Original Research Paper

Influence of compression garments on postural stability during a transition task from double-leg stance to single-leg stance

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Background: **Though there is currently only limited scientific evidence of the usefulness of compression garments for healthy sport participants, they are widely used in sports.**
Objectives: To investigate if compression garments can influence postural stability.
Design: **Participants performed a transition task from double-leg stance to single-leg stance wearing well-fitted compression garments, loose fitted compression garments and underwear (=suit conditions), alternating between an eyes open and eyes closed condition. Deviations of the center of pressure during the transition from double-leg stance to single-leg stance were registered on a single force plate.**
Setting: **Laboratory.**
Participants: **Twenty healthy male soccer players. Subjects were recruited from a lower division soccer club.**
Main Outcome Measures: **Using a standardized methodology, different outcomes were calculated from the center of pressure deviations and used as proxies for postural stability. Self-reported stability was registered using a visual analogue scale,**
Results: **Neither in the stability outcomes from the center of pressure analysis nor in the self-reported stability a statistical significant difference was observed between the different suit conditions.**
Conclusions: **The results of this study suggest that there is no effect of wearing compression garments on postural stability outcomes during the transition from double-leg stance to single-leg stance.**

Keywords: postural stability, double-leg stance, single-leg stance, compression garment

Introduction

In contrast to the evidence for using compression garments (CG) in the therapeutic setting, where applications include prevention of edema, deep vein thrombosis and wound management or hypertrophic scarring (Agu, Hamilton, & Baker, 1999; Asano, Matsubara, Suzuki, Morita, & Shinomiya, 2001; Blair, Wright, Backhouse, Riddle, & McCollum, 1988; Brennan & Miller, 1998), only limited data is available to support sport-specific use. The use of CG in sports is popular due to studies indicating that they can optimize performance and recovery (MacRae, Cotter, & Laing, 2011). Besides these possible effects, enhanced cutaneous stimulation by an external compression gradient was suggested to improve proprioception and joint positional awareness (Hylton & Allen, 1997; Perlau, Frank, & Fick, 1995). Pearce et al. (Pearce, Kidgell, Grikepelis, & Carlson, 2009) found improved visuomotor tracking performance while wearing CG, and more recently Michael et al. (Michael, Dogramaci, Steel, & Graham, 2014) reported a significantly longer overall balance time during single-leg stance while wearing CG. This would implicate that these CG may have a role in injury prevention, as multiple studies demonstrated that impaired postural control is an important risk factor for sports (re-)injuries (McGuine, Greene, Best, & Leverson, 2000; Negahban, Mazaheri, Kingma, & van Dieën, 2014; Paterno et al., 2010; Vrbanić, Ravlić-Gulan, Gulan, & Matovinović, 2007; Wang, Chen, Shiang, Jan, & Lin, 2006; Wikstrom, Naik, Lodha, & Cauraugh, 2010).

However, the interpretation of the few available studies concerning CG is complicated by the differences in type and pressure characteristics of the CG. CG are made of different types of fabric with differences in compression generated by each fabric and production process. Moreover, CG can vary from full body compression to compression of a part of the limbs (MacRae et al., 2011). Due to the methodological limitations and the variety in experimental tasks and suits used in above-mentioned studies concerning CG and proprioception or postural stability, it is difficult to make firm conclusions on the effect of CG on postural stability.

The evaluation of a possible improvement in postural stability should be done with a well-validated protocol. Center of pressure (COP) and center of mass (COM) analysis is a common method of balance assessment during postural perturbation, such as the transition from double-leg stance (DLS) to single-leg stance (SLS). When moving from DLS to SLS, a person moves first towards the opposite direction with a certain maximum deviation (contralateral push-off movement) followed by the movement towards the single standing leg to finish in the SLS phase (Bart Dingenen, Staes, & Janssens, 2013). Dingenen et al. (2013) were able to discriminate between non-injured subjects and subjects with chronic ankle instability during the transition from DLS to SLS with a standardized methodology, whereby the COP displacement during the first three seconds after time to new stability point (TAT) outcome was the most discriminative parameter. Analogous findings were observed between subjects who underwent anterior cruciate ligament reconstruction and non-injured controls (B. Dingenen, Janssens, Claes, Bellemans, & Staes, 2014).

The aim of this study was to investigate if short sleeve full body compression clothing can affect postural stability outcomes during the transition task from DLS to SLS in non-injured subjects. We hypothesized that wearing CG would improve the postural stability outcomes when standing on one leg.

Material and Methods

Subjects

Twenty healthy male soccer players (17.75 years SD 1.91; 68.65 kg SD 12.40; 177.55 m SD 6.93) participated in this study. Subjects were recruited from a lower division soccer club. Participation was voluntary. Before participating in the study, all subjects read and signed an informed consent form, which was approved by the local ethical committee. Inclusion criteria were male gender, 16 years and over and all subjects needed to be fully participating in training and matches. Participants who had a neurological illness, musculoskeletal injury, or any disease/condition that would interfere with their normal balance were excluded.

Compression garments

The well fitted compression garments (WF-CG) used in this study were designed by V!GO® and produced by Lymed®. The CG were well fitted short sleeve and short trousers compression clothes. The fabric type ‘P40’ is a combination of 40% elastin and 40% polyamide. Data from the manufacturer mentions that the aim of compression by the garments lies between 10 and 15 mmHg. To improve wearing comfort, less compression is generated on the thorax, armpits and abdomen. Seams were fitted on the outside of the CG (Figure1).

Figure 1 Picture of well-fitted compression garment on one of the participants

A conventional, commercially available, loose fitted compression garment (LF-CG) was used as a placebo condition. The LF-CG also were outfitted with short sleeves and short trousers, similar color and no brand was visible.

Data collection

Ground reaction forces and moments were measured by a single force plate (Bertec Corporation®) at 500 Hz using a Micro 1401 data-acquisition system and Spike2 software (Cambridge Electronic Design, UK) and low pass filtered with a cut-off frequency of 5 Hz.

Procedure

The specific testing procedure used in this study is based on a previous study (Bart Dingenen et al., 2013). In short, subjects were asked to stand barefoot on a force plate with the feet separated by the width of the hips and the arms hanging loosely at the side. They performed a transition task from DLS (13 seconds) to SLS (13 seconds). Only the dominant leg, which was defined as the preferred leg to kick a ball was tested. The position of the feet during DLS was indicated on a paper lying on the force plate to ensure that subjects returned to the same starting position after each trial. Subjects were instructed to lift one leg on the command of the examiner towards approximately 60 degrees of hip flexion within one second, using a metronome as a reference. As most postural stability outcomes during this experimental task can be influenced by the speed (Bart Dingenen et al., 2013), we standardized the speed of the transitional movement. For all subjects, an equal number of fake trials (shifting the weight to the non-tested leg) were randomly included to avoid preparedness. The transition task from DLS to SLS was tested with eyes open and with eyes closed (Figure 2). Both visual conditions were repeated four times in an alternating order and were applied to all suit conditions. Participants performed the balance task wearing conventional underwear (Control), a well fitted compression garments (WF-CG), and loose fitted compression garments (LF-CG). The order in which the suit conditions were tested was randomly assigned. In the eyes open tests, subjects were instructed to keep their gaze straight ahead facing a white wall. In the eyes closed tests, subjects were asked to close their eyes. All subjects were allowed to familiarize with the test conditions and movement speed by performing two practice trials of each suit condition before the actual measurements. Between suit conditions, subjects could rest to avoid fatigue.

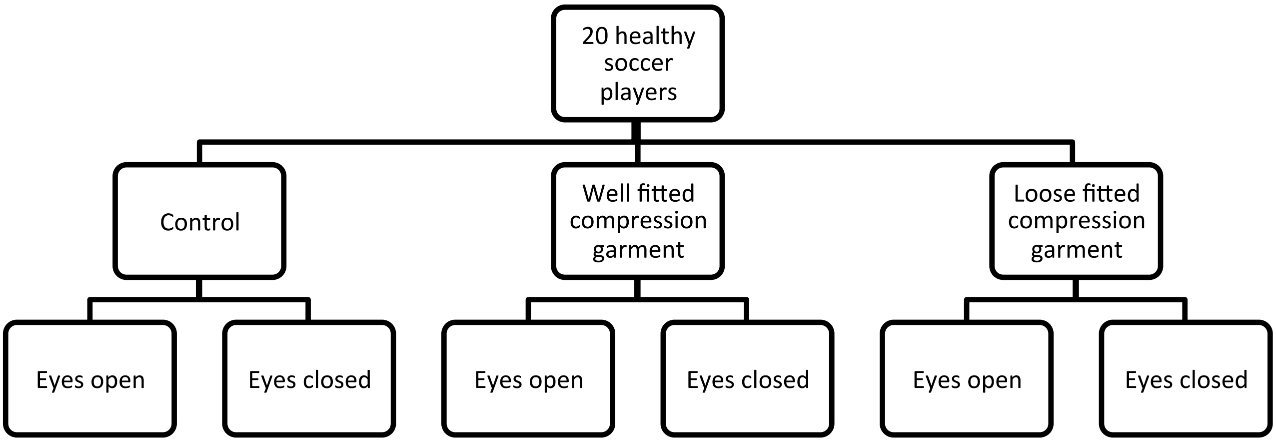

Figure 2 Flowchart of study design

Data analysis

Data analysis of the transition from DLS to SLS was identical to the study of Dingenen et al. (Bart Dingenen et al., 2013) and is hence described briefly. First, the anteroposterior (AP) and mediolateral (ML) COP displacements were calculated by dividing respectively the AP and ML moments of force by the vertical force. The average AP and ML COP were calculated from the first ten seconds of each trial because a subject is undoubtedly standing on two legs during this time period. The starting point of the contralateral push-off movement was defined as the last time point where the ML COP crossed the average ML COP before the contralateral push-off movement. The time point where the ML COP crossed the average ML COP after the contralateral push-off movement on the way to the SLS phase was defined as the crossing point.

The DLS phase was defined as the period from the start of the trial until the crossing point. The duration of the contralateral push-off movement was the time between the starting point and the crossing point. The COP displacement (modulus of the COP vector) during this period was derived from the AP and ML displacements with the formula $\sqrt{(AP^2+ML^2)}$. The maximum contralateral COP excursion was also calculated.

Starting from the crossing point, a sequential estimation method was used to determine the stabilization time. A sequential estimation series was considered stable if the sequential average of the COP data remained within 0.25 standard deviation of the overall series COP data average (Colby, Hintermeister, Torry, & Steadman, 1999). The time at which this was reached, was considered as the time to the new stability point (TNSP). The period between the crossing point and TNSP was considered as the intermediate phase (IP). The COP displacement during this period was calculated and divided by the duration (in seconds) of this period (mean absolute COP velocity). In addition, the COP displacement during the first three seconds after TNSP (TAT) was calculated. The peak COP velocity when moving to the upcoming single-leg stance was calculated as the maximum first derivative in time of the COP displacement between the starting point and TNSP.

Self-reported stability

After completing the transitions in the three different suit conditions all, subjects filled out an individual score form (a 100 mm visual analogue scale). The score form measured the stability experienced during the transitions in every suit condition. Zero and 100 mm represented worst and best perceived stability respectively.

Statistical analysis

Means and standard deviations were calculated to describe the subject characteristics (age, length and weight). The variables collected during the four trials of every condition were summarized as averages. These averages were regarded as the outcomes. We checked the normality of outcomes using the Shapiro-Wilk statistic. Outcomes with a normal distribution were further analyzed for differences between visual and suit condition with linear mixed effect models. Differences between suit conditions for outcomes that were not normally distributed were analyzed with a Kruskal-Wallis rank sum test followed by a Mann-Whitney U test for between-groups comparisons with Bonferroni correction for multiple comparisons. The self-reported stability experienced in the different suit conditions was analyzed using a one-way ANOVA. Significance was set at $p<0.05$ for all analyses. Statistical analyses were performed using R-software version 2.15 (R-Project, Vienna, Austria, packages; lme4, lsr, stats).

Results

Data collection

One subject failed to perform the transition task in the eyes closed condition in one of the suit conditions and was discarded from the study. Data collection on the other 19 subjects was complete. Each subject performed 24 trails, eight in every suit condition of which four with eyes closed and four with eyes open.

Postural stability outcomes

The duration of the contralateral push-off moment (CLPO), COP excursion during CLPO, COP displacement during CLPO and the peak COP velocity during the transition were normally distributed.

Also time to new stability point (TNSP) and mean absolute COP velocity in the intermediate phase (IP) were normally distributed. The COP displacement in the first three seconds after reaching the new stability point (TAT) was not normally distributed ($p<0.05$).

Differences between suit conditions

All postural stability outcomes were not significantly different between suit conditions irrespective of whether the visual condition was considered or not (Table 1).

Differences between visual conditions

The mean absolute velocity in the IP and COP displacement during TAT were significantly larger for the eyes closed condition as compared to the eyes open condition irrespective of whether the suit condition was considered or not ($p<0.001$) (Figure 3, Figure 4). The difference in the time to new stabilization point (TNSP) between visual conditions was not significant ($p=0.523$) (Figure 5). CLPO duration, COP excursion during CLPO, COP displacement during CLPO and the peak COP velocity during the transition were not significantly different for the different visual conditions (Table 1).

No significant interaction effects were found between the visual condition and the suit condition for the IP ($p=0.660-0.967$) and TAT variables ($p=0.430-0.882$).

Self-reported stability

The self-reported stability experienced during transition was 47,4 mm (SD 20,1) on average for the control condition, 55,1 mm (SD 16,4) for the LF- CG condition and 57,4 mm (SD 20,6) for the WF-CG condition. The differences in self-reported stability for the different suit conditions were non-significant ($p=0.24$).

Table 1 Differences between suit conditions for peak COP velocity, CLPO COP excursion, CLPO duration and CLPO COP displacement.

	Control		*LF-CG*		*WF-CG*	
	Eyes open	Eyes closed	Eyes open	Eyes closed	Eyes open	Eyes closed
Peak COP velocity (m/s) (M ± SD)	1.34 ± 0.33	1.23 ± 0.33	1.49 ± 0.33	1.30 ± 0.33	1.46 ± 0.33	1.29 ± 0.33
CLPO COP excursion (m) (M ± SD)	0.09 ± 0.03	0.07 ± 0.03	0.09 ± 0.04	0.09 ± 0.03	0.09 ± 0.04	0.07 ± 0.04
CLPO duration (s) (M ± SD)	0.47± 0.10	0.44 ± 0.08	0.45 ± 0.08	0.46 ± 0.10	0.48 ± 0.08	0.45 ± 0.10
CLPO COP displacement (m) (M ± SD)	0.20 ± 0.07	0.18 ± 0.06	0.21 ± 0.08	0.19 ± 0.07	0.22 ± 0.08	0.18 ± 0.08

(COP=Center of pressure, CLPO=Contralateral push-off, M=mean, SD=standard deviation)

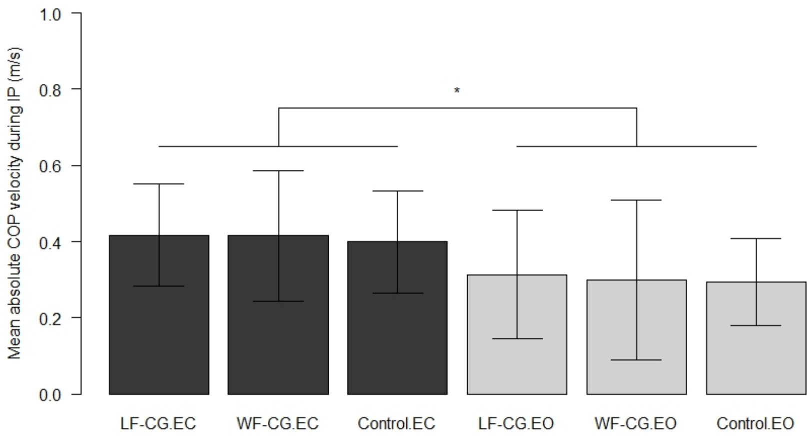

Figure 3 Mean and standard deviation COP displacement in the first three seconds after reaching the new stability point (TAT) (m)) for loose fitted compression garments (LF-CG), well fitted compression garments (WF-CG), and control wearing shorts (control) in eyes open (EO) and eyes closed (EC) conditions (* p<0.001)

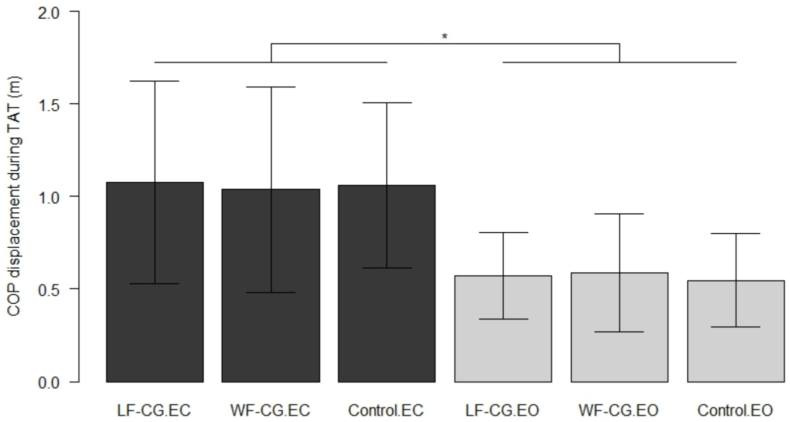

Figure 4 Mean and standard deviation mean absolute COP velocity in the intermediate phase (IP) (m/s) for loose fitted compression garments (LF-CG), well fitted compression garments (WF-CG), and control wearing shorts (control) in eyes open (EO) and eyes closed (EC) conditions (* p<0.001)

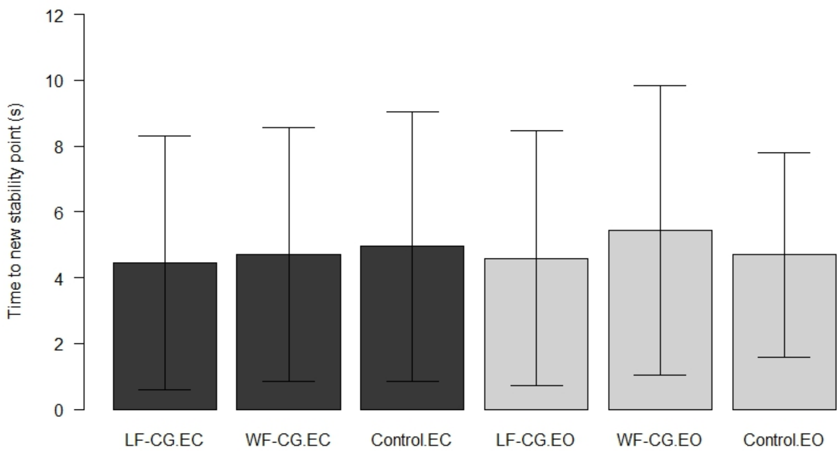

Figure 5 Mean and standard deviation time to new stability point (TNSP) (s),) for loose fitted compression garments (LF-CG), well fitted compression garments (WF-CG), and control wearing shorts (control) in eyes open (EO) and eyes closed (EC) conditions (* p<0.001).

Discussion

The goal of the present study was to evaluate if CG could influence postural stability as measured by changes in COP outcomes during the transition from DLS to SLS. In contrast with our hypothesis, neither in the eyes open nor in the eyes closed condition could any significant difference be found in any of the outcome variables between the suit conditions. Our study offers no arguments for the assumption that CG are associated with an improved postural stability as tested by the transition from DLS to SLS.

To improve the sensitivity of this study the three suit conditions were performed in two scenarios: one with eyes open and one with eyes closed. Based on previous studies (Bart Dingenen et al., 2013), this eyes closed condition was known to result in increased postural instability when finally standing on one leg after transitioning from DLS to SLS (B. Dingenen et al., 2014). The results of our study confirm these findings, as the IP and TAT outcome variables were significantly increased in the eyes closed condition for all suit conditions irrespective the suit conditions.

Though there are some indications that CG may aid recovery from strenuous exercise, evidence for possible beneficial effects on performance is limited and confounded by psychological effects (Hill, Howatson, van Someren, Leeder, & Pedlar, 2014; Pruscino, Halson, & Hargreaves, 2013). The size of a possible psychological effect was assessed by a self-reported stability score for each suit condition. To distinguish a possible psychological effect from the physical effect of CG, a placebo garment was added to the conditions. The results of the present study showed no significant differences between conditions in which a suit was worn (the LF-CG or the WF-CG) and the control condition in which no CG was worn. In addition, no significant subjective differences in self-reported stability were found. Therefore, no indication was found for a placebo effect of CG on stability during the transition task.

Our findings conflict with the results reported by Michael et al. (2014). In their study, the overall balance time, which was the time the participants could perform a single-leg stance balance task, was significantly longer when well fitted lower body CG were worn compared to the control condition wearing shorts. The reason might be that full-length lower body compression clothing improves postural stability as it includes the knee and ankle joints. However, some shortcomings in this study need to be addressed. In the study of Michael et al. the effect could not be confirmed between the placebo condition (LF-CG) and the well-fitted CG and no significant findings were found in COM and COP analysis. The conclusion of this study might also be influenced by a possible learning effect as the first testing condition was always the use of shorts. Moreover the overall stabilization time (with a maximum of 60 seconds single leg stance) is a non-validated evaluation of postural stability. In the eyes open condition all subject completed the maximum of 60 seconds single leg stance. In our study we randomized all conditions including the control condition (wearing underwear), and we applied a validated assessment of postural stability.

Possibly, the limited effect that CG can have on proprioception as suggested by previous studies (Kraemer et al., 1998; Pearce et al., 2009) might not be enough to influence the more complex process of postural stability. Findings concerning improved visuomotor tracking as demonstrated in the preliminary study by Pearce et al. (2009) might also be explained by better recuperation after the eccentric exercise wearing CG, rather than improved postural stability. The gain of functionality associated with compression clothing in patients with cerebral palsy suggests however that CG can influence body control and balance (Hylton & Allen, 1997) in this patient population. In an active, healthy population of sportsmen, the effects might be less obvious or non-existing in contrast to children with manifest neuromotor deficits. In this population the gain of functionality might also be a result of correction of inaccurate movements by reduction of overshooting of the limb known as a 'dampening effect' rather than by a direct influence on proprioception or joint position awareness (Hylton & Allen, 1997).

The execution of the transition from DLS to SLS in our study was difficult for many participants, especially in the eyes closed conditions. One subject even failed to complete the SLS in one condition. The age (17.75 SD 1.91 years) of the participants might explain the wide range in postural stability outcomes. During adolescence a temporary disruption of motor coordination known as 'adolescent awkwardness' has been described (Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). The COP displacement during TAT in the eyes closed condition is comparable to findings in mature injured subjects (Bart Dingenen et al., 2013). Improved postural stability outcomes might be obtained when testing non-injured adult men and women.

Another limiting factor in our study might be that COP analysis is not sensitive enough to measure the effect of CG on postural stability. The transition task from DLS to SLS as used in this study has previously been shown useful for the differentiation between injured and non-injured subjects (Bart Dingenen et al., 2013; B. Dingenen et al., 2014) but might be insufficient to draw conclusions on the effect of CG on postural stability. In our study the suit did not cover knee and ankle joint. On the other hand, these suits are typically used during soccer. Overall, further research with larger populations and different types of compression clothing is needed. The addition of reinforcement of certain areas with extra fabric (spiders) covering joints should be part of future investigations as it could improve cutaneous feedback.

Conclusion

In this study no significant effect of wearing compression clothing on postural stability could be demonstrated during a transition task from double-leg stance to single-leg stance as measured by the deviation of the center of pressure. The compression garments had also no influence on the subjective perceived grade of stability.

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