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A preliminary study on the influence of high heel footwear on lumbar spine proprioception

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Summary

Study aim: High heel footwear (HHF) alters posture and kinetics of the lower limbs and spine. Various musculoskeletal disorders in the lower quadrant can occur as a consequence of HHF use. This study aimed to investigate the effect of habitual use of HHF on lumbar spine proprioception.
Material and methods: Thirty young healthy women (mean age: 21.6 ± 1.6 years; height: 157.6 ± 5.9 cm; weight: 57 ± 10.2 kg) participated in this study. Participants were randomly allocated to one of the two sequences of walking with HHF or walking barefoot for five minutes on a predetermined walkway consisting of an even surface, ramp and stairs. A 24-hour washout period was incorporated between each walking condition. Lumbar spine repositioning error was measured using a Back Range of Motion II (BROM II) device before and after walking for lumbar spine forward flexion, right, and left lateral flexion.
Results: Measurements showed that repositioning error was significantly higher in all spinal movements after walking with HHF (forward flexion $p = 0.0044$; right lateral flexion $p = 0.0243$ left lateral flexion $p = 0.0379$) as compared to barefoot walking.
Conclusion: The findings of this study suggest that HHF alters lumbar spine proprioception. This study provides evidence to support early assessment of proprioception and incorporation of retraining exercises in habitual users of HHF.

Keywords: Low back pain – Repositioning error – Stilettos – Work

Introduction

High heel footwear (HHF) has been used as a fashion statement and is an attribute of femininity [6, 12]. Wearing HHF has been suggested to produce adverse effects on the musculoskeletal system [2, 17, 18] and linked to several dysfunctions including knee pain, ankle sprain and low back pain (LBP) [13, 16, 17, 24]. Various biomechanical alterations in the body occur with the use of HHF and studies have shown postural malalignment [7, 17], increased ground reaction force (GRF) [2], increase in the height of the centre of body mass [16] and impaired trunk and hip extensor muscle co-ordination patterns [18] in HHF users.

Compensatory changes in the muscle activation pattern leading to imbalance have been suggested to be a potential contributing factor to the development of LBP [17]. An altered neuromuscular activation pattern with earlier onset of erector spinae muscle coupled with the delayed onset of the gluteus maximus muscle activity was observed in a study [14]. There was overall heightened compensatory activity in the erector spinae muscles to maintain the abnormal spinal posture [18]. High heels are known to cause sustained, large amplitude activation of the lumbar muscles, thereby increasing the energy requirements of these muscles [4]. Lumbar position following the use of HHF is debatable, with some studies showing a decrease and others showing lordosis or no change in the lumbar position [22]. As a common cause of disability, LBP is the leading reason for physician consultation, hospital admission, health care service utilization and one of the costliest musculoskeletal diseases [2, 8].

Spinal proprioceptive deficit was seen in the LBP population as compared to healthy individuals [15, 19]. Proprioception has been described as a complex interaction between afferent and efferent inputs to control body movement and position [8, 19]. It provides a sense of position

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of the body and limbs without using vision and is essential for maintaining normal spinal movement and stability. Impaired lumbar proprioception is a plausible mechanism for the development and recurrence of LBP [23]. Altered lumbar proprioception can decrease the ability to attain and maintain a neutral spinal posture [21]. It is not known whether the spinal proprioception becomes altered with the variation in biomechanics and alignment of the spine in women who wear HHF.

Repositioning accuracy reflects the ability to appreciate the orientation of the body in space. It has been used as a measure of proprioceptive ability in various studies [8]. Reduced proprioception may delay the neuromuscular protective reflexes and co-ordination, increasing the risk of development of recurrent injuries. To date, no studies have investigated the effect of habitual use of HHF on lumbar spine proprioception, despite LBP being a significant problem among HHF users. Hence, the purpose of this study was to explore the lumbar spine repositioning error in habitual users of HHF.

Materials and methods

Study design

Institutional research and ethics committee (IEC 737/2016) approval was obtained before commencement of the study. Screened and informed participants were recruited to participate. A randomised crossover study was performed where participants were randomly allocated to one of the two sequences, and the lumbar spine repositioning error was measured at four time points, i.e. before and after walking barefoot and with HHF. The study was conducted between August 2016 and January 2017.

Participants

Thirty young, healthy women participated in the study through purposive sampling. To be included in the study the participants had to be above 18 years of age, habitual users of high-heeled shoes, who had worn shoes with a heel height of four inches (10 cm) or above, once a week, three hours per day for the last one year. Participants were excluded if they had a history of LBP, recent (< 6 months) musculoskeletal disorders of the lower quarter or neurological conditions affecting balance.

Procedure

The participants were assigned to one of the two sequences of the experimental procedure by simple randomization. Demographic variables were recorded, and joint repositioning error for movements of the lumbar spine forward flexion, right lateral flexion and left lateral flexion were measured using a BROM II device, before and after two walking conditions, i.e. barefoot walking and walking with high heel footwear. As per the crossover study design, each participant was exposed to both experimental conditions – barefoot walking and walking with HHF. The sequence was applied for randomization and also to equalise the effect of learning due to the repetition of lumbar movement repositioning error for both walking conditions.

Sequence A – Participants were measured for barefoot repositioning error for movements of the lumbar spine following which they ambulated barefoot at a self-selected pace for five minutes on a 70-meter walkway consisting of an even surface, ramp, and stairs. Subsequently, the lumbar spine repositioning error was measured. After a 24-hour washout period, the participants had to walk with HHF on the same walkway for five minutes, and repositioning error was measured with high heeled footwear before and after the walk.

Sequence B – Participants in this sequence were measured for repositioning error values before and after the walk first with HHF, and after a 24-hour washout period, the repositioning error was again recorded before and after barefoot walking.

In the HHF walking condition, the measurements were performed with the footwear ON, and this was done to obtain a more functional or realistic scenario where women routinely perform activities with HHF. Although it is more challenging to reproduce the target position under this condition, it is not known whether the habitual users are accustomed to HHF. Moreover, no studies have been conducted to detect the alteration in proprioception in these individuals. This study also intended to identify whether a mere change in posture due to high heels can alter lumbar reposition accuracy. All participants were requested to carry their footwear for reasons of comfort, feasibility and to ensure the right fit.

Instrument

A BROM II device was used to measure the repositioning error of the lumbar spine. Before the beginning of the study, two testers (RB and LR) practised using the BROM II device as per the instructions in the manual on eight healthy females who were not involved in the study. The intra-rater reliability of the BROM II device for measuring forward flexion was good to fair (ICC range, 0.84–0.79) and side flexion was good (ICC range, 0.85–0.83) [14]. Tester 1 (RB) fixed the BROM II device on to the participants and gave instructions on performing the movements to measure the repositioning error. A second tester (LR) was involved in palpating the landmarks and recording the angles obtained for each participant. T12 and S1 spinous processes were palpated for the placement of the BROM II instrument. The S1 spinous process was palpated using the technique described by Hoppenfeld [11], and the T12 spinous process was identified by palpating and following the 12th rib upwards and medially.

Measurement of repositioning error

To measure forward flexion repositioning error, the inclinometer frame of the BROM II device was applied to the participant's skin overlying the sacrum using Velcro straps around the pelvis to hold the device in place. The L-shaped slide arm was inserted into the unit to record the distance between T12 and S1 spinous processes. During the flexion movement, the L-shaped slide arm was held at T12 to guide the plastic protractor. The range of motion (ROM) was recorded in degrees from the protractor that was marked in 1° increments. To measure lateral flexion a gravity inclinometer was used; ROM was read from the goniometer, which has 2° increments marked on it.

The participant was positioned in an upright neutral standing position. The target position was predetermined for the testing protocol; it was 30° of forward flexion and 15° of right lateral flexion and left lateral flexion. The testing procedure was preceded by a practice session, where each participant could perform one repetition of the test. Participants were passively positioned at the desired target trunk position for 10 seconds and were asked to remember this position, as they would have to reproduce the position (Fig. 1). Participants then returned to the neutral position for a few seconds before attempting to reproduce the initial target position as accurately as they could, and after attaining the target position it was reported to the investigator. They were asked to hold the position for a few seconds when the readings were recorded. The test was repeated three times with a rest period of 10 seconds between each trial. Participants were blindfolded while performing the repositioning error to block any visual feedback.

Fig. 1. Measurement of forward flexion repositioning error using the BROM II device

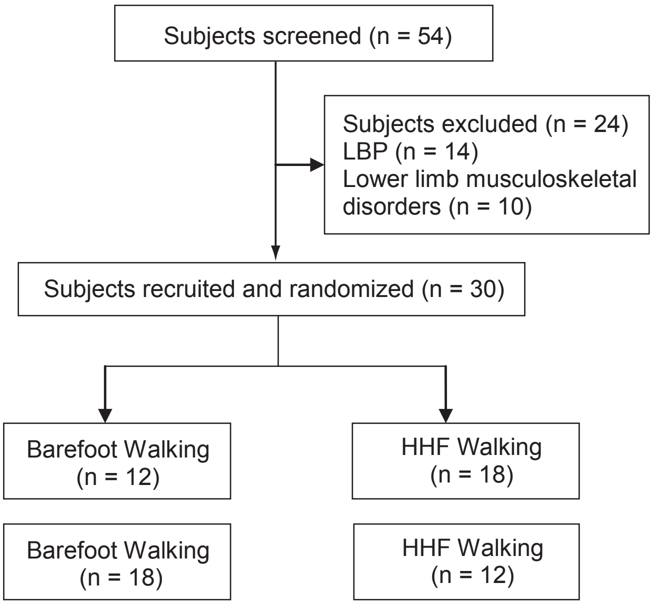

Fig. 2. Subject recruitment flow diagram
LBP – Low Back Pain; HHF – High Heel Footwear.

Statistical analysis

The statistical analysis was conducted using SPSS software version 16.0. Demographic data were analysed using descriptive statistics. The level of statistical significance was set at $\alpha = 0.05$. Normality of the data was assessed using the Kolmogorov-Smirnov test. A multivariate analysis of variance (MANOVA) with repeated measurements was used for evaluation of the significance in the difference of proprioception with and without high heel footwear. Since the differences were significant, a post hoc comparison using the Bonferroni test was performed.

Results

A total of 54 participants were screened for inclusion criteria, and 30 were recruited for the study, as shown in Figure 2. A summary of the demographic characteristics of all participants and the mean heel height of the footwear is provided in Table 1. The repositioning errors, measured in degrees, between the target and reproduced position in

Table 1. Demographic characteristics of the participants

Demographic variables	Mean ± SD
Age [years]	21.6 ± 1.6
Height [cm]	157.6 ± 5.9
Weight [kgs]	57 ± 10.2
Heel Height [inches/cm]	4.58 ± 0.55/11.63±1.39

Table 2. Comparisons of repositioning errors registered pre – and post-walking for barefoot and high heels conditions

Movement	Pre barefoot repositioning error	Pre HHF repositioning error	p-value
Forward flexion [a] (degrees)	2.19 ± 1.89	2.41 ± 1.87	ns
Right lateral flexion [b] (degrees)	2.68 ± 2.22	1.77 ± 1.78	ns
Left lateral flexion [c] (degrees)	4.03 ± 2.77	3.70 ± 2.81	ns
	Post barefoot activity repositioning error	Post HHF activity repositioning error	p-value
Forward flexion [a] (degrees)	2.10 ± 1.71	3.79 ± 2.53	0.0044
Right lateral flexion [b] (degrees)	1.87 ± 2.19	3.40 ± 1.83	0.0243
Left lateral flexion [c] (degrees)	4.31 ± 2.94	5.93 ± 3.03	0.0379
p-value	a ns; b ns; c ns	a .0258; b .0142; c .0021	

both sequences were calculated for all participants. The results are presented in Table 2.

MANOVA revealed a significant difference in repositioning errors between two walking conditions – barefoot vs. high heels ($F_{3,27} = 3.96$, $p = 0.0185$, $\eta^2 = 0.305$) as well as pre- and post-walking measurement ($F_{3,27} = 4.48$, $p = 0.0112$, $\eta^2 = 0.332$). Significant interaction between repeated factor and walking conditions ($F_{3,27} = 5.63$, $p = 0.0039$, $\eta^2 = 0.385$) was noticed. Lumbar spine repositioning error values were significantly greater with the use of HHF than barefoot. The participants after barefoot walking repositioned their back more accurately to the target position in all three movements, whereas the same participants after walking in HHF had a significantly larger repositioning error in reaching the target position. Considering the large effect size post hoc comparison was conducted using the Bonferroni test (Table 2). Baseline lumbar reposition errors with bare feet were compared with lumbar repositioning error recorded with HHF before walking with HHF to identify any change in lumbar spine repositioning error due to change in posture because of HHF.

Discussion

This study evaluated the effect of HHF on lumbar spine proprioception. The participants included were young, healthy females who were habitual users of HHF without a history of LBP. Lumbar spine repositioning error was measured using the BROM II device for the movements of forward flexion and lateral flexion. The results of this study indicated that HHF increased the lumbar spine repositioning error in all three spinal movements.

Wearing HHF alters gait mechanics, aligns the foot in plantar flexion and causes increased GRF transmitted to the spine [2]. Habitual HHF users appear to adopt a specific control strategy on gait with an increase in the activity of trunk muscles as heel height increases, resulting in discomfort and back muscle fatigue [3]. According to the literature, almost two-thirds of habitual wearers of HHF complain of LBP [24].

Lumbar spine proprioception is seen to be affected in individuals with LBP as compared to controls [1, 5, 8, 9, 15, 19]. Trunk muscle dysfunction may cause an alteration in normal afferent input from the affected muscle [20]. The decrease in proprioception has been proposed to reduce the ability to attain and maintain a neutral spine posture and coordinate muscle activation. It could further affect and compromise segmental spinal stability and eventually lead to abnormal loading across the joint and subsequently lead to LBP [5]. Impairment in lumbar proprioception with HHF could be a plausible mechanism for the development of LBP in this population. Previous studies performed on chronic LBP patients have shown that addition of proprioceptive training improved repositioning accuracy [1, 5]. Results of this study provide evidence supporting early assessment of proprioception and incorporation of retraining exercises in habitual users of HHF.

Limitations: There are a few limitations of this study: firstly the low sample size, and secondly, the lack of standardisation of footwear. Another limitation could be the BROM II device used to measure repositioning error; through its straps attached to the pelvis, it might provide excess sensory inputs to the participant, and recording the measurements in standing position could lead to proprioceptive inputs from the lower limbs. Moreover, the active joint position detection requires the kinaesthetic memory of a pre-established position as well as sufficient motor control [10]. A study utilizing a more sophisticated device to obtain precise readings is suggested in future trials. This study paves the way for further research to determine proprioceptive deficits in experienced HHF users with LBP and whether this can be improved with specific exercise interventions.

Conclusion

The results of this study showed that walking in HHF increased the repositioning error for movements of lumbar spine forward flexion, right lateral flexion and left lateral flexion. This study provides evidence to support early assessment of proprioception and incorporation of retraining exercises in habitual users of HHF.

Conflict of interest: Authors state no conflict of interest.

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