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Compression and Texture in Socks Enhance Football Kicking Performance

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Abstract

The purpose of this study was to observe effects of wearing textured insoles and clinical compression socks on organisation of lower limb interceptive actions in developing athletes of different skill levels in association football. Six advanced learners and six completely novice football players (15.4 ± 0.9 years) performed 20 instep kicks with maximum velocity, in four randomly organised insoles and socks conditions, a) Smooth Socks with Smooth Insoles (SSSI); b) Smooth Socks with Textured Insoles (SSTI); c) Compression Socks with Smooth Insoles (CSSI) and d), Compression Socks with Textured Insoles (CSTI). Reflective markers were placed on key anatomical locations and the ball to facilitate three-dimensional (3D) movement recording and analysis. Data on 3D kinematic variables and initial ball velocity were analysed using one-way mixed model ANOVAs. Results revealed that wearing textured and compression materials increased the maximum velocity instep kick and increased initial ball velocity among advanced learners compared to the use of non-textured and compression materials. Adding texture to football boot insoles appeared to interact with compression materials to improve kicking performance. This is likely to have occurred through enhanced somatosensory system feedback utilised for foot placement and movement organisation of the lower limbs during kicking performance. Advanced learners were better at

harnessing the augmented feedback information from compression and texture to regulate emerging movement patterns compared to novice participants.

Keywords:

Textured insoles; clinical compression socks; instep kick; somatosensory information; skill level; attunement

1. Introduction

Textured materials, comprised of raised nodules added to shoe insoles, socks or support surfaces, are hypothesized to enhance sensory input from regions of indentation (Orth et al., 2013). Research has shown that adding texture to the upper surface of shoe insoles provides better mechanical contact and increased sensory afferent feedback via enhanced stimulation of cutaneous mechanoreceptors on the plantar surface of the foot (Hatton, Dixon, Martin, & Rome, 2009). Results have revealed that use of these materials can alter joint kinematics and kinetics of the foot (Nurse, Hulliger, Wakeling, Nigg, & Stefanyshyn, 2005) during performance of standing and walking tasks, implying a relatively cheap method for improving perceptual-motor performance, compared to more expensive foot orthotics or vibrating insoles (Qiu et al., 2012). A recent meta-analysis (Orth et al., 2013) suggested that simple deformation of the skin surface by adding texture to insole surfaces can improve performance in fundamental tasks such as balancing and postural regulation. Different types of textured materials (insoles, inserts, socks and surfaces) have been examined in various populations to study their effects on postural stability, foot positioning and locomotion (Chiu & Shiang, 2007; Corbin, Hart, Palmieri-Smith, Ingersoll, & Hertel, 2007; Dixon et al., 2012; Hartmann, Murer, de Bie, & de Bruin, 2010; Hatton et al., 2009; Qiu et al., 2012; Qiu et al., 2013; Waddington & Adams, 2003) .

Compression socks have also begun to receive attention from researchers, albeit mostly in investigations of physiological benefits (Ali, Creasy, & Edge, 2010; Blättler & Zimmet, 2008; Kemmler et al., 2009) including blood circulation during sport performance (e.g. in running). However, the role of compression socks in supporting somatosensory feedback (arising from pressure on and contortion of cutaneous surfaces and joint receptors of the lower leg) has received limited attention in the sports science and medicine literature (Woo, Davids, Liukkonen, Jaakkola, & Chow, 2014). In a recent study by Woo et al. (2014), textured compression socks were used by physically active elderly individuals to investigate effects on postural stability. The researchers sought to understand whether the textured components of the socks (comprised of indentations) located at the interface with the soles of the feet, ankles (medial, lateral and posterior sides), and tibia (anterior and proximal sides) would enable exploitation of additional "sensorimotor system noise" in nervous system function, which would, counterintuitively, boost the sensory signals from receptors in the sole of the foot (Davids, Shuttleworth, Button, Renshaw, & Glazier, 2004). The textured surface of the clinical compression socks (including the compressive tightness of the socks too) deforms plantar tissues and enable participants to exploit the presence of sensorimotor system noise to enhance perception of haptic information for lower limb positioning (Davids, et al., 2004). Wearing the normal socks may dampen the noise arising from variable tissue deformation at the foot area compared to when textured compression socks are worn (Davids et al., 2004). The use of textured compression socks in the study by Woo et al. (2014) might have enhanced the capacity of pickup and integration of weak and diffuse information signals (Davids et al., 2004) in the nervous system to aid balance and postural control.

Woo et al. (2014) also studied whether the added compression feature of socks enhanced stimulation of the mechanoreceptors in the lower leg, with the aim of helping participants achieve better balance control, compared to using textured materials only. Despite higher mechanical pressure from the compression socks (compared to normal socks), almost all participants reported feeling comfortable during the balance tests, indicating that the tightness of the socks (mainly at the ankle and calf areas) had provided them with enhanced somatosensory information. However, the use of the textured-compression socks in the previous study did not produce significant effects on postural control in participants. In the current study, the effects of the textured-compression socks were investigated during performance of a more dynamic movement. It was expected that significant changes would emerge in movement organisation of instep kicking due to effects of enhanced somatosensory feedback.

We sought to understand whether use of texture and compression may provide athletes, categorised as advanced learners, with an advantage in the regulation of actions in sport, due to their greater attunement to proprioceptive information from limb movements (Fajen, Riley, & Turvey, 2008; Han, Waddington, Anson, & Adams, 2013). To date, there have been few studies undertaken to ascertain effects of wearing such materials on movement patterns in elite and developing athletes in sport. In two previous textured material studies (Waddington & Adams, 2000, 2003) conducted on athletic populations, participants were tested on perceptual discrimination of ankle inversion and eversion movements. Data showed better ankle movement discrimination scores and improved ankle inversion movements among participants (netballers and footballers) due to wearing textured insoles, compared to smooth insoles. However, these findings emerged during performance of static movements (e.g. balance) and it needs to be understood whether enhanced somatosensory system feedback, gained from wearing textured and compression materials, can also enhance performance of dynamic, multi-articular action like kicking.

Kicking is the defining action in association football (Lees, Asai, Andersen, Nunome, & Sterzing, 2010) and a powerful kick is characterised by the achievement of maximum ball velocity (Kellis & Katis, 2007). Previous biomechanical analyses on kicking (Katis & Kellis, 2010; Kellis & Katis, 2007) have investigated types of kicking in association football and the instep kick was observed to be the most suitable technique to achieve a powerful ball velocity compared to other kicks (e.g. outstep). During the foot-ball contact phase of an instep kick performance, the ankle should achieve greater ranges of motion (plantarflexion) to generate maximum ball velocity (Kellis & Katis, 2007; Shan & Westerhoff, 2005; Shinkai, Nunome, Ikegami, & Isokawa, 2008). A previous investigation (Waddington & Adams, 2003) reported improved ankle movements when wearing textured insoles in football shoes. It was expected that effects of enhanced somatosensory feedback when wearing textured insoles and clinical compression socks in this study would reveal improved ankle movements (a greater plantarflexed position) during the foot-ball contact phase in generating maximum ball velocity.

Therefore, the purpose of this investigation was to gain insights into effects of wearing textured insoles and clinical compression socks on kicking performance in association football. We sought to understand whether improved sensory afferent feedback from the foot, gained by wearing textured and compression materials (insoles and socks), would enhance movement organisation of the lower limbs, especially on the ankle (Waddington & Adams, 2003) when kicking a ball. We also investigated whether the benefits gained from wearing textured and compression materials, through enhanced proprioceptive information from the lower limb, were dependent on greater attunement to skill level of participants to enhance kicking performance (Han, Anson, Waddington, & Adams, 2014).

2. Methods

2.1 Participants

Twelve youth males (right footed) agreed to participate in the study. Six participants (n = 6, mean age 15.7 ± 0.7 years, mean height 165.2 ± 8.0 cm, mean weight 57.7 ± 8.3 kg) were recruited from local football clubs and had at least four years' participation in competitive football and formal training throughout the year. They were classified as advanced learners for the purpose of this study. Another six participants (n = 6, mean age 15.2 ± 1.1 years, mean height 169.1 ± 6.4 cm, and mean weight 50.9 ± 4.0 kg) had never played competitively and had little playing experience at recreational level. They were classified as novice participants for the purpose of this study. Participants of this age were recruited because they had already developed basic haptic perception capacity (Gori, Del Viva, Sandini, & Burr, 2008) and were able to integrate the available and additional stimulation of the lower leg mechanoreceptors gained from wearing textured insoles and clinical compression socks. This propensity was confirmed by a peripheral sensation test (on the foot and ankle) performed by all participants, in order to exploit the use of textured and compression materials in this study. All participants responded well to the peripheral sensation test. In the advanced novices group, two participants could feel the monofilaments up to the lowest level (2.83/0.07 g) while the other four players could feel up to the second lowest level (3.61/0.4 g). For the novices group, four participants could feel up to the lowest level while the other two participants could feel up to the second lowest level. The findings provided evidence that all participants had functional plantar cutaneous receptors for detecting pressure/deformation of their feet. Skill level differences were examined to understand whether specific task experience in football kicking would facilitate somatosensory perception of athletes. The Queensland University of Technology Human Research Ethics Committee approved all experimental procedures on human participants. Written informed parental consent was obtained prior to the start of the study.

2.2 Instep kicks

The instep kicks were performed on a static football kicked towards an empty goal, which narrowed the task constraints to limit potential effects of peculiarities in a force-accuracy trade off. The distance between the ball and the goal was 6.1 metres, a similar length reported in previous kicking research by Finoff, Newcomer and Laskowski (2002). All participants were required to use an angled approach (Katis & Kellis, 2010; Lees et al., 2010) in performing the instep kick, as this approach has been demonstrated in previous work to produce maximum ball velocity in instep kicking (Barfield, Kirkendall, & Yu, 2002; Isokawa & Lees, 1988). Each participant performed 20 instep kicks under the specific task constraints of generating maximum velocity, in four randomly organised insoles and sock conditions: a) Smooth Socks with Smooth Insoles (SSSI); b) Smooth Socks with Textured Insoles (SSTI); c) Clinical Compression Socks with Smooth Insoles (CSSI) and d) Clinical Compression Socks with Textured Insoles (CSTI). Five trials were undertaken in every insole and sock condition. All participants were required to warm up and were given enough time to change and become familiarized (5-10 minutes) with the insole and sock conditions.

2.3 Experimental Protocol

Seventeen-reflective spherical markers (15mm) were placed using double-sided tape and fixed securely using additional tape to prevent movement during performance of an instep kicking. Markers were placed on key anatomical landmarks namely; the acromion process, iliac crest, greater trochanter on the right and left sides, medial and lateral epicondyles, medial and lateral malleolus, fifth metatarsal head and first metatarsal head (non-kicking foot). A minimum of three and a maximum of four markers were placed on each body segment to construct the segment model in three-dimensional (3D) software analyses (i.e. one marker each on medial and lateral epicondyle and medial and lateral malleolus to create shank segment). Special consideration was taken during marker placement to ensure it did not limit the movement of participants. In addition, eight hemispherical markers (Chow, Davids, Button, & Koh, 2007) were placed equidistantly on the ball (FIFA-approved size-5) for 3D movement recording and analysis. Kinematic data were captured by eight infrared cameras (Hawk Digital Camera, Motion Analysis Corporation) and recorded at 200Hz on the Cortex software (Motion Analysis Corporation, Santa Rosa, CA, USA). Before kicking trials, a static posture of each participant was captured to record the relative position between each marker (Inoue, Nunome, Sterzing, Shinkai, & Ikegami, 2014) and the same procedures were followed for marker positions on the ball.

Visual three-dimensional (V3D) software (C-Motion V3D, USA) was used (Chow et al., 2007; Lee, Chow, Komar, Tan, & Button, 2014) to construct an eight-segment model consisting of thorax, pelvis, thigh, shank and feet for each participant and to calculate 3D kinematic variables. 3D Euler joint angles of flexion and extension were derived for hip, knee and ankle from the respective segments as defined by the marker sets (Chow et al., 2007). The ball model was also constructed using V3D and the software automatically tracked the relative positions of the markers to determine the ball centre of mass for initial ball velocity measurement. The initial ball velocity was measured by plotting the segment velocity of the ball about the y-axis of the local coordinate system (Chow et al., 2007). Values of initial ball velocity were measured 10 frames after the point of ball contact (Kellis, Katis, & Gissis, 2004). Position of the planted foot relative to the centre of the ball (in cm) was measured by video digitizing images recorded from an overhead view, similar to study by McLean and Tumilty (1993). The distance was determined using Kinovea 2D software (V0.8.15, France).

Kinematic data from the kicking limb were collected for the duration of the limb movement sequence beginning at the instant of knee flexion and continuing to the end of peak hip flexion (Chow, Davids, Button, & Koh, 2008). The collected data were then filtered using a fourth order low-pass Butterworth digital filter (cut-off frequency of 12 Hz) (Ball, 2011; Lees & Rahnama, 2013). Previous biomechanical research (Knudson & Bahamonde, 2001) has raised issues on the effects of smoothing through impact as this method produced significant errors in the data after filtering (large underestimation). The smoothing through impact method was reported to produce percentage differences (underestimation) of 1.2% to 6.4% (wrist angles) and 54.4% to 75.9% (angular velocity) between the raw and filtered data (Knudson & Bahamonde, 2001), using automatic cut-off frequency on Peak Motus software. Compared to the suggested smoothing methods by Knudson and Bahamonde (2001), the linear and polynomial extrapolation methods only produced -4.6 % to 23.7% (small underestimation). However, the smoothing through impact method applied in this study did not produce large underestimation. We conducted analyses on the raw and filtered data during impact and the percentage differences were only 0.03% (ankle angles) and 2.02% (foot velocity). These percentage different values were quite similar to the values using suggested methods by Knudson and Bahamonde (2001). In addition, the percentage difference between point of impact data (applied in this study) and before impact data (another alternative method applied by Ball, 2008) was also considered small (1.16% to 2.0%). Therefore, it can be concluded that the smoothing through impact method applied in this study was valid to measure angular position and velocity estimations during impact in the kicking analysis.

The textured insoles (Evalite Pyramid Lightweight EVA, 3mm thickness, shore value A50, black) used in this study (Fig. 1a) had small pyramidal peaks with centre-to-centre distances of approximately 2.5mm (Hatton, Dixon, Rome, Newton, & Martin, 2012). The smooth insoles (Medium Density EVA, 3mm thickness, shore value A50, black) had a completely flat surface. All insoles (Algeos, Australia) were cut according to participant shoes size. Clinical compression socks (Woo et al., 2014) were also used (Zero Point, Finland). These were comprised of small indentations (coarse surface) on the sole, ankle and tibia bones area, and were constructed from nylon (72%) and lycra (28%), with a clinical compression level of 20-30 mmHg (Fig. 1b). The use of clinical compression socks created increased compression (at the specified level) of the soft tissues and receptors around the lower leg compared to smooth socks. The control socks were smooth football socks, of similar thickness, comprised of 80% cotton, 20% spandex.

Fig. 1. The characteristics of the textured insoles (a) and the clinical compression socks (b) used in this research.

2.4 Data analysis

A mixed-model ANOVA with one between-participant (novice participants; advanced novice participants) and one within-participant factor (SSSI; SSTI; CSSI; CSTI) was used to compare maximum velocity of instep kicks. Bonferroni corrections were applied to control Type I errors and violations of the sphericity assumption for repeated measures variables were checked using Mauchley’s test of sphericity. When a violation of this assumption was apparent, the Hyunh-Feldt method was undertaken to adjust the degrees of freedom of the error term for the F ratios. The Bonferroni method post hoc test was used to further analyse significant main effects and interactions to determine the location of differences between (skill groups) and within (insoles and sock conditions) factors. Alpha values were set at $p < .05$ and effect size was calculated using partial eta squared (η_p^2) [an effect size of .0099 = small, an effect size of .0588 = medium, and an effect size of > .1379 = large (Cohen, Cohen, West, & Aiken, 2013; Richardson, 2011)]. All data were analysed using the Statistical Package for Social Sciences (SPSS V21.0, Chicago, IL, USA).

3. Results

3.1 Initial Ball Velocity

There was a significant main effect for insoles and socks conditions on initial ball velocity values (Fig. 2), F (3, 174) = 5.228, $p = .002$, $\eta_p^2 = .083$ (medium effect size). Post hoc comparisons identified that initial ball velocity values were significantly higher in the CSSI condition compared to the SSSI condition, and in the CSSI condition compared to the SSTI condition. In addition, initial ball velocity values observed in the CSTI condition were higher compared to the SSSI condition, but the results were not statistically significant ($p = 0.07$). The main effect of group also showed significant differences, F (1, 58) = 31.168, $p < .001$, $\eta_p^2 = .350$ (large effect size). Movement organisation in advanced learners was constrained by using the textured and compression materials, with significantly higher initial ball velocity values observed in the CSTI condition compared to the SSTI condition. In addition, initial ball velocity values observed in the CSTI condition for advanced novice participants were higher compared to the SSSI condition, but the results were not statistically significant. Movement organisation in novice participants also seemed to be constrained by using the textured and compression materials for generating initial ball velocity, which was significantly higher in the CSSI condition compared to the SSSI condition. In addition, the initial ball velocity values observed in the CSTI condition for novice participants were higher compared to the SSSI condition, but the results were not statistically significant. Furthermore, there was no significant interactions observed in Group*Insoles/Socks conditions, F (3, 174) = 2.266, p = .083, η_p^2 = .038 (small effect size).

Fig. 2. Mean (SD) initial ball velocity values for novice and advanced novice participants under four insoles and socks conditions.

3.2 Foot Velocity

There was no significant main effect for insoles and sock conditions on maximum foot velocity values (Fig. 3), F (3, 174) = .326, p = .807, η_p^2 = .006 (small effect size), but there was a significant main effect of group, F (1, 58) = 24.377, $p < .001$, η_p^2 = .296 (large effect size). Post hoc comparisons showed that movement organisation in novice participants was constrained by using the textured and compression materials, with significantly higher maximum foot velocity values observed in the SSTI condition compared to the CSTI condition. There was no statistical difference in maximum foot velocity values observed in advanced novices participants. Furthermore, there was also a significant interaction between Group*Insoles/Socks conditions, F (3, 174) = 3.97, p = .009, η_p^2 = .064 (large effect size). Results revealed that maximum foot velocity values were significantly higher for advanced novices compared to novices in the SSSI, CSSI and CSTI conditions.

Fig. 3. Mean (SD) maximum foot velocity values for novice and advanced novice participants under four insoles and socks conditions.

There was no significant main effect for insoles and socks conditions on foot velocity at ball contact (Fig. 4), F (2.7, 156.58) = .532, p = .642, η_p^2 = .009 (small effect size), but there was, however, a significant main effect of group, F (1, 58) = 23.689, p < .001, η_p^2 = .290 (large effect size). Post hoc comparisons identified that movement organisation in novice participants was constrained by using the textured insoles with significantly higher foot velocity at ball contact values in the SSTI condition compared to the CSTI condition. In addition, novice participants achieved higher foot velocity at ball contact values in the CSSI condition, followed by the SSSI and CSTI conditions, but the results were not statistically significant. There was also a significant interaction between Group*Insoles/Socks conditions, F (2.7, 156.58) = 4.952, p = .004, η_p^2 = .079 (medium effect size). Results revealed that foot velocity at ball contact values were significantly higher for advanced novice participants compared to novice participants in the SSSI, CSSI and CSTI conditions.

Fig. 4. Mean (SD) foot velocity at ball contact for novice and advanced novice participants under four insoles and socks conditions.

3.3 Ankle ROM

There was a significant main effect for insoles and socks conditions on ankle ROM values (Fig. 5), F (2.71, 157.04) = 3.38, p = .023, η_p^2 = .055 (small effect size). Post hoc comparisons identified that ankle ROM values were significantly higher in the CSSI condition compared to the SSTI condition and also in the CSTI condition compared to the SSTI condition. The main effect of group also showed significant differences F (1, 58) = 86.249, p < .001, η_p^2 = .598 (large effect size). Movement organisation in advanced novice participants was constrained by using the textured and compression materials with significantly higher ankle ROM values observed in the CSSI condition compared to the SSTI condition. However, ankle ROM values were also significantly higher in the SSSI condition compared to SSTI condition. In addition, ankle ROM values were higher in the CSSI and CSTI conditions compared to SSSI condition, but the results were not statistically significant. There was also a significant interaction between Group*Insoles/Socks conditions, F (2.7, 157.04) = 4.02, p = .011, η_p^2 = .065 (medium effect size). Advanced novice participants achieved significantly higher ankle ROM values compared to novice participants, under all four insoles and socks conditions.

Fig. 5. Mean (SD) ankle ROM values for novice and advanced novice participants under four insole and socks conditions.

3.4 Hip and Knee ROM

There was no significant main effect for insoles and socks conditions on hip and knee ROM values (Table 1), F (1.435, 8.230) = 1.779, p = .184, η_p^2 = .030 (small effect size), F (2.746, 159.268) = .751, p = .512, η_p^2 = .013 (small effect size). There was also no significant main effect of group on hip and knee ROM values, F (1, 58) = 3.599, p = .063, η_p^2 = .058, F (1, 58) = 1.729, p = .194, η_p^2 = .029 (small effect size). In addition, the interactions between Group*Insoles/Socks conditions for the above mentioned dependent variables were not statistically significant, F (1.435, 83.230) = .614, p = .492, η_p^2 = .010 (small effect size), F (2.746, 159.268) = 1.239, p = .297, η_p^2 = .021 (small effect size).

Table 1. Mean (SD) hip ROM, knee ROM and planting foot placement for novice and advanced novice participants under four insoles and socks conditions.

Conditions	**Group**	**Hip ROM (^{o})**	**Knee ROM (^{o})**	**Planting Foot Placement (cm)**
SSSI	Novices	146.06 (7.71)	141.62(10.08)	28.78 (4.36)
	Advanced novices	148.75 (5.18)	147.24 (7.68)	31.54 (5.25)

SSTI	Novices	144.89 (6.06)	143.89 (9.09)	29.60 (4.81)
	Advanced novices	150.32 (7.62)	146.16 (10.61)	31.47 (6.36)
CSSI	Novices	149.66 (19.07)	144.63 (10.02)	28.86 (4.20)
	Advanced novices	151.13 (9.90)	144.63(10.24)	31.60 (5.83)
CSTI	Novices	146.31 (6.97)	145.12 (8.52)	28.24 (3.39)
	Advanced novices	148.76 (5.71)	147.73 (15.31)	31.35 (4.50)

3.5 Planting Foot Placement

There was no significant main effect for insoles and socks conditions on planting foot placement values, F (3, 174) = .465, p = .707, η_p^2 = .008 (small effect size). However, there was a significant effect of group, F (1, 58) = 6.737, p = .012, η_p^2 = .104 (medium effect size). In addition, there was no significant interactions between Group*Insoles/Socks conditions, F (3, 174) = .347, p = .791, η_p^2 = .006 (small effect size). Results showed that the recorded distance of foot placement was significantly different between advanced novice and novice participants in the SSSI, CSSI and CSTI conditions. Advanced novice participants planted the supporting foot further away from the centre of the ball compared to novice participants. The advanced novices participants also showed consistency in the distance of the planted foot to the centre of the ball, as the observed distance values between each insole and socks conditions were quite similar (approximately 31 cm ± 4.5 – 6.36 cm).

4. Discussion

The purpose of this study was to determine effects of wearing textured insoles and clinical compression socks on movement organisation during performance of an instep kicking task among advanced learners and novice football players.

4.1 Effect of various insoles and socks conditions on kicking performance

To achieve this aim we investigated effects of four different insoles and socks interactions in performing maximum velocity instep kick. Added texture and compression was introduced to the participants in these conditions namely: SSTI (textured insoles), CSSI (clinical compression socks) and CSTI (clinical compression socks and textured insoles). Based on our observations of participants' movement organisation tendencies, the use of clinical compression socks (CSSI) provided a significant main effect on maximizing initial ball velocity, producing larger ankle ROM and higher foot velocities (maximum velocity and velocity at ball contact for novice participants). When the clinical compression socks were used with textured insoles (CSTI condition), advanced learners produced higher values of initial ball velocity, which could be attributed to the advantages of added texture and compression in socks and insoles. In addition, this performance outcome was attained with a large effect size. This observation suggests that textured insoles, when used with clinical compression socks, might play a significant role in producing changes in movement organisation during performance of an instep kicking task. This is an important advance in the literature since there have been few efforts focusing on the effects of wearing textured and compression materials on emergent movement patterns of athletes during performance of a sport-related task. Previous studies have been limited to studying performance in perceptual discrimination tasks (Waddington & Adams, 2000, 2003).

The current findings showed that clinical compression socks might have been more functional than wearing textured insoles only (Wheat, Haddad, Fedirchuk, & Davids, 2014) in enhancing perception of somatosensory information from cutaneous mechanoreceptors among football players in organising the kicking action. The use of clinical compression socks in this study provided some added texture to the plantar foot surface (Wheat et al., 2014) and to other areas of the foot (i.e. ankle and tibia bones) (Woo et al., 2014). The added compression in textured socks seemed to provide greater stimulation to the lower leg mechanoreceptors, enhancing somatosensory system feedback for the performer. In addition, the use of clinical compression socks can alter the stiffness properties of the ankle and foot system (graduated compression around the ankle), potentially improving proprioception (Hooper et al., 2015; Woo et al., 2014) and guiding the lower limbs towards more efficient movements during performance.

4.2 Effect of textured and compression materials on skill level of participants

Advanced learners seemed more attuned (better able to use) to available information from the garments (textured insole and compression socks) to regulate actions compared to the novice participants (Araújo & Davids, 2011). Initial ball velocity values in advanced learners were significantly higher with the combined textured insole and compression socks (in the CSTI condition), while their ankle movement was also enhanced in the CSSI condition, compared to performance in the SSTI condition. For novice participants, these performance outcomes were only evident in initial ball velocity values when they were presented with the CSSI condition (significantly higher values compared to SSSI condition). In addition, results also showed that movement organisation in novice participants wasconstrained by enhanced somatosensory feedback separately; either using textured insoles (in the SSTI condition) or compression socks only (in the CSSI condition). It is possible that use of textured and compression materials (in the CSSI and CSTI conditions) allowed advanced learners to harness haptic information from the feet in order to regulate kicking actions during performance, for example, during stable placement of the planted foot. For novice participants, there were some minimal effects of added texture during performance of an instep kicking task. One explanation for the inability of novice participants to use added texture and compressions for regulating movement organisation of kicking actions is that they may have not been attuned to the enhanced proprioceptive information that emerged (Fajen et al., 2008). An interesting question for future research is to examine whether novice participants would be able to use the textured and compression materials after extended periods of practice to facilitate learning and experience. In line with this view, Qiu et al. (2013) suggested that the time course of adaptation of participants to the presence of textured and compression materials is one of the main priorities for future investigations in this area.

4.3 Using textured and compression materials improved ankle movement

Studies by Waddington and Adams (2000, 2003) found that using textured insoles improved ankle movement positioning compared to wearing non-textured insoles. These findings on improved ankle movement discrimination are harmonious with the results of the current study which extended the literature base by examining effects on emergent movement organisation tendencies. Since the textured insoles were worn on the foot and the clinical compression socks worn up to knee height, effects of added texture and compression were prominent on the distal end of the lower limbs, producing a significant effect on ankle ROM (associated with foot-ball contact). Our results showed a significant main effect of insoles and socks conditions between CSSI-SSTI and CSTI-SSTI conditions. Furthermore, advanced novice participants revealed significantly larger ankle ROM values in the CSSI conditions, compared to the SSTI conditions, with the effect of compression not being present in the latter condition. Here, the data revealed that wearing textured and compression materials played a significant role in the emergence of increased ankle ROM. A study by Han et al. (2013) found that having good ankle positioning discrimination is important for sporting success (e.g. in association football) and it may underpin elite sport performance. The findings from that previous study (Han et al., 2013) support the need for enhanced proprioceptive acuity from the lower limbs and ankle joint in particular.

4.4 Using textured and compression materials improved initial ball velocity

Ball velocity production was associated with the velocity of the foot and the quality of foot-ball impact (Kellis & Katis, 2007). The findings of this study showed that foot velocities and initial ball velocity were significantly increased when using textured and compression materials. An ideal instep kicking technique suggested by Shinkai, Nunome, Isokawa, and Ikegami (2009), during the ball contact phase, the kicking foot was observed to be in an abducted, everted and plantarflexed position. Functional foot fixation (at ball contact) during this phase is vital in performing a quality instep kick. Earlier, it was noted that participants produced larger ankle ROM values with added texture and compression. Previous biomechanical research (Kellis & Katis, 2007; Shinkai et al., 2008) on instep kicking has highlighted that higher values of ankle ROM during the foot-ball contact phase is important in achieving maximum ball velocity. When values of ankle ROM are larger, it is most likely that the ball surface area will be distributed evenly on the upper part of the foot (ball contact point closer to the ankle area). This performance outcomes creates an effective striking mass (Lees & Nolan, 1998), produced greater momentum transfer between the foot and the ball (Shinkai et al., 2009) and could lead to higher ball velocity. Effects of textured and compression materials in this study constrained participant movement organisation in producing significantly higher initial ball velocity compared to non-textured and compression materials. In addition, the reported initial ball velocity for advanced novice participants (in the CSTI condition, 21.27 $ms^{-1} \pm 2.43 ms^{-1}$) was higher than other insoles and socks conditions.

5. Conclusion

Using clinical compression socks or wearing textured insoles in football shoes seemed to improve the detection of haptic information from the plantar sole of the foot, evidenced by enhanced kicking performance, especially in advanced learners. Effects of wearing textured and compression materials were associated with positive outcomes during performance of a dynamic instep kicking task with maximum velocity. Our study revealed that when wearing these materials, even young participants significantly improved their ankle range of motion, resulting in higher foot velocity and increased initial ball velocity. These performance outcomes were obtained with small-to-large effect sizes. Based on our findings, clinical compression socks seem more functional than simply using textured insoles alone in providing the additional feedback information to regulate actions, conforming with previous suggestions by Wheat et al. (2014). The effect of added texture and use of compression materials constrained movement organisation in both advanced novice and novice participants by producing enhanced joint kinematics results during performance of an instep kicking task. Further work should investigate whether wearing textured and compression materials on other parts of the body (e.g. the torso or upper body) can benefit athletic performance and enhance skill performance through improvement of movement perception. In addition, an interesting issue for future research would be to require participants to wear textured and compression materials on either the kicking foot or the standing foot to enable identification of specific effects on separate limbs during kicking performance.

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