in knee extensor MVIC (28.9%) occurred in the experimental group. Significant differences ($p < 0.05$) between the experimental group and control group were found for change in CMJ (2.24% vs -0.78% respectively) and KD (8.8% vs -2.5% respectively); however, change in SSB, ZSB, SS, or ZS were non-significant for both within- and between-group comparisons.

Conclusions: Results indicate that a 6-week isometric knee extension RT intervention can improve jump height and kicking ability of amateur female soccer players.

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Key words: strength ■ anaerobic power ■ speed ■ agility ■ change of direction

INTRODUCTION

Soccer is the most popular sport in the world and the most popular team sport for women.[1] In 2006, 4.1 million women were playing within organised structures; a 54% increase from the year 2000.[2] The development of recreational and professional soccer leagues has provided opportunities for women to train and compete at a higher standard. Despite this increase in professionalism, there is still a gap in the amount of research involving female players.

Soccer involves intermittent high intensity of effort activity. Strength and anaerobic power, particularly of the lower limbs, likely affects the explosive efforts of jumping, kicking and sprinting, which it has been argued may be key determinants of successful soccer performance.[3] As such, it may be important to consider training of these characteristics. Sprinting and high intensity efforts only represent 10–15% of covered running distance; however, they can be the most critical and decisive movements affecting the outcome of a game.[4]

Strength and rate of force development in the leg muscles might impact change of direction (COD) at speed, acceleration and jumping performance. This 'speed-strength' is thought to be important for explosive, anaerobic movements,[5] and resistance training (RT) of the knee extensors has positive effects on jump and sprint performance of professional soccer players[6]. Strength and conditioning also plays a role in decreasing risk and severity of injury, and preventing injury re-occurrence.[7] However, females may be more susceptible to injury than males. Knee injuries are more common in females and 82% of female injuries occur in the lower extremities with 22% of major injuries occurring at the knee.[8] Indeed, RT has been shown to effectively reduce sports injuries risk.[7]

Knee extension is a repetitive movement in soccer, with running, jumping and kicking all requiring this action. The instep kick is considered to be an important skill for long distance passing, free kicks, shooting and the penalty kick.[9] Improvements have been found to occur in lower limb strength and ball velocity through RT of the knee extensors in isolation.[10] Knee extension may also be important for jumping which is regularly used as a measure of anaerobic power in soccer players.[3] However, it is unclear whether knee extensor strength affects other soccer related skills such as COD performance with and without a ball.

Most research on the effects of specific training on soccer related skills has involved male participants, limiting application to amateur female soccer populations. Furthermore, many studies have investigated the effects of plyometric training and examined outcomes which resemble the training performed. Thus, performance improvements might be a result of specific practice of movements mimicking the tests; not necessarily due to any one underlying component adapting. For example, jumping in plyometric training would likely improve jump height as an outcome, as would sprint or COD training likely

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From the School of Sport, Health, and Social Science, Southampton Solent University, UK (L.B., L.L., J.P.F., J.S.)

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Correspondence to Dr. James Steele, School of Sport, Health, and Social Science, Southampton Solent University, East Park Terrace, Southampton, Hampshire, UK, SO14 0YN. Email: james.steele@solent.ac.uk

enhance acceleration and speed as well as COD testing. As such the role of knee extension strength improvements alone are not well understood in their translation to soccer related skills such as kicking, jumping and COD. Therefore, we chose to examine the effects of a *neutral* isolated knee extension training intervention, and thus the role of increasing strength without specific motor schema transfer, upon soccer related skills performance.

METHODS

Methodological Design

A randomized controlled trial design was used to determine the effect of isometric knee extension training on soccer related performance variables within female participants. Outcomes included counter movement jump (CMJ), kicking distance (KD), sprint speed and a zigzag, with (SSB and ZSB, respectively) and without (SS and ZS, respectively) a ball. Participants completed a 6-week intervention consisting of either once weekly maximal isometric knee extension training alongside current soccer training, or continuation of their current soccer training. Ethics committee approval was obtained from the author's institution (ID No. 366). All participants were provided with a participant information sheet and informed consent was obtained prior to any testing/training.

Participants

Sixteen female undergraduate university students playing soccer in the British University and College Sports (BUCS) league volunteered. On average, participants took part in two soccer-training sessions and played one competitive 90-minute match per week. All participants had at least 5 years of soccer training experience playing at county level. Participants were randomized into an experimental training group (EG; $n = 8$) and a control group (CG; $n = 8$). The CG took part in regular soccer practice and the EG completed additional once-weekly isometric training. Participants reported having no current or recent injury that may have affected their efforts in the training programme. None of the players had any experience in isometric exercise before the tests; however, 6 out of 8 participants in the EG group and 7 out of 8 participants in the CG group had previously taken part in some form of RT. See table 1 for participant demographics.

Procedures

Testing was conducted during the soccer mid-season. Pre- and post-tests were completed at the beginning of the first and end of the last week of the 6-week intervention respectively. CMJ, SS, ZS, SSB, ZSB and KD were performed in that order for each session. Both pre- and post- soccer-related skill tests were completed in one single session each (20:00 – 22:00 hours) with sufficient recovery for each player to rest between the CMJ, KD and SSB, ZSB, SS and ZS tests. Post-tests were organized so each participant had at least three days recovery following the final training session. All participants were required to wear full kit with appropriate soccer boots during testing. Tests were performed on 3G artificial turf, a familiar surface to the players. Prior to testing, all protocols were explained thoroughly and a standardized warm up was enforced. This consisted of jogging, dynamic stretches, transitional movements, sprints and ball drills. Practice trials were allowed for habituation.

Countermovement Jump:

CMJ was assessed using the portable Just Jump mat (Just Jump, Probiotics Inc, Alabama, USA). The highest jump (cm) from 3 maximal efforts, with a 2-minute recovery between each trial was used for analysis.

Zig Zag with and without ball:

The zig zag test was based on the previous protocol used by Young et al.[11] but its implementation was adapted to include only two stages of the original test. First, a straight 30m sprint with and without a ball and second, using the fourth stage of the test, with and without a ball. This involved slalom around 4 cones, turning at 100º angles. Cone placement was determined using trigonometry. Figure 1 displays the cone placement of all original 7 stages, however, for this study only stages 1 and 4

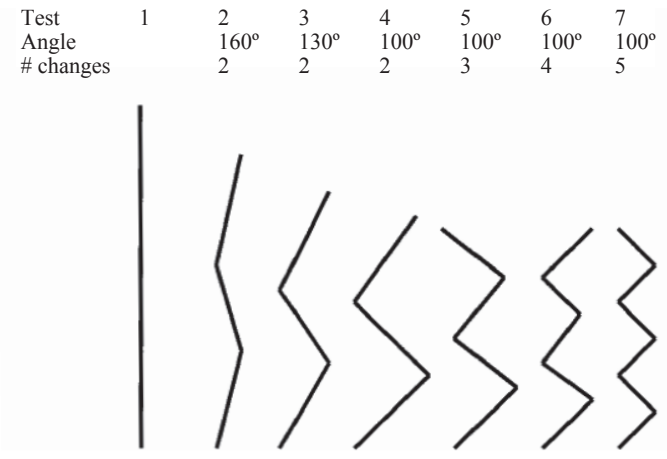

Figure 1 Zig Zag test layout.

Table 1 Participant Demographics and Descriptive Statistics.

	Experimental Group ($n = 8$)	Control Group ($n = 8$)	p
Age (yrs)	20.5 ± 1.19	20.9 ± 1.12	0.529
Mass (kg)	72.9 ± 14.61	64.4 ± 2.31	0.147
Stature (cm)	166.9 ± 6.38	169.3 ± 3.10	0.349

Results are mean ± SD.

were required.

Two trials were completed at both stages, with the average of the 2 used for analysis. A 5-minute rest between the first and second stage was enforced to allow full recovery. A Brower TC Timing System (Utah, USA) was setup with one gate at the start line and one at the end to record times. Each participants' trial was self-initiated; starting with their front foot positioned 0.3m behind the first pair of Brower gates.

Kicking Distance:

A starting point was marked on the midpoint of an end zone line, with a regulation soccer goal centered on the pitch 70 yards (64 metres) away. An 8 yard (7.32 metre) wide target lane (width of a FIFA accredited soccer goal) was marked from the end zone line to the goal posts with cones. Kicks landing outside the target lane were disqualified. First ball contact with the ground was used and the distance recorded. Subjects had 10 trials using their dominant leg and a 1-step approach, with 30 seconds rest in between attempts. The best 5 kicks were averaged and used for analysis.

Knee Extension Strength & Intervention:

The 6-week isometric knee extension intervention was performed on a knee extension/flexion dynamometer (MedX, Ocala, Florida, USA). Participants in the EG group completed isometric training sessions once per week for the 6-week training period. During each session participants performed repeated maximal voluntary isometric contractions (MVIC). The dynamometer used for training recorded torque during each MVIC allowing examination of changes in strength across the training intervention for the EG group (change from week 1 to week 6). Each session began with a dynamic, bilateral warm up of knee extensions at 81.35Nm using a 2-s concentric, 1-s isometric and 4-s eccentric repetition duration through the participants full range of motion. Before MVICs, participants performed 3 practice isometric contractions at 50% of perceived maximal effort at 3 angles (108º, 60º, and 12º). Subsequently, participants then performed MVICs at 7 angles through their range of motion (108º, 96º, 78º, 60º, 42º, 24º, and 12º). The participants were instructed to build up to maximal effort over a 3-second period, to maintain that effort for a further 3 seconds, and to then relax. A rest period of 10-seconds was permitted between angles. Verbal encouragement was given to motivate the participants. The peak torque recorded for each angle was used to calculate a Strength Index (SI) by the MedX software where SI represented the area under the torque curve using the trapezoidal method.

Statistical Analyses

Statistical analysis was performed using SPSS (version 22.0; IBM, Portsmouth, Hampshire, UK), with alpha for significance accepted at ≤ 0.05. The independent variable was the group and the dependant variable was the absolute change in the outcome variables (post- minus pre-test scores). Data met assumptions of normality (examined using a Shapiro-Wilk test). Analysis of covariance (ANCOVA) was used to compare absolute change in each outcome variable between groups with pre-test scores used as a covariate. Further, 95% confidence intervals (CI) were examined for within group change. Significant within group change was considered to have occurred if the 95%CIs for changes did not cross zero.

RESULTS

Change in Soccer Related Skills:

Between groups comparisons using ANCOVA for absolute change detected significant differences between the EG and CG for CMJ ($F_{(1,15)} = 7.019$, $p = 0.02$) and KD ($F_{(1,15)} = 11.774$, $p = 0.004$) but not SS ($F_{(1,15)} = 0.759$, $p = 0.4$), ZS ($F_{(1,15)} = 0.215$, $p = 0.651$), SSB ($F_{(1,15)} < 0.001$, $p = 0.998$), or ZSB ($F_{(1,15)} = 0.631$, $p = 0.441$). Significant within-group changes, as indicated by 95%CIs, occurred in the EG group for absolute change in CMJ (0.25 to 1.19 cm) and KD (1.32 to 4.15 metres) but no other outcomes. No significant within-group changes occurred for the CG group. Results of the change in soccer related skills are presented in Table 2 below.

Change in Strength Index for the Experimental Group:

Descriptive statistics show that average change in SI values for the EG group from week 1 to week 6 were 5067.25 ± 4119.57 Nm. 95% confidence intervals indicated that change in SI was significant (1240.78 to 7879.72 Nm).

Table 2 Changes in Soccer Related Skills Between the Experimental and Control Group.

	Experimental Group	Control Group	*p*
Change in CMJ (cm)	0.72 ± 0.22	-0.15 ± 0.22	0.003
Change in SS (seconds)	0.00 ± 0.07	0.09 ± 0.07	0.281
Change in ZS (seconds)	0.05 ± 0.06	0.09 ± 0.06	0.656
Change in SSB (seconds)	0.04 ± 0.11	0.04 ± 0.11	0.937
Change in ZSB (seconds)	0.13 ± 0.07	0.05 ± 0.07	0.359
Change in KD (metres)	2.73 ± 0.65	-0.58 ± 0.65	0.001

Abbreviations: CMJ, countermovement jump; SS, sprint speed without ball; ZS, zigzag speed without ball; SSB, sprint speed with ball; ZSB, zigzag speed with ball; KD, kicking distance; Results are marginal means ± standard error

DISCUSSION

The present study examined the effect of 6 weeks isometric RT of the knee extensors on soccer related performance in amateur female soccer players. CMJ and KD performance improved significantly in the EG group compared with the CG. However, there were no changes or between group differences for SS, ZS, SSB, and ZSB.

The EG had a mean post CMJ height of 36.84 ± 4.73 cm similar to that reported in amateur female soccer players.[12] CMJ increased 2.24% in the EG, in comparison to no change in the CG. Prior research found 7 weeks of plyometric training produced increases in CMJ in amateur female soccer players of 8.3%.[13] However, whilst isometric knee extensor training may be less effective than plyometric training for increasing CMJ, isometric training is evidently an approach that may still benefit jump performance and some have argued that explosive training (such as plyometrics) may represent an unnecessary injury risk.[14,15] Potential mechanisms for improved CMJ may include increased tendon stiffness and rate of force development.[16]

Fast onset of activation of the leg muscles is beneficial for CMJ as this increases impulse and consequently, jump height.[17] Knee extensor electromyography during the first 100ms of the rise in ground reaction force is associated with jump height.[18] This suggests a relationship between the force applied in a jumping movement with knee extension. Indeed, our results suggest improving isometric knee extension strength, even without specific movement training of the stretch-shortening cycle (i.e. plyometrics), has a positive impact upon jump performance. Isometric strength has a strong positive relationship to numerous dynamic performance measures.[19,20] Further, isometric training at multiple angles throughout knee extension ROM produces similar isokinetic strength gains to traditional dynamic repetition training.[20] Isometric knee extension training may therefore have applications over short training cycles where higher impact, weight bearing training such as plyometrics might be ill advised (e.g. leading up to an important cup match) for fear of potentially increased injury risk.[14,15] In female populations, this may be particularly important due to their increased injury risk.[8]

No significant changes were observed in either group for SS, ZS, SSB, or ZSB. Indeed, there is debate regarding the importance of knee extension strength to speed or COD ability.[21] Studies examining changes in speed and COD ability in soccer players after RT, plyometric, and other interventions alone or in combination report contrasting findings.[22,23] The lack of changes in the present study might also be a result of the short intervention duration. For example, Michailidis et al.[24] found that only after 12-weeks of plyometric training did 30m-sprint time reduce by 3%. However, it is thought very specific training is required to optimize COD speed.[11] The timing of the intervention (mid-season) may have meant that the participants had already been engaged in specific training for speed and COD ability during their soccer specific training sessions. As such, there may have been less scope for additional improvement to occur as a result of the intervention.

The instep kick is one of the most widely used skills in soccer and the quadriceps femoris recognized as potentially important for its performance.[25] Despite this, knee extension strength alone is likely not the single determinant of ball velocity. However, knee extension imparts a large proportion of the force to a kick and typically, males can produce higher peak forces than females.[26] Therefore, kicking may be an area requiring development in females. In the present study KD increased 8.8% for the EG while the CG did not change. Prior research reports increases in KD of 11.5% after 7-weeks of plyometric training in female adolescent players[13] and 22.5% after 12-weeks of plyometric training in pre-adolescent boys.[24] Whilst such rapid increases could potentially be due to age and maturation, Haldankar et al.[27] reported 12-weeks of RT significantly improved KD in adult amateur soccer players (11.5%). Increased strength likely contributes to an explosive knee extension motion increasing force production during the final kicking phase.[28] Despite arguments that isolating specific components of the kicking action do not transfer well to kicking performance[29] the present results suggest isolated isometric training of the knee extensors enhances kicking performance.

The increase in knee extensor strength was substantial (28.9%) despite low volume and frequency of training. However, a limitation in this study was the lack of strength data for the CG. Lack of improvement in other variables in the CG group suggests change in strength was unlikely, though it remains possible that strength increased with regular soccer practice.

CONCLUSION

The present study appears the first to investigate the effects of isometric knee extensor training on soccer related skills performance. Improvements in knee extensor strength from the intervention may have contributed to improved CMJ and KD. However, no improvements were observed in SS, ZS, SSB, or ZSB. As such, isometric training might be incorporated within soccer training programmes to enhance jumping and kicking ability in amateur female soccer players. A low frequency (1 × / week) and volume (7 MVICs per session) intervention could be easily implemented alongside existing training or soccer specific practice as used in this study. Further, the short intervention duration suggests this could be used in short training cycles (e.g. in preparation for key competitions where higher impact activities such as plyometrics might be undesirable due to the potential for injury).

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