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The influence of motion control shoes on the running gait of mature and young females

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ABSTRACT

Background: This study compared the running gait of mature and young females, and investigated the effect of a motion control shoe. First, it was hypothesised that in a neutral shoe, mature females would display significantly greater rearfoot eversion, knee internal rotation and external adductor moments when compared to a younger group. Secondly, the motion control shoe would reduce rearfoot eversion and knee internal rotation in both groups. Thirdly it was hypothesised that the motion control shoe would increase knee external adductor moment, through an increase in knee varus and moment arm.
Methods: 15 mature (40–60 years) and 15 young (18–25 years) females performed 10 running trials at $3.5\ \mathrm{m\,s^{-1}} \pm 5\%$ over a force platform. Two shoes were tested, the Adidas Supernova Glide (neutral), and the Adidas Supernova Sequence (motion control). Ankle and knee joint dynamics were analysed for the right leg, and the mean of ten trials was calculated. Joint moments were calculated using inverse dynamics.
Findings: In the neutral condition, mature females presented greater peak rearfoot eversion, knee internal rotation, and external adductor moments than young females ($p < 0.05$). A motion control shoe significantly reduced peak rearfoot eversion and knee internal rotation among both groups ($p < 0.05$). No between shoe differences in knee external adductor moment were observed.
Interpretation: A motion control shoe is recommended to reduce risk of injury associated with rearfoot eversion and knee internal rotation in mature females. However since the knee external adductor moment is a variable commonly associated with medial knee loading it is suggested that alternative design features are required to influence this moment.

1. Introduction

It is widely acknowledged that participation in running as a recreational or competitive activity contributes positively to health and fitness outcomes [1]. However, this activity is also associated with high rates of musculoskeletal injury, evidenced by a study reporting one running injury to occur every 100 training hours [2]. Among the twenty-six most common conditions to affect runners, women have been shown to have higher incidences of patella femoral pain syndrome, iliotibial band friction syndrome, plantar fasciitis, meniscal damage and pathology of the patella, Achilles tendinopathy and osteoarthritis of the knee compared to men [3]. Increased age, specifically >50 years, has also been found to be associated with a higher incidence of overuse running injuries [3]. The higher incidence of running related overuse injuries in women compared to men, and in runners over the age of 50 years indicates that mature female runners are particularly susceptible to injury occurrence.

Mature female runners have been found to yield significantly greater magnitudes of rearfoot eversion, knee internal rotation, knee external adductor moment and peak loading rate (of vertical ground reaction force) compared to younger runners [4]. While this study did not control for footwear, these age-related changes in female running gait may indicate biomechanical risk factors for overuse injury development and progression of degenerative conditions. Footwear provides an accessible method for changing patterns of running gait [5]. Thus investigation of the influence of footwear manipulation on mature female running gait is important in order to investigate the potential for reducing biomechanical risk factors associated with overuse injury and degenerative conditions that may be exacerbated by regular participation in running.

Motion control aspects of a shoe aim to reduce excessive rearfoot motion and subsequent internal rotation of the lower leg and knee valgus, through altering deformation rates and geometry between the medial and lateral sides of the shoe [6]. Although a magnitude of rearfoot eversion is essential to produce a flexible forefoot to enhance shock absorbency and allow adaptation to

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irregularities in the running surface [7], excessive movement has been frequently associated with certain running-related overuse injuries [8]. Excessive rearfoot motion is suggested to increase knee pain and overuse injury risk via elevated levels of lower limb strain [9], increased knee internal rotation and a forefoot loading [10–12]. Studies investigating the ability of greater medial support in footwear to reduce rearfoot eversion and lower leg internal rotation during running, have found promising results [13].

However, a negative effect of motion control shoes has been an increase in knee external adductor moment during running [14]. High values of this moment are related to increased loading of the medial knee [15], and are primarily contributed to by the frontal plane moment arm length of the ground reaction force about the knee joint centre [15]. This moment arm length may increase due to a varus position of the knees, or a medial shift in the location of the centre of pressure of the ground reaction force. Increased medial support in shoes can potentially move the line of action of the ground reaction force medially, thereby increasing the moment arm at the knee [16]. This is in contrast to the alternative method often prescribed to reduce knee external adductor moments, and subsequent loading of the medial knee, which involves wedging the lateral sole [17]. It is therefore important to assess whether medial support has any negative influence on the knee external adductor moment for the population of mature female runners.

The first aim of this study was to test the conclusions of the previous study comparing running gait in mature and young females [4] by repeating this comparison but with a consistent neutral trainer. The second aim was to investigate the influence of a motion control shoe on lower limb biomechanics of both study groups. It was hypothesised that (a) a neutral shoe would result in higher peak rearfoot eversion, knee internal rotation angle and knee external adductor moment for mature compared to younger females; (b) the motion control shoe would yield reduced magnitudes of rearfoot eversion and knee internal rotation in both groups compared to a neutral shoe and (c) the motion control shoe would increase knee external adductor moment.

2. Methods

2.1. Participants

Fifteen young (age range 18–25 years, mean 21.2 years, SD 1.3) and fifteen mature females (age range 40–60 years, mean 49.7 years, SD 4.1) volunteered to participate in this study. The young females were from the Sport and Health Sciences student cohort of the University of Exeter, while the mature participants volunteered from a local women's running club (Women's Running Network). All females had a minimum of three years running experience and attended a running club three nights a week. Best 10-km run time was used as an indicator of standard (Table 1). Each participant completed a Physical Activity Readiness Questionnaire (PAR-Q) form to assess participant statistics (age, height and weight) and health and suitability to perform physical testing (PAR-Q, Canadian Society for Exercise Physiology, 2002). A summary of demographic data for both groups is illustrated in Table 1.

Table 1
Demographic data from each of the female groups. Means and SD are presented.

	Young	Mature
Age (years)	21.2 (2.1)	49.7 (3.7)
Mass (kg)	60.5 (7.8)	58.2 (5.1)
10-km time (min)	56.5 (5.2)	58.5 (9.5)

2.2. Gait analysis

Three dimensional analysis of running gait occurred using an eight camera motion capture system (Vicon Peak, 120 Hz, automatic, opto-electronic system; Peak Performance Technologies, Inc., Englewood, CO), synchronised with a single floor mounted force platform (960 Hz, AMTI, Advanced Mechanical Technology, Inc., MA). Data were synchronised within the Vicon software using initial foot strike as an automatic event detection (vertical force > 10 N).

Each subject was affixed with 11 reflective markers on the right lower limb using a modified version of the model presented by Soutas-Little et al.; greater trochanter, medial and lateral knee at the tibial plateaus, the musculo tendinous junction where the medial and lateral belly of the gastrocnemius meet the Achilles tendon, the mid tibia below the belly of the tibialis anterior, the superior and inferior calcaneus, the lateral malleolus, the proximal head of the third metatarsal, and the distal head of the fifth metatarsal joint to monitor the spatial movement of the thigh, shank and foot [18]. Markers representing the foot were placed directly on the shoe.

Participants performed randomised running trials in a motion control shoe (Adidas Supernova Sequence) and a neutral shoe (Adidas Supernova Glide). Description of the components inherent to each shoe is presented in Table 2. All kinematic data were referenced to a standing position in the neutral shoe. During this static trial, posture was standardised with arms crossed over the chest, and feet shoulder width apart on the force plate.

Running velocity was recorded using two 1 m high infrared light timing gates located along the 10 m concrete runway, situated 2.5 m either side of the centre of the force plate, categorising each trial acceptable at $3.5\ \text{m s}^{-1} \pm 5\%$ (speed determined in a pilot study). Each trial was accepted when the participant made full right foot contact with the force plate with no adjustment in stride. Unacceptable trials were repeated.

Mean results were collected for each participant performing 10 trials in each condition. Peak rate of loading was calculated using the first central difference

Table 2
Description of key running technologies of both Adidas shoes.

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Supernova Sequence	Supernova Glide
FORMOTION: Adapts to the ground for smoothness and comfort.	FORMOTION: Adapts to the ground for smoothness and comfort.
adiPRENE: Shock absorbent material that cushions and protects heel at impact.	adiPRENE: Shock absorbent material that cushions and protects heel at impact.
adiPRENE+: Resilient cushioning to protect forefoot and provide responsive dynamic toe-off.	adiPRENE+: Resilient cushioning to protect forefoot and provide responsive dynamic toe-off.
GEOFIT: Internal footwear technology enhancing fit and comfort.	GEOFIT: Internal footwear technology enhancing fit and comfort.
TORSION: Adaptive midfoot support.	TORSION SYSTEM: Lightweight arch support enabling independent movement of the forefoot and rearfoot.
adiLITE: Lightweight, Increases comfort.	adiLITE respoEVA: Sockliner for instep comfort and antimicrobial protection.
adiWEAR: Outsole for high-wear durability.	Women's specific outsole with larger forefoot platform and anatomically adjusted flex grooves.
PROMODERATOR: Medial device prevents over pronation.	Blown rubber outsole for lightweight grip and cushion.