The effect of neoprene shorts on leg proprioception in Australian football players

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KEYWORDS
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Summary Our purpose was to assess the effect of wearing close-fitting neoprene shorts on swinging leg movement discrimination (MD) scores in elite level Australian Football players. Twenty players had their swinging leg MD assessed using the active movement extent discrimination apparatus (AMEDA), once wearing close-fitting neoprene and once wearing loose-fitting running shorts. Subjects were randomly allocated to one of the shorts conditions prior to repeating the test in the other condition. The AMEDA was used to assess the accuracy at which subjects judge the extent of a standing backward swinging leg movement corresponding to the late swing early stance phase of running. Each subject performed 40 movements made to one of five randomly set physical limits, and without the aid of vision made a judgment as to the perceived limit position. From the accuracy of these judgments, a movement discrimination (MD) score was calculated for each subject under each condition. Subjects were grouped as having low or high neuromuscular control, or ability to use proprioception when controlling active movements without vision, based on their loose-shorts MD score. Analysis was performed on the MD scores obtained for each limb from subjects in the two groups, under the two shorts-wearing conditions. There was no main effect of wearing close-fitting shorts when the cohort was treated as a whole. A significant interaction effect was obtained ($F = 17.027$, $p = 0.0006$) whereby the mean MD score of the low neuromuscular control ability group was improved when wearing neoprene shorts but was reduced for the high ability group. Wearing close-fitting neoprene shorts has a beneficial effect on leg swing judgment accuracy in subjects with low neuromuscular control ability. Conversely, leg swing judgment accuracy for subjects with high ability was reduced by wearing neoprene shorts.

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Introduction

Hamstring strain injuries occur most frequently in sports that involve sprinting, particularly football and athletics.\textsuperscript{1–3} Many factors have been suggested and investigated as possible contributors.
to hamstring injury, including previous hamstring and other lower limb injury, age,\(^4\) hamstring inflexibility,\(^5\) hamstring muscle weakness or lower limb strength imbalance\(^6\) and poor control of leg movements and muscle contractions.\(^7,8\) From the above list, it is the reversible risk factors that are of greatest interest, as it is these factors that have the potential to be modified by injury prevention methods.\(^9\) One suggested factor, poor lower limb neuromuscular control, has been found to be associated with an increased rate of hamstring injury in Australian Football players.\(^8\) Any method of improving lower limb neuromuscular control could have the potential to reduce the risk of hamstring injury.

Proprioception can be defined as the sensations of position and movement of body segments, and of the force and timing of muscle contractions.\(^10\) Many receptors convey proprioceptive information via afferent pathways to the neuromuscular control centres of the central nervous system\(^11\) and several studies conducted in the last decade have demonstrated a potential for improvement in measures of proprioception obtained from various body regions. For example, at the ankle, trunk, knee and shoulder, elastic neoprene sleeves and braces have been found to improve joint position sense.\(^12–15\) The commonly proposed mechanism by which these techniques improved performance on various proprioception-based measures is increased afferent input from skin, muscle and joint receptors arising from wearing the tape or brace.\(^12\) Afferent information from tactile and muscle sources is the most important to proprioception,\(^16\) and any enhancement of the cutaneous input from wearing an aid should allow better neuromuscular control of the relevant limb.\(^17\) Neoprene shorts may provide additional afferent input to the neuromuscular control centres for the hip, in a similar way that braces, elastic sleeves and bandages have been proposed to do at other joints.

However, elastic sleeves or braces do not improve performance on proprioceptive tests to the same extent in all subjects. Several studies on wearing orthoses have demonstrated the greater improvement to be in subjects whose proprioception ability was lowest to begin with\(^15,18\) or who were injured.\(^14,19\)

The aim of this study was to test the effect of wearing neoprene shorts on leg neuromuscular control, as assessed by the judgment accuracy of active leg movements, in a group of elite level Australian Football players. A further aim was to determine whether or not wearing neoprene shorts affected the performance of low scoring subjects on this proprioception-based task, in a manner different to high scoring subjects.

**Participants**

Twenty male Australian Football players were recruited by advertisement from one professional Australian Football League team that consisted of 39 players. Subjects were excluded if they had sustained a significant lower limb injury in the 12 weeks prior to assessment. At the time of recruitment, 9 players were so excluded and a further 10 players did not volunteer. Three players recruited had suffered a previous hamstring injury, but more than 12 weeks previously. At commencement, all subjects were participating in full pre-season training and were not currently using neoprene shorts. Written informed consent was obtained from each subject and The University of Sydney Human Research Ethics Committee granted ethics approval for the study.

**Method**

Swinging leg neuromuscular control was assessed by using movement extent judgment on a device that provides automatic stop control for these movements, the active movement extent discrimination apparatus (AMEDA). The device was originally used to test ankle inversion judgment accuracy. Reported reliability for this application was high, with an ICC (2, 1) of 0.89.\(^20\) The AMEDA has previously been used to assess swinging leg neuromuscular control in footballers,\(^8,21\) as well as being used at the ankle and knee,\(^22\) though the reliability for these uses of the AMEDA is unknown. The testing procedure involved subjects standing on the AMEDA platform facing away so as to prevent direct vision of the apparatus. The movement of the tested leg corresponded to the motion occurring in the late swing phase and terminated in the equivalent of the early stance phase of running (Fig. 1). While standing on the other leg, subjects lifted the leg to be tested upward and forward to touch a start bar, then swung it down and backward until their heel was stopped by an adjustable plate. The five stop positions of this contact plate were each 5.6 mm apart and equally spaced in the range from 20 to 3 mm behind the posterior margin of the heels in standing. Prior to data collection, each subject was given a series of trial movements to familiarise them with the swinging movement required and with each plate stop position. A laptop computer (Travelmate 512DX) manufactured by Acer
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Subjects were randomly allocated to testing either wearing close-fitting Thermoskin® shorts that extended to the mid-thigh or wearing the alternative loose-fitting running shorts. They were also randomly allocated to either their left or right side to test first, and a 5-min break was provided between each test condition and side tested. The loose-fitting running shorts contained a “jockey” style undergarment and were made of a polyester and cotton blend fabric not designed to exert compression. The neoprene shorts were individually fitted according the manufacturer’s recommendations.

Following data collection and calculation of an MD score for each limb under each shorts condition, subjects were grouped according to their discrimination ability. In order to classify a subject, the mean of a subject’s left-side and right-side scores for the without-shorts condition was used. The mean movement discrimination score of the pooled limbs from a previous sample of Australian Football players was known to be 0.78. This same value was therefore used to assign the subjects in the current study as having high (MD score ≥0.78) or low (MD <0.78) leg neuromuscular control, and deemed to be more valid a method than using the mean of the sample to create groups. The expectation for this study was that approximately 10 subjects would be allocated to each of the low and high groups. Power analysis indicated that, for a group of 10 subjects and a large effect size, power to detect differences would be average to good, at 72%.

**Statistical analysis**

MD scores were calculated for both legs of each subject, from tests conducted when wearing loose and wearing neoprene shorts. SPSS 10.0 for Windows software was used to perform a $2 \times 2 \times 2$ ANOVA with the between-groups factor Discrimination Ability (high/low) and repeated measures factors Shorts Condition (running shorts/neoprene shorts) and Side (left/right). In the presence of any interaction effects, $2 \times 2$ ANOVAs were planned to determine the source. To test for an order of testing effect, subjects were re-grouped according to their discrimination ability using the mean of the left- and right-side scores obtained at their first testing occasion, irrespective of shorts wearing condition. MD scores for each leg of each subject for the first and second testing occasion were then analyzed. A second $2 \times 2 \times 2$ ANOVA was performed with the between-groups factor being Discrimination Ability (high/low) and repeated measures factors Order of Testing (first/second) and Side (left/right). Again,
any significant interaction effects were to be further examined with $2 \times 2$ ANOVAs.

**Results**

When the mean of each subject’s left and right MD scores in the loose-fitting shorts condition was calculated, nine subjects had scores below 0.78 and they were assigned to the low ability group. The 11 with mean scores above 0.78 became the high ability group. Subject characteristics for each group are contained in Table 1. The MD scores for left and right limbs for each group under both shorts conditions are shown in Table 2. A $2 \times 2 \times 2$ ANOVA was then conducted to evaluate the effect of the two shorts conditions on left- and right-side leg swing MD scores of each group. No interaction effects involving side ($F_{(1,18)} = 1.937$, $p = 0.181$), shorts condition ($F_{(1,18)} = 0.487$, $p = 0.494$) or both ($F_{(1,18)} = 4.223$, $p = 0.055$), were significant, nor was there a main effect for limb side tested ($F_{(1,18)} = 1.899$, $p = 0.185$, effect 0.034, 95% CI $-0.018$ to 0.087). There was no main effect for shorts condition ($F_{(1,18)} = 1.070$, $p = 0.315$, effect 0.025, 95% CI $-0.077$ to 0.026). However, there was an interaction effect between shorts condition and the leg swing neuromuscular control ability group ($F_{(1,18)} = 17.027$, $p = 0.0006$), whereby high ability subjects were worse at the discrimination task when wearing neoprene shorts but low ability subjects performed better in neoprene shorts. The mean movement discrimination scores of the low and high groups under the two shorts-wearing conditions are depicted in Fig. 2.

A $2 \times 2$ ANOVA conducted only on scores for the low ability group showed a significant main effect for shorts condition ($F_{(1,8)} = 6.860$, $p = 0.031$, effect 0.076, 95% CI 0.009–0.143), with no signif-

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**Table 1** Characteristics of subjects in the low and high movement discrimination ability groups

<table>
<thead>
<tr>
<th></th>
<th>Low ($n=9$)</th>
<th>High ($n=11$)</th>
<th>Difference</th>
<th>$F$ statistic from ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.7 (18.5–22.8)</td>
<td>22.5 (19.7–25.2)</td>
<td>1.8 ($F_{(1,18)} = 1.213$, $p = 0.285$)</td>
<td></td>
</tr>
<tr>
<td>Training years</td>
<td>2.3 (0.5–4.2)</td>
<td>4.8 (2.1–7.6)</td>
<td>2.5 ($F_{(1,18)} = 2.528$, $p = 0.129$)</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>188.8 (183.0–194.5)</td>
<td>186.4 (182.3–190.5)</td>
<td>2.4 ($F_{(1,18)} = 0.633$, $p = 0.437$)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.0 (77.7–90.3)</td>
<td>84.5 (80.6–88.3)</td>
<td>0.5 ($F_{(1,18)} = 0.021$, $p = 0.886$)</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean (95% confidence interval). $F$ statistic from ANOVA.

**Table 2** Movement discrimination scores for each limb and left—right combined of high and low ability groups for both shorts conditions

<table>
<thead>
<tr>
<th></th>
<th>Loose shorts</th>
<th>Neoprene shorts</th>
<th>Difference</th>
<th>95% CI of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.61 (0.13)</td>
<td>0.76 (0.12)</td>
<td>0.076$^a$</td>
<td>95% CI 0.009–0.143</td>
</tr>
<tr>
<td>R</td>
<td>0.75 (0.14)</td>
<td>0.76 (0.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>0.68 (0.09)</td>
<td>0.76 (0.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.92 (0.09)</td>
<td>0.76 (0.16)</td>
<td>0.127$^b$</td>
<td>95% CI 0.043–0.210</td>
</tr>
<tr>
<td>R</td>
<td>0.89 (0.10)</td>
<td>0.79 (0.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>0.90 (0.06)</td>
<td>0.78 (0.12)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are mean (S.D.). CI, confidence interval; High, high movement discrimination ability group; L, left leg; Low, low movement discrimination ability group; LR, mean of left and right combined; R, right leg.

$^a$ Significant difference between short conditions ($t_{(1,8)} = 2.619$, $p = 0.031$).

$^b$ Significant difference between short conditions ($t_{(1,10)} = -3.38$, $p = 0.007$).
significant interaction effect involving side and shorts ($F_{(1,8)} = 2.888$, $p = 0.128$), nor a significant main effect for side ($F_{(1,8)} = 3.508$, $p = 0.098$, effect 0.069, 95% CI $-0.016$ to $0.154$). Likewise, a $2 \times 2$ ANOVA also conducted on the scores for the high ability group showed a significant main effect for shorts condition ($F_{(1,10)} = 11.444$, $p = 0.007$, effect 0.127, 95% CI $0.043$–$0.210$) but no significant interaction effect involving side and shorts ($F_{(1,10)} = 1.210$, $p = 0.297$), nor a significant main effect for side ($F_{(1,10)} = 0.000$, $p = 0.992$, effect 0.0, 95% CI $-0.016$ to $0.154$). As there were no significant main effects or interactions involving side tested, the left and right sides have been pooled prior to plotting the graphs.

An alternative to using the looser-fitting shorts condition as the base condition is using the test taken first as a base. When the mean of each subject’s left and right MD scores from the first testing occasion was calculated, 10 subjects had scores below 0.78 and were assigned to the order-based low ability group, and 10 to the order-based high ability group. A $2 \times 2 \times 2$ ANOVA was conducted to evaluate the effect of testing occasion on left- and right-side leg swing movement discrimination scores of both groups. No significant results emerged. There were no interaction effects involving side and order of testing ($F_{(1,18)} = 1.327$, $p = 0.264$), side and discrimination ability ($F_{(1,18)} = 1.937$, $p = 0.181$), order of testing and discrimination ability ($F_{(1,18)} = 0.077$, $p = 0.784$), or involving all three ($F_{(1,18)} = 1.009$, $p = 0.328$). There was no main effect for limb side tested ($F_{(1,18)} = 1.462$, $p = 0.242$, effect 0.031, 95% CI $-0.023$ to $0.084$) or order of testing ($F_{(1,18)} = 0.043$, $p = 0.839$, effect 0.007, 95% CI $-0.064$ to $0.079$), and the mean MD scores of the two groups for the two testing occasions, pooled over left and right, are depicted in Fig. 3.

The change in the mean MD score between the two testing occasions of the high group was 0.029 area under the curve units, and of the low group 0.043. While there is no agreed-on method for adjusting for any regression to the mean effect, the estimate of the magnitude of the regression to the mean in this study was thus 0.029 and 0.043 for the high and low groups, respectively. To accommodate for this regression-to-the-mean effect, the magnitude of the order effect of the respective group was used to correct each subject’s score in the neoprene shorts condition. The corrected mean MD scores are plotted in Fig. 4. The ANOVA was repeated on the corrected MD scores, to evaluate the effect of neoprene shorts using scores that included a regression to the mean estimate. A significant interaction effect still occurred between the factors shorts condition and high-low grouping ($F_{(1,18)} = 11.284$, $p = 0.003$). That is, the shorts–no shorts difference was still significantly different between the high and low groups, such that the low-scorers improved and the high-scorers worsened when wearing the close-fitting shorts, even with corrected scores.

**Discussion**

When this cohort of footballers was treated as a single group, wearing neoprene shorts did not improve swinging leg MD scores derived from a lower limb neuromuscular control test based on proprioception. However, when the group were
divided according to their level of leg swing control ability, an interaction effect was observed. From this, two significant effects arose. Neoprene shorts had significantly different effects on subjects with high and low leg swing discrimination scores. Subjects with low leg swing movement discrimination scores experienced an improvement when wearing tight fitting neoprene shorts, whereas subjects with good leg swing movement discrimination ability without the neoprene shorts showed the reverse effect.

While subjects in the low ability group were wearing neoprene shorts, they were better able to judge backward leg swing extents. This improved accuracy likely represents an enhancement of proprioception when swinging a leg backwards in single leg standing. Similar findings have been reported in studies into various proprioception measures of other regions of the body, where an improvement in low-scoring and injured performers was observed when wearing elastic supports over the region.14,15,18,19 The neoprene shorts studied here are close fitting from the waist and across the hips to the mid thigh of both legs. It has been suggested that the wearing of such a garment may increase cutaneous stimulation and afferent signals to proprioceptive centers.14 Relatively large amplitude leg swing movements, such as employed in this study, may result in movement occurring between the shorts and the legs, and this may stimulate rapidly adapting tactile receptors and further enhance afferent input.18 Wearing a knee brace has been demonstrated to increase intramuscular pressure at rest and during exercise.15 It is possible that the compressive pressure of the shorts may similarly activate deeper skin and muscle receptors, and further increase proprioceptive information; however, any increase in intramuscular pressure by wearing neoprene shorts is currently unknown.

Subjects with good accuracy of judgment without neoprene shorts experienced deterioration in their ability to judge leg swing movement extents when wearing neoprene shorts—a finding which was unexpected. The suggestion that these shorts would have less of an effect on athletes with higher initial leg swing MD scores was based on a number of previous findings that had reported neutral effects when wearing braces or neoprene sleeves on uninjured patient groups or those with higher levels of proprioceptive ability.14,18 A negative, rather than only neutral, effect of a neoprene garment on high performers had previously been demonstrated in a study by McNair and Heine15 that revealed a decrease in trunk flexion proprioceptive ability in a low error (thus high performing) group of subjects when wearing a neoprene lumbar brace. In addition, the wearing of a lumbar support for 2 h was also shown to worsen proprioceptive ability in a control group, but not in a symptomatic group.19 The authors suggested that a possible reason for the lack of improvement in proprioception in subjects with a reasonable level of ability is the notion that there is a “physiologic normal value” for proprioception that has an upper limit.19 They also suggest that an external brace or device may temporarily depress afferent discharge of the body’s proprioceptors; however, it is unclear as to why this effect should be greater in asymptomatic individuals. Another possibility for the negative effect of wearing a sleeve around a joint in subjects with a higher level of neuromuscular control is that the enhanced afferent stimulation may be unhelpful and indeed confusing to the control system.18,19 In subjects with better neuromuscular control, close-fitting shorts may initially provide an excess of information to the lower limb control centres, which are already receiving an adequate amount from internal sources. Consequently, there is either confusion as to which information is the most important or there is an inability to attend to all the cues in the available time, resulting in an increase in error and poorer performance. This consequence may only be for a short period of time until accommodation or some amount of re-setting of proprioceptors occurs, and any effects of neoprene shorts are not known beyond the 5 min between testing occasions used in this study.

The determination of high or low level of leg swing proprioceptive ability employed here was not arbitrary but based on the mean MD score of 0.78 determined from a previous study.8 In a 2-year prospective period, hamstring injured Australian Football players were found to have lower MD scores than the mean of 0.78.8 In the current study, 9 of 20 subjects had a pooled MD score below this “at-risk” level when tested wearing loose-fitting shorts, and 4 of these improved to above this threshold when re-tested wearing neoprene shorts. Conversely, in the 11 subjects with high MD scores, four experienced a decrease in leg swing neuromuscular control to below this threshold when wearing close-fitting neoprene shorts. The decision as to the use of such shorts should therefore be made upon determining the baseline levels of an individual.

Although each block involved 40 trials and took 20 min, there were no significant order effects of the testing procedure, which indicates that there was unlikely to have been any learning or fatigue effects over two occasions of testing. However, the mean of the high group was slightly lower and the mean of the low group was slightly higher for
the repeated test (Fig. 3). Despite there not being a significant order effect, there may have been some degree of regression to the mean—a statistical phenomenon that occurs with repeated testing of a variable. Any score on a test can be considered to include error in addition to the true score, and with repeated testing the magnitude of this error is unlikely to persist and will on average approximate zero, which in turn results in the more extreme scores regressing toward the mean.26 This statistical factor needed to be addressed when assessing the true effect of wearing neoprene shorts on leg swing proprioceptive ability. The improvement in mean MD scores of low scorers when wearing neoprene shorts was 0.036 following the order effect or regression to the mean correction, and the deterioration for high scorers was 0.068. This conservative estimate represents a 22.2% gain and a 16.4% loss, respectively, when the change is expressed relative to the mean score in the loose-fitting shorts condition for each group. Given these potential gains, neoprene shorts may represent an appropriate method of improving neuromuscular control in players with low scores, and there may be a potential for improving function or reducing the risk of subsequent hamstring injury in these players. However, there may be some negative effects experienced by athletes such as additional stiffness to movement, increasing skin temperature during exercise and heat retention after exercise.27 Further, any positive effect may not be long-lasting or may only exist while the neoprene shorts are worn. Therefore a more comprehensive method of improving leg swing neuromuscular control is needed.

The current study included only elite-level Australian Football players and caution should therefore be exercised if extending any findings or implications to the sub-elite or community levels or other sporting populations. The test used in this study consisted of some functional movement patterns, but was performed in single leg standing and therefore the test was not a complete reproduction of the swing phase of running and thus may not directly reflect lower limb neuromuscular control during running. In addition, the test was performed at a self-selected movement pace and did not attempt to replicate leg movement speed during running. However, the major determinant of spatial error in a high-speed task has been shown to be the amount of movement amplitude, with variations in movement time being unrelated to spatial accuracy.28 The current leg swing test represented a spatial task and assessed discrimination of leg swing movements to points in space within the range of motion of the running cycle. Further, a functional link had previously been reported between swinging leg movement discrimination ability and coach-rated football kicking performance, and that link afforded some validity to the procedure used in this study.21

Wearing close-fitting neoprene shorts had a small but positive effect on accuracy of leg-swing movement extent judgment in subjects with low neuromuscular control scores. Conversely, there was a negative effect on such leg swing accuracy in subjects with high neuromuscular control scores. The use of close-fitting neoprene shorts for those athletes with lower levels of leg swing control may be a relatively low-cost, minimally invasive intervention to enhance leg proprioception. Further techniques to enhance leg swing neuromuscular control and bring about more longer-lasting changes are required for the rehabilitation and prevention of those sporting injuries, including hamstring strains, in which poor performance of the neuromuscular control system may be a contributing factor.

Practical implications

- Some Australian Football players have a reduced ability to make accurate judgments regarding running-like leg movements.
- Wearing neoprene shorts can improve the ability to judge backward swinging movements of the leg.
- Wearing neoprene shorts does not have the same beneficial effect for football players who already have good leg swing movement judgment and may, in fact, hamper their ability.

Acknowledgments

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References