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HASAN, Hosni, DAVIDS, Keith <<http://orcid.org/0000-0003-1398-6123>>, CHOW, Jia Yi and KERR, Graham

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1 **Compression and Texture in Socks Enhance Football Kicking Performance**

2
3 Hosni Hasan^{1,5,6*}, Keith Davids^{2,3}, Jia Yi Chow⁴, Graham Kerr^{1,5}

4
5 ¹School of Exercise and Nutrition Science, Queensland University of Technology, Brisbane,
6 Australia

7
8 ²FiDiPro Programme, Faculty of Sport and Health Sciences, University of Jyväskylä, Finland

9
10 ³Centre for Sports Engineering Research, Sheffield Hallam University, Sheffield, United
11 Kingdom,

12
13 ⁴Physical Education and Sports Science, Nanyang Technological University, Singapore

14
15 ⁵Movement Neuroscience, Institute of Health and Biomedical Innovation, Queensland
16 University of Technology, Brisbane, Australia

17
18 ⁶Faculty of Sports Science and Recreation, Universiti Teknologi MARA, Shah Alam,
19 Malaysia

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29 *Corresponding author:

30 Hosni Hasan
31 School of Exercise and Nutrition Sciences,
32 O Block, Room A10-13, Kelvin Grove, Victoria Park Road,
33 Kelvin Grove QLD 4059, Queensland, Australia
34 Telephone: +61451113652

35 E-mail: hosni.hasan@hdr.qut.edu.au

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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

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

3

4 Keywords:

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

7

8 **1. Introduction**

9 Textured materials, comprised of raised nodules added to shoe insoles, socks or support
10 surfaces, are hypothesized to enhance sensory input from regions of indentation (Orth et al.,
11 2013). Research has shown that adding texture to the upper surface of shoe insoles provides
12 better mechanical contact and increased sensory afferent feedback via enhanced stimulation
13 of cutaneous mechanoreceptors on the plantar surface of the foot (Hatton, Dixon, Martin, &
14 Rome, 2009). Results have revealed that use of these materials can alter joint kinematics and
15 kinetics of the foot (Nurse, Hulliger, Wakeling, Nigg, & Stefanyshyn, 2005) during
16 performance of standing and walking tasks, implying a relatively cheap method for
17 improving perceptual-motor performance, compared to more expensive foot orthotics or
18 vibrating insoles (Qiu et al., 2012). A recent meta-analysis (Orth et al., 2013) suggested that
19 simple deformation of the skin surface by adding texture to insole surfaces can improve
20 performance in fundamental tasks such as balancing and postural regulation. Different types
21 of textured materials (insoles, inserts, socks and surfaces) have been examined in various
22 populations to study their effects on postural stability, foot positioning and locomotion (Chiu
23 & Shiang, 2007; Corbin, Hart, Palmieri-Smith, Ingersoll, & Hertel, 2007; Dixon et al., 2012;
24 Hartmann, Murer, de Bie, & de Bruin, 2010; Hatton et al., 2009; Qiu et al., 2012; Qiu et al.,
25 2013; Waddington & Adams, 2003) .

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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.

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

13
14 We sought to understand whether use of texture and compression may provide athletes,
15 categorised as advanced learners, with an advantage in the regulation of actions in sport, due
16 to their greater attunement to proprioceptive information from limb movements (Fajen, Riley,
17 & Turvey, 2008; Han, Waddington, Anson, & Adams, 2013). To date, there have been few
18 studies undertaken to ascertain effects of wearing such materials on movement patterns in
19 elite and developing athletes in sport. In two previous textured material studies (Waddington
20 & Adams, 2000, 2003) conducted on athletic populations, participants were tested on
21 perceptual discrimination of ankle inversion and eversion movements. Data showed better
22 ankle movement discrimination scores and improved ankle inversion movements among
23 participants (netballers and footballers) due to wearing textured insoles, compared to smooth
24 insoles. However, these findings emerged during performance of static movements (e.g.
25 balance) and it needs to be understood whether enhanced somatosensory system feedback,

1 gained from wearing textured and compression materials, can also enhance performance of
2 dynamic, multi-articular action like kicking.

3
4 Kicking is the defining action in association football (Lees, Asai, Andersen, Nunome, &
5 Sterzing, 2010) and a powerful kick is characterised by the achievement of maximum ball
6 velocity (Kellis & Katis, 2007). Previous biomechanical analyses on kicking (Katis & Kellis,
7 2010; Kellis & Katis, 2007) have investigated types of kicking in association football and the
8 instep kick was observed to be the most suitable technique to achieve a powerful ball velocity
9 compared to other kicks (e.g. outstep). During the foot-ball contact phase of an instep kick
10 performance, the ankle should achieve greater ranges of motion (plantarflexion) to generate
11 maximum ball velocity (Kellis & Katis, 2007; Shan & Westerhoff, 2005; Shinkai, Nunome,
12 Ikegami, & Isokawa, 2008). A previous investigation (Waddington & Adams, 2003) reported
13 improved ankle movements when wearing textured insoles in football shoes. It was expected
14 that effects of enhanced somatosensory feedback when wearing textured insoles and clinical
15 compression socks in this study would reveal improved ankle movements (a greater
16 plantarflexed position) during the foot-ball contact phase in generating maximum ball
17 velocity.

18
19 Therefore, the purpose of this investigation was to gain insights into effects of wearing
20 textured insoles and clinical compression socks on kicking performance in association
21 football. We sought to understand whether improved sensory afferent feedback from the foot,
22 gained by wearing textured and compression materials (insoles and socks), would enhance
23 movement organisation of the lower limbs, especially on the ankle (Waddington & Adams,
24 2003) when kicking a ball. We also investigated whether the benefits gained from wearing
25 textured and compression materials, through enhanced proprioceptive information from the

1 lower limb, were dependent on greater attunement to skill level of participants to enhance
2 kicking performance (Han, Anson, Waddington, & Adams, 2014).

3

4 **2. Methods**

5 *2.1 Participants*

6 Twelve youth males (right footed) agreed to participate in the study. Six participants ($n = 6$,
7 mean age 15.7 ± 0.7 years, mean height 165.2 ± 8.0 cm, mean weight 57.7 ± 8.3 kg) were
8 recruited from local football clubs and had at least four years' participation in competitive
9 football and formal training throughout the year. They were classified as advanced learners
10 for the purpose of this study. Another six participants ($n = 6$, mean age 15.2 ± 1.1 years,
11 mean height 169.1 ± 6.4 cm, and mean weight 50.9 ± 4.0 kg) had never played competitively
12 and had little playing experience at recreational level. They were classified as novice
13 participants for the purpose of this study. Participants of this age were recruited because they
14 had already developed basic haptic perception capacity (Gori, Del Viva, Sandini, & Burr,
15 2008) and were able to integrate the available and additional stimulation of the lower leg
16 mechanoreceptors gained from wearing textured insoles and clinical compression socks. This
17 propensity was confirmed by a peripheral sensation test (on the foot and ankle) performed by
18 all participants, in order to exploit the use of textured and compression materials in this study.
19 All participants responded well to the peripheral sensation test. In the advanced novices
20 group, two participants could feel the monofilaments up to the lowest level (2.83/0.07 g)
21 while the other four players could feel up to the second lowest level (3.61/0.4 g). For the
22 novices group, four participants could feel up to the lowest level while the other two
23 participants could feel up to the second lowest level. The findings provided evidence that all
24 participants had functional plantar cutaneous receptors for detecting pressure/deformation of
25 their feet. Skill level differences were examined to understand whether specific task

1 experience in football kicking would facilitate somatosensory perception of athletes. The
2 Queensland University of Technology Human Research Ethics Committee approved all
3 experimental procedures on human participants. Written informed parental consent was
4 obtained prior to the start of the study.

5

6 *2.2 Instep kicks*

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

21

22 *2.3 Experimental Protocol*

23 Seventeen-reflective spherical markers (15mm) were placed using double-sided tape and
24 fixed securely using additional tape to prevent movement during performance of an instep
25 kicking. Markers were placed on key anatomical landmarks namely; the acromion process,

1 iliac crest, greater trochanter on the right and left sides, medial and lateral epicondyles,
2 medial and lateral malleolus, fifth metatarsal head and first metatarsal head (non-kicking
3 foot). A minimum of three and a maximum of four markers were placed on each body
4 segment to construct the segment model in three-dimensional (3D) software analyses (i.e. one
5 marker each on medial and lateral epicondyle and medial and lateral malleolus to create
6 shank segment). Special consideration was taken during marker placement to ensure it did not
7 limit the movement of participants. In addition, eight hemispherical markers (Chow, Davids,
8 Button, & Koh, 2007) were placed equidistantly on the ball (FIFA-approved size-5) for 3D
9 movement recording and analysis. Kinematic data were captured by eight infrared cameras
10 (Hawk Digital Camera, Motion Analysis Corporation) and recorded at 200Hz on the Cortex
11 software (Motion Analysis Corporation, Santa Rosa, CA, USA). Before kicking trials, a static
12 posture of each participant was captured to record the relative position between each marker
13 (Inoue, Nunome, Sterzing, Shinkai, & Ikegami, 2014) and the same procedures were
14 followed for marker positions on the ball.

15
16 Visual three-dimensional (V3D) software (C-Motion V3D, USA) was used (Chow et al.,
17 2007; Lee, Chow, Komar, Tan, & Button, 2014) to construct an eight-segment model
18 consisting of thorax, pelvis, thigh, shank and feet for each participant and to calculate 3D
19 kinematic variables. 3D Euler joint angles of flexion and extension were derived for hip, knee
20 and ankle from the respective segments as defined by the marker sets (Chow et al., 2007).
21 The ball model was also constructed using V3D and the software automatically tracked the
22 relative positions of the markers to determine the ball centre of mass for initial ball velocity
23 measurement. The initial ball velocity was measured by plotting the segment velocity of the
24 ball about the y-axis of the local coordinate system (Chow et al., 2007). Values of initial ball
25 velocity were measured 10 frames after the point of ball contact (Kellis, Katis, & Gissis,

1 2004). Position of the planted foot relative to the centre of the ball (in cm) was measured by
2 video digitizing images recorded from an overhead view, similar to study by McLean and
3 Tumilty (1993). The distance was determined using Kinovea 2D software (V0.8.15, France).
4
5 Kinematic data from the kicking limb were collected for the duration of the limb movement
6 sequence beginning at the instant of knee flexion and continuing to the end of peak hip
7 flexion (Chow, Davids, Button, & Koh, 2008). The collected data were then filtered using a
8 fourth order low-pass Butterworth digital filter (cut-off frequency of 12 Hz) (Ball, 2011; Lees
9 & Rahnama, 2013). Previous biomechanical research (Knudson & Bahamonde, 2001) has
10 raised issues on the effects of smoothing through impact as this method produced significant
11 errors in the data after filtering (large underestimation). The smoothing through impact
12 method was reported to produce percentage differences (underestimation) of 1.2% to 6.4%
13 (wrist angles) and 54.4% to 75.9% (angular velocity) between the raw and filtered data
14 (Knudson & Bahamonde, 2001), using automatic cut-off frequency on Peak Motus software.
15 Compared to the suggested smoothing methods by Knudson and Bahamonde (2001), the
16 linear and polynomial extrapolation methods only produced -4.6 % to 23.7% (small
17 underestimation). However, the smoothing through impact method applied in this study did
18 not produce large underestimation. We conducted analyses on the raw and filtered data
19 during impact and the percentage differences were only 0.03% (ankle angles) and 2.02%
20 (foot velocity). These percentage different values were quite similar to the values using
21 suggested methods by Knudson and Bahamonde (2001). In addition, the percentage
22 difference between point of impact data (applied in this study) and before impact data
23 (another alternative method applied by Ball, 2008) was also considered small (1.16% to
24 2.0%). Therefore, it can be concluded that the smoothing through impact method applied in

1 this study was valid to measure angular position and velocity estimations during impact in the
2 kicking analysis.

3

4 The textured insoles (Evalite Pyramid Lightweight EVA, 3mm thickness, shore value A50,
5 black) used in this study (Fig. 1a) had small pyramidal peaks with centre-to-centre distances
6 of approximately 2.5mm (Hatton, Dixon, Rome, Newton, & Martin, 2012). The smooth
7 insoles (Medium Density EVA, 3mm thickness, shore value A50, black) had a completely
8 flat surface. All insoles (Algeos, Australia) were cut according to participant shoes size.
9 Clinical compression socks (Woo et al., 2014) were also used (Zero Point, Finland). These
10 were comprised of small indentations (coarse surface) on the sole, ankle and tibia bones area,
11 and were constructed from nylon (72%) and lycra (28%), with a clinical compression level of
12 20-30 mmHg (Fig. 1b). The use of clinical compression socks created increased compression
13 (at the specified level) of the soft tissues and receptors around the lower leg compared to
14 smooth socks. The control socks were smooth football socks, of similar thickness, comprised
15 of 80% cotton, 20% spandex.

16

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

19

20 *2.4 Data analysis*

21 A mixed-model ANOVA with one between-participant (novice participants; advanced novice
22 participants) and one within-participant factor (SSSI; SSTI; CSSI; CSTI) was used to
23 compare maximum velocity of instep kicks. Bonferroni corrections were applied to control
24 Type I errors and violations of the sphericity assumption for repeated measures variables
25 were checked using Mauchley's test of sphericity. When a violation of this assumption was

1 apparent, the Hyunh-Feldt method was undertaken to adjust the degrees of freedom of the
2 error term for the F ratios. The Bonferroni method post hoc test was used to further analyse
3 significant main effects and interactions to determine the location of differences between
4 (skill groups) and within (insoles and sock conditions) factors. Alpha values were set at $p <$
5 $.05$ and effect size was calculated using partial eta squared (η_p^2) [an effect size of $.0099 =$
6 small, an effect size of $.0588 =$ medium, and an effect size of $> .1379 =$ large (Cohen, Cohen,
7 West, & Aiken, 2013; Richardson, 2011)]. All data were analysed using the Statistical
8 Package for Social Sciences (SPSS V21.0, Chicago, IL, USA).

9

10 **3. Results**

11 *3.1 Initial Ball Velocity*

12 There was a significant main effect for insoles and socks conditions on initial ball velocity
13 values (Fig. 2), $F(3, 174) = 5.228$, $p = .002$, $\eta_p^2 = .083$ (medium effect size). Post hoc
14 comparisons identified that initial ball velocity values were significantly higher in the CSSI
15 condition compared to the SSSI condition, and in the CSSI condition compared to the SSTI
16 condition. In addition, initial ball velocity values observed in the CSTI condition were higher
17 compared to the SSSI condition, but the results were not statistically significant ($p = 0.07$).
18 The main effect of group also showed significant differences, $F(1, 58) = 31.168$, $p < .001$,
19 $\eta_p^2 = .350$ (large effect size). Movement organisation in advanced learners was constrained by
20 using the textured and compression materials, with significantly higher initial ball velocity
21 values observed in the CSTI condition compared to the SSTI condition. In addition, initial
22 ball velocity values observed in the CSTI condition for advanced novice participants were
23 higher compared to the SSSI condition, but the results were not statistically significant.
24 Movement organisation in novice participants also seemed to be constrained by using the
25 textured and compression materials for generating initial ball velocity, which was

1 significantly higher in the CSSI condition compared to the SSSI condition. In addition, the
2 initial ball velocity values observed in the CSTI condition for novice participants were higher
3 compared to the SSSI condition, but the results were not statistically significant. Furthermore,
4 there was no significant interactions observed in Group*Insoles/Socks conditions, $F(3, 174)$
5 $= 2.266$, $p = .083$, $\eta_p^2 = .038$ (small effect size).

6

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

9

10 *3.2 Foot Velocity*

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

22

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

25

1 There was no significant main effect for insoles and socks conditions on foot velocity at ball
2 contact (Fig. 4), $F(2.7, 156.58) = .532$, $p = .642$, $\eta_p^2 = .009$ (small effect size), but there was,
3 however, a significant main effect of group, $F(1, 58) = 23.689$, $p < .001$, $\eta_p^2 = .290$ (large
4 effect size). Post hoc comparisons identified that movement organisation in novice
5 participants was constrained by using the textured insoles with significantly higher foot
6 velocity at ball contact values in the SSTI condition compared to the CSTI condition. In
7 addition, novice participants achieved higher foot velocity at ball contact values in the CSSI
8 condition, followed by the SSSI and CSTI conditions, but the results were not statistically
9 significant. There was also a significant interaction between Group*Insoles/Socks conditions,
10 $F(2.7, 156.58) = 4.952$, $p = .004$, $\eta_p^2 = .079$ (medium effect size). Results revealed that foot
11 velocity at ball contact values were significantly higher for advanced novice participants
12 compared to novice participants in the SSSI, CSSI and CSTI conditions.

13

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

16

17 *3.3 Ankle ROM*

18 There was a significant main effect for insoles and socks conditions on ankle ROM values
19 (Fig. 5), $F(2.71, 157.04) = 3.38$, $p = .023$, $\eta_p^2 = .055$ (small effect size). Post hoc
20 comparisons identified that ankle ROM values were significantly higher in the CSSI
21 condition compared to the SSTI condition and also in the CSTI condition compared to the
22 SSTI condition. The main effect of group also showed significant differences $F(1, 58) =$
23 86.249 , $p < .001$, $\eta_p^2 = .598$ (large effect size). Movement organisation in advanced novice
24 participants was constrained by using the textured and compression materials with
25 significantly higher ankle ROM values observed in the CSSI condition compared to the SSTI

1 condition. However, ankle ROM values were also significantly higher in the SSSI condition
 2 compared to SSTI condition. In addition, ankle ROM values were higher in the CSSI and
 3 CSTI conditions compared to SSSI condition, but the results were not statistically significant.
 4 There was also a significant interaction between Group*Insoles/Socks conditions, $F(2.7,$
 5 $157.04) = 4.02$, $p = .011$, $\eta_p^2 = .065$ (medium effect size). Advanced novice participants
 6 achieved significantly higher ankle ROM values compared to novice participants, under all
 7 four insoles and socks conditions.

8

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

11

12 *3.4 Hip and Knee ROM*

13 There was no significant main effect for insoles and socks conditions on hip and knee ROM
 14 values (Table 1), $F(1.435, 8.230) = 1.779$, $p = .184$, $\eta_p^2 = .030$ (small effect size), $F(2.746,$
 15 $159.268) = .751$, $p = .512$, $\eta_p^2 = .013$ (small effect size). There was also no significant main
 16 effect of group on hip and knee ROM values, $F(1, 58) = 3.599$, $p = .063$, $\eta_p^2 = .058$, $F(1, 58)$
 17 $= 1.729$, $p = .194$, $\eta_p^2 = .029$ (small effect size). In addition, the interactions between
 18 Group*Insoles/Socks conditions for the above mentioned dependent variables were not
 19 statistically significant, $F(1.435, 83.230) = .614$, $p = .492$, $\eta_p^2 = .010$ (small effect size), F
 20 $(2.746, 159.268) = 1.239$, $p = .297$, $\eta_p^2 = .021$ (small effect size).

21

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

Conditions	Group	Hip ROM (°)	Knee ROM (°)	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)

1

2 *3.5 Planting Foot Placement*

3 There was no significant main effect for insoles and socks conditions on planting foot
4 placement values, $F(3, 174) = .465$, $p = .707$, $\eta_p^2 = .008$ (small effect size). However, there
5 was a significant effect of group, $F(1, 58) = 6.737$, $p = .012$, $\eta_p^2 = .104$ (medium effect size).
6 In addition, there was no significant interactions between Group*Insoles/Socks conditions, F
7 $(3, 174) = .347$, $p = .791$, $\eta_p^2 = .006$ (small effect size). Results showed that the recorded
8 distance of foot placement was significantly different between advanced novice and novice
9 participants in the SSSI, CSSI and CSTI conditions. Advanced novice participants planted the
10 supporting foot further away from the centre of the ball compared to novice participants. The
11 advanced novices participants also showed consistency in the distance of the planted foot to
12 the centre of the ball, as the observed distance values between each insole and socks
13 conditions were quite similar (approximately $31 \text{ cm} \pm 4.5 - 6.36 \text{ cm}$).

14

15 **4. Discussion**

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

19

20 *4.1 Effect of various insoles and socks conditions on kicking performance*

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

19

20 The current findings showed that clinical compression socks might have been more
21 functional than wearing textured insoles only (Wheat, Haddad, Fedirchuk, & Davids, 2014)
22 in enhancing perception of somatosensory information from cutaneous mechanoreceptors
23 among football players in organising the kicking action. The use of clinical compression
24 socks in this study provided some added texture to the plantar foot surface (Wheat et al.,
25 2014) and to other areas of the foot (i.e. ankle and tibia bones) (Woo et al., 2014). The added

1 compression in textured socks seemed to provide greater stimulation to the lower leg
2 mechanoreceptors, enhancing somatosensory system feedback for the performer. In addition,
3 the use of clinical compression socks can alter the stiffness properties of the ankle and foot
4 system (graduated compression around the ankle), potentially improving proprioception
5 (Hooper et al., 2015; Woo et al., 2014) and guiding the lower limbs towards more efficient
6 movements during performance.

7

8 *4.2 Effect of textured and compression materials on skill level of participants*

9 Advanced learners seemed more attuned (better able to use) to available information from the
10 garments (textured insole and compression socks) to regulate actions compared to the novice
11 participants (Araújo & Davids, 2011). Initial ball velocity values in advanced learners were
12 significantly higher with the combined textured insole and compression socks (in the CSTI
13 condition), while their ankle movement was also enhanced in the CSSI condition, compared
14 to performance in the SSTI condition. For novice participants, these performance outcomes
15 were only evident in initial ball velocity values when they were presented with the CSSI
16 condition (significantly higher values compared to SSSI condition). In addition, results also
17 showed that movement organisation in novice participants was constrained by enhanced
18 somatosensory feedback separately; either using textured insoles (in the SSTI condition) or
19 compression socks only (in the CSSI condition). It is possible that use of textured and
20 compression materials (in the CSSI and CSTI conditions) allowed advanced learners to
21 harness haptic information from the feet in order to regulate kicking actions during
22 performance, for example, during stable placement of the planted foot. For novice
23 participants, there were some minimal effects of added texture during performance of an
24 instep kicking task. One explanation for the inability of novice participants to use added
25 texture and compressions for regulating movement organisation of kicking actions is that they

1 may have not been attuned to the enhanced proprioceptive information that emerged (Fajen et
2 al., 2008). An interesting question for future research is to examine whether novice
3 participants would be able to use the textured and compression materials after extended
4 periods of practice to facilitate learning and experience. In line with this view, Qiu et al.
5 (2013) suggested that the time course of adaptation of participants to the presence of textured
6 and compression materials is one of the main priorities for future investigations in this area.

7 *4.3 Using textured and compression materials improved ankle movement*

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

25

1 *4.4 Using textured and compression materials improved initial ball velocity*

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

22

23 **5. Conclusion**

24 Using clinical compression socks or wearing textured insoles in football shoes seemed to
25 improve the detection of haptic information from the plantar sole of the foot, evidenced by

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

18

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23

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