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Effect of motion control running shoes compared with neutral shoes on tibial rotation during running

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Abstract

Objective To determine whether a motion control running shoe reduces tibial rotation in the transverse plane during treadmill running.
Design An experimental study measuring tibial rotation in volunteer participants using a repeated measures design.
Setting Human Movement Laboratory, School of Health Professions, University of Brighton.
Participants Twenty-four healthy participants were tested. The group comprised males and females with size 6, 7, 9 and 11 feet. The age range for participants was 19 to 31 years.
Main outcome measures The total range of proximal tibial rotation was measured using the Codamotion 3-D Movement Analysis System.
Results A one-tailed paired *t*-test indicated a statistically significant decrease in the total range of proximal tibial rotation when a motion control shoe was worn (mean difference 1.38°, 95% confidence interval 0.03 to 2.73, $P = 0.04$).
Conclusions There is a difference in tibial rotation in the transverse plane between a motion control running shoe and a neutral running shoe. The results from this study have implications for the use of supportive running shoes as a form of injury prevention.

Keywords: Tibial rotation; Running; Motion control shoe

Introduction

In today's society, one of the greatest challenges faced by the Department of Health is the growing epidemic of obesity. The cost of overweight and obese individuals to the National Health Service is estimated to be £4.2 billion [1]. This has led to considerable media attention on the wider health risks of our sedentary lifestyles, and has resulted in an increase in the number of people participating in recreational running [2]. In order to understand the effect of running shoes on gait, a basic knowledge of lower limb mechanics is essential.

Within the first 20% of the stance phase, the subtalar joint pronates to allow solid contact of the foot with the ground [3]. As forward progression continues through the middle of the stance phase, maximum pronation and ankle dorsiflexion occur. Pronation is a normal part of the running cycle because it allows for shock absorption and accommodation on uneven terrain [3]. However, in some individuals, excessive pronation may occur for various biomechanical reasons [4]. Excessive pronators present with a broad range of pathologies, such as stress fractures, achilles tendonitis and iliotibial band (ITB) tendonitis [4]. Yates and White studied naval recruits and found that those with a pronated foot type were almost twice as likely to develop medial tibial stress syndrome compared with those with a normal or supinated foot posture [5]. A risk estimate revealed that recruits with a more pronated foot type had a higher relative risk (1.70) than injury-free recruits. In an attempt to minimise the risk of injury, athletes have started to seek specific equipment, particularly running shoes [5].

Neutral cushion shoes are generally best for runners with an excessive supinatory gait to provide additional shock absorption, whereas motion control shoes are better for the moderate to severe overpronator. Motion control shoes include a reinforced heel counter and a denser midsole to help control any excessive pronation [5]. Clarke *et al.* [6] found that shoes with a positive heel flare and a hard midsole allowed significantly less maximum pronation and total rear-foot movement compared with shoes with a softer midsole.

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Research has shown that motion control shoes also have an effect on tibial internal rotation [7]. This is a normal part of the gait cycle and occurs in conjunction with pronation and hindfoot eversion due to the mitered hinge effect of the subtalar joint [3]. Running can lead to an increase in internal tibial rotation for people with excessively pronated feet. Miller *et al.* [8] found that runners with a history of ITB syndrome demonstrated increased tibial internal rotation. They predicted that an increase in internal rotation of the tibia could increase the strain in the ITB, and therefore be a contributing factor to ITB syndrome. However, the critical degree of internal tibial rotation leading to injuries has not been confirmed, and research is required in this area. It is reasonable to assume that by reducing rearfoot pronation with motion control shoes, tibial rotation would consequently decrease when running. This may support the use of supportive running shoes as a form of injury prevention. To date, there is minimal evidence on the effects of running shoes on tibial rotation [8–10]. Stacoff *et al.* [10] used intracortical bone pins with injury-free participants to measure the effects of shoe sole construction on skeletal motion during running. They found no statistically significant change in tibiocalcaneal rotations. It was concluded that the tibiocalcaneal kinematics of running may be unique to the individual, and shoe sole modifications may not be able to make substantial changes.

Running gait can be analysed using a number of methods including real-time observational gait analysis, high-resolution cameras and video-recording devices, force plates and computer systems. Computerised three-dimensional (3-D) motion analysis measurements are currently a widespread and useful tool for both clinical practice and biomechanical research. The Coda motion 3-D Movement Analysis System is able to measure locations of active markers in 3-D with high resolution and accuracy. Maynard *et al.* [11] studied the intra- and inter-rater reliability of gait measurements using a Cartesian optoelectronic dynamic anthropometer (CODA, Charnwood Dynamics Limited based in Leicestershire). They suggested that natural variation of the participant's gait cycle may be overcome by capturing at least three gait trials. They concluded that they had not shown complete reproducibility of gait measurements using CODA, but this does not suggest that CODA is unreliable. Many studies have used CODA in the past and none have recorded any anomalies or errors attributal to CODA itself [12,13].

Published literature suggests that running footwear can influence lower extremity kinematics and kinetics. Currently, research into the effects of running footwear on tibial rotation is limited. Therefore, the aim of this study was to determine whether motion control running shoes reduce tibial rotation in the transverse plane during treadmill running.

Methods

An experimental study was conducted with two conditions: neutral shoes and motion control shoes. The effect on range of tibial rotation in the transverse plane during treadmill running in the two styles of running shoes was measured in degrees.

Participants

Ethical approval was gained from the School Ethics Committee at the University of Brighton. Thirty-two consecutive volunteers from the University of Brighton health professional courses who responded to a recruitment e-mail were included. This e-mail included an information sheet for participants to read before volunteering. On arrival at the Human Movement Laboratory, all details of the study were explained to participants and they were asked to sign a consent form.

In order to be included, participants were required to have size 6, 7, 9 or 11 feet and be able to run comfortably for 5 to 10 minutes. Participants were excluded from the study if they had a history of cardiovascular problems, a lower limb condition that was exacerbated by running, a vestibular disorder or an allergy to hypoallergenic adhesive tape.

Instrumentation

A Biodex RTM 500 treadmill (Biodex Medical Systems, Inc., New York, USA) was used for all participants and for both conditions. The treadmill was placed in the middle of the laboratory with one CODA MPX30 (Charnwood Dynamics Ltd., Leicester, UK) scanner unit in front and one scanner unit behind. These units picked up signals emitted by the infra-red 'active' markers which provided an immediate and precise 3-D measurement. All information from the scanners was stored on the CODA computer system.

Procedure

A pilot study was carried out on one individual to test the proposed methodology. No problems were experienced, so no changes were made to the methodology. The data from the pilot study were included in the main results.

The laboratory was set up before participants arrived on the first day. The origin or zero point of the system's mutually orthogonal measurement framework was established by placing a single marker in the centre of the treadmill, mid-way between the two sensor units. The alignment of the system's X, Y and Z axes was set using two additional pairs of markers. The orientation of the three axes used throughout the data collection was as follows:

- positive Y axis – direction of walking;
- positive X axis – to the participant's right;
- positive Z axis – up.

All data were collected using the right leg, and the axis orientation was set in accordance with the recommendations of the Standardization and Terminology Committee of the International Society of Biomechanics [14].

Fig. 1. Neutral shoe: Mizuno Wave Rider.

Participants were asked to attend a single session lasting approximately 30 minutes. Participants were asked to come wearing shorts and to put on the neutral pair of running shoes (Fig. 1) before marker attachment took place. Active markers were attached using double-sided hypoallergenic adhesive tape to the following landmarks on the right leg: medial condyle of tibia, head of fibula, tibial tuberosity, two-thirds of tibial shaft, medial malleolus and lateral malleolus (Fig. 2). Marker placement complied with the Joint Co-ordinate System recommendation [9]. Technical markers (medial condyle of tibia and two-thirds of tibial shaft) were used to define the co-ordination of the virtual markers during running trials. Batteries were connected to the markers and attached to the leg using hypoallergenic adhesive tape. The safety clip of the treadmill was attached to the participants and they were given a 5-minute practice run to allow them to adapt to the treadmill motion and the shoes. Lavcanska *et al.* found that it takes 5 to 6 minutes to become familiar with treadmill running; therefore, participants were acclimatised for this period prior to commencement of measurements. The treadmill speed was then gradually increased to 8 km/hour [15]. The average running speed of unimpaired young adults is between 7 and 9 km/hour [15].

Participants were shown the emergency stop button and assured that they could stop running at any time. Confirmation was gained that the participant was happy running at this speed. On confirmation, lights were switched off to do a 'test' collection of data to ensure that all markers were in view of the scanners. One researcher carried out all the tests with an assistant to help. If all the markers were in view, three sets of data were collected and saved to the computer. If a marker went out of view at any point, the treadmill was stopped and the markers were adjusted accordingly or retaped. Once the three sets of data were saved, participants dismounted the treadmill and changed into the motion control shoes (Fig. 3). Markers were checked for secure attachment. The procedure was then repeated for the motion control shoes. All data were saved to a password-secured computer.

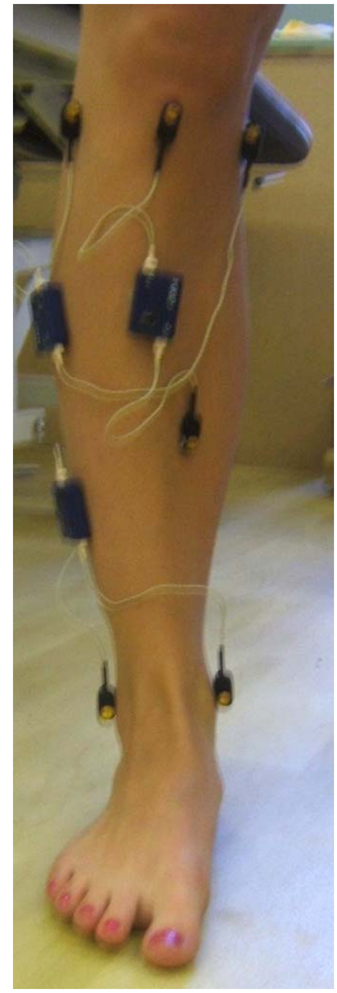

Fig. 2. Front view of active markers.

Data analysis

The first useable set of data of the three sets collected per participant was used for data analysis. The average range of

Fig. 3. Motion control shoe: Mizuno Wave Inspire.

Table 1
Total range of proximal tibial rotation in the *XY* plane of the Cartesian optoelectronic dynamic anthropometer for the two running shoes.

Participant	Total range of tibial rotation (degrees)		
	Neutral shoe	Support shoe	Difference (°)
1	10	16	−6
2	4	9	−5
3	5	9	−4
4	10	14	−4
5	12	14	−2
6	7	7	0
7	6	6	0
8	22	21	1
9	17	16	1
10	8	7	1
11	5	4	1
12	9	8	1
13	15	14	1
14	7	5	2
15	23	21	2
16	9	6	3
17	18	15	3
18	18	15	3
19	10	7	3
20	12	8	4
21	11	6	5
22	20	14	6
23	10	4	6
24	28	17	11
Mean Standard deviation	12.3 (6.4)	10.9(5.3)	1.4 (3.8)

motion of the leg in the transverse plane during the contact phase of running was calculated using CODA. The data were copied into Microsoft Excel, and graphs were plotted to show the total range of proximal tibial rotation in the *XY* plane of CODA for the two running shoes. A one-tailed paired *t*-test was used to test for differences in tibial rotation recorded for the two experimental conditions (neutral and motion control shoes), and the *P*-level was set at 0.05.

Results

All 32 participants took part in the study, but only 24 participants provided adequate data for analysis. Naturally, every individual's running gait is different and sometimes this meant that the signals from the active markers were not picked up by the scanner units. This occurred for eight of the participants; therefore, the data were excluded from the analysis. Table 1 shows the data collected from the 24 participants.

The paired *t*-test revealed a statistically significant difference in tibial rotation between the two conditions (mean difference 1.38°, 95% confidence interval 0.03 to 2.73, $P = 0.04$). This showed that there is a statistically significant difference in tibial rotation in the transverse plane during treadmill running when using motion control running shoes compared with neutral running shoes.

The overall trend showed that the total range of proximal tibial rotation for participants running in motion control shoes (mean 10.9°, standard deviation 5.3°) was smaller compared with running in neutral shoes (mean 12.9°, standard deviation 6.4°). The largest individual difference was 11°, but the mean difference between the two conditions was small (mean 1.38°). The tibial rotation in five participants was smaller in the neutral running shoes (Table 1).

The largest difference was 11°; two participants had a total range of tibial rotation of 10° in the neutral shoes and 4° in the motion control shoes.

Discussion

The aim of this study was to determine whether motion control running shoes reduce tibial rotation in the transverse plane during treadmill running, with implications for injury prevention. The findings suggest that there is a statistically significant difference in tibial rotation in the transverse plane during treadmill running between motion control running shoes and neutral running shoes. The total range of proximal tibial rotation was generally reduced when participants ran in motion control shoes. Although the mean difference was rather small, some participants demonstrated a difference which was half of the total range, and hence could be clinically significant in their cases.

Clarke *et al.* [6] analysed the effects of different shoe design parameters on rearfoot control in running. They found that participants displayed an average of approximately 2.7° smaller maximum pronation when running in shoes with a hard midsole compared with a soft midsole. If rearfoot motion and tibial rotation are taken as a coupled mechanism [3], it can be assumed that this is the mechanism by which tibial rotation was reduced in this study. Controlling rearfoot motion with running in motion control shoes will subsequently reduce the participant's tibial rotation. The results from the current study support this assumption because the total range of proximal tibial rotation was reduced when running in motion control shoes compared with running in neutral shoes for the majority of participants (79%). For example, one participant had a total range of tibial rotation of 28° in the neutral shoes and 17° in the motion control shoes (reduction 11°).

The results from the current study relate to similar research by Butler *et al.* [7], which showed that in low arched runners, peak tibial internal rotation decreased in motion control shoes and was increased in cushion shoes. They found no interaction between high arched runners and lower extremity kinematics. Since arch height was not measured in the current study, it is unclear if this factor contributed to the degree of tibial rotation. To confirm this association, further research needs to be undertaken in the area. Butler *et al.* [7] found no reduction in peak rearfoot eversion for runners in the motion control shoes. This is unusual because if there was a coupled relationship between rearfoot eversion and tibial internal rotation, it would be expected that both of these movements would decrease when running in motion control shoes. These unusual results may be due to the motion control shoes having increased support in the midfoot; therefore, the positioning of this support would not have influenced rearfoot motion.

This study does not provide direct support for the hypothesis that motion control running shoes are a form of injury prevention; however, it does have some supporting implications. Miller *et al.* [8] found that runners with a history of ITB syndrome demonstrated more tibial internal rotation, thus suggesting that an increase in tibial internal rotation could be a contributing factor to ITB syndrome. The links between tibial rotation and running injuries are further supported by Stergiou and Bates [16]. They investigated knee and ankle kinematics in five runners, and showed a strong relationship between pronation and knee joint function via tibial rotation; this was identified as a possible mechanism for injury. They went on to explain that overpronation could lead to maximum pronation (and subsequent internal tibial rotation) occurring later in the stance phase. This could then lead to soft tissue stress around the knee or patellofemoral malalignment [16]. Since anyone with a lower limb condition that is exacerbated by running was excluded from this study, the hypothesis that motion control shoes could be a form of injury prevention for runners was not tested. However, the links between increased internal tibial rotation and running injuries found to date seem promising, and there is scope for further research.

The Codamotion 3-D Movement Analysis System is easy to use, and previous studies that have used CODA have not found any anomalies or errors attributal to CODA itself [12,13]. However, there are certain limitations that may have affected the outcome of the results. The issue of skin movement artefacts when using skin markers in gait analysis has been raised [3], although tibial rotation is considered to be more accurate than other measurements of knee and thigh movement [12]. When comparing bone pins with skin markers, Reinschmidt *et al.* [12] found an average error of 1.1°, implying that tibial rotation can be determined with reasonable accuracy using skin markers. In this study, the active markers were placed over bony structures where underlying soft tissue was minimal, with the hope that skin movement artefacts would be minimised. This is especially the case around the ankle where the skin is tightly bound and there is a decreased chance of soft tissue and skin movement.

Maynard *et al.* [11] studied the intra- and inter-rater reliability of gait measurements using CODA, and suggested that natural variation of the participant's gait cycle may be overcome by capturing at least three gait trials. In this study, three gait trials were captured for each participant and the first useable set of data was used for data analysis. This improved the reliability of the measurement technique and minimised potential error.

Although treadmill running allows for easy, continuous observation and monitoring, it may cause variation in movement pattern compared with overground running. Therefore, for a true representation of running biomechanics, tibial rotation would need to be measured over ground.

Five participants did not follow the trend of results and showed an increase in tibial rotation when wearing motion control running shoes compared with neutral shoes. A number of factors could have contributed to this unusual difference. During data collection, it became apparent that there was inconsistency with the level of treadmill experience between the participants. This could have resulted in the less experienced participants becoming fatigued by the time they reached the second test condition. Links between fatigue and rearfoot kinematics have been recorded [7,17].

Participants in this study ran first in the neutral shoes and then in the motion control shoes. This may have contributed to some of the increases in tibial rotation in the motion control shoes. To minimise possible order effects, the shoes should have been presented in a randomised order. This would have eliminated a potential confounding variable and strengthened the internal validity of the study. Due to limited funding, only eight pairs of shoes were used for the study, which excluded participants outside the available shoe sizes. Therefore, the results may not be representative of the general population. This study would need to be reproduced with a larger sample size (including all shoe sizes) to make the results more applicable to the wider population.

The results from the study are open to observer bias because the researcher collected the study data. To eliminate this potential confounding variable, an independent data collector should have been used.

A number of ideas for further research arose while evaluating the current study. As highlighted above, the results from this study have implications for the theory that motion control running shoes could be a form of injury prevention for runners. The experiment could be expanded to include participants with running-related injuries. Researchers could then investigate to see if injured participants displayed more tibial rotation in the neutral shoes, and furthermore if this tibial rotation decreased for these participants when wearing the motion control shoes.

Conclusions

The results from this study show that there is a difference in tibial rotation in the transverse plane during treadmill running when comparing motion control running shoes with neutral running shoes. This is indicated by the statistically significant decrease in the total range of proximal tibial rotation when motion control shoes were worn. Previous research findings have demonstrated links between increased tibial rotation and running injuries [8,9]. The results from this study therefore suggest that supportive running shoes may have an important role to play in running injury prevention.

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Conflict of interest: None declared.

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