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The impact of different footwear characteristics, of a ballet flat pump, on centre of pressure progression and perceived comfort

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ABSTRACT

Background: Uncomfortable shoes have been attributed to poor fit and the cause of foot pathologies. Assessing and evaluating comfort and fit have proven challenging due to the subjective nature. The aim of this paper is to investigate the relationship between footwear characteristics and perceived comfort.
Methods: Twenty-seven females assessed three different styles of ballet pump shoe for comfort using a comfort scale whilst walking along a 20 m walkway. The physical characteristics of the shoes and the progression of centre of pressure during walking were assessed.
Results: There were significant physical differences between each style, square shoe being the shortest, widest and stiffest and round shoe having the least volume at the toe box. Centre of pressure progression angle was centralised to the longitudinal axis of the foot when wearing each of the three shoes compared to barefoot. Length, width and cantilever bending stiffness had no impact on perceived comfort.
Conclusion: Wearing snug fitting flexible soled round ballet flat pump is perceived to be the most comfortable of the shoe shapes tested producing a faster more efficient gait. Further investigations are required to assess impact/fit and upper material on perceived comfort to aid consumers with painful feet in purchasing shoes.

1. Introduction

The perceived comfort of a shoe may vary across individuals with multiple physical factors being reported as important, such as material properties [1], shoe fit [2], skeletal alignment [3] and fashion [4]. The specific conditions that define a comfortable shoe and therefore good fit are not clear but the most frequent and significant findings for shoe comfort have been attributed to (1) a feeling of support from the upper, (2) foot-bed contact with the foot and (3) stability of the shoe as a whole [5]. Deviations away from any of these parameters may play a considerable role in influencing the perceived comfort level of the shoe, which, has been shown to be considered as a significant factor when purchasing new shoes [11].

Uncomfortable shoes are often attributed to the cause of foot pain and pathology with 60% of female subjects experiencing foot pain related to the shoes worn. Previous research indicates that the most frequent area of discomfort and pain is around the toes, with the population studied having a greater circumference of the metatarsal heads associated to pain [6]. A shoe that is either too loose or too tight can also influence comfort with tissue compression in a snug shoe and slippage or friction in a larger shoe [4]. Observations on shoe wearing habits in the elderly indicates that up to 72% wear shoes that are ill-fitting associated to foot pain and ulceration [7]. Despite the strong evidence to support the notion that ill-fitting footwear can cause foot pain and ulceration, people continue to wear shoes that do not fit the foot [8].

Given that, the individual variations in foot dimension are high, matching the shape of the foot to a suitable shoe style and therefore improving the fit can be challenging. In orthopaedic shoes the profile and depth of the toe box has previously been investigated for its association with increased plantar pressure under the toes [9,10]. Additional toe box depth did not however, improve skin lesion pathology in rheumatoid patients although pain and function scores did improve [10]. This type of orthopaedic shoe with greater toe depth is only worn by a small sample of the

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population, often elderly, and little is known about the impact shoe styling and manufacturing variations have on the comfort of shoes worn everyday by younger generations.

A previous investigation demonstrated that the shoe of choice for everyday school wear is a flat ballet slip on pump [11]. This unstructured shoe does not provide any fastening or support and can easily fall from the foot on walking and has been previously characterised as a poor fit for patients who suffer from gout [12]. Recommendations for suitable fitting of footwear include (1) the presence of a fastening, (2) firm heel counter, (3) appropriate bending stiffness of the sole and (4) height of the heel [13,14]. According to published research reports, incorrect or poor fitting footwear can be detrimental to the wearer; for example an increase in heel height escalates forefoot plantar pressure [15], altered flare at the toe box being mis-matched to foot shape causing increases in toe pressure [16] and increased risk of falls in the elderly attributed to instability [17].

Footwear stability is most frequently researched within the areas of athletic and high-heeled shoes, with papers mainly focusing on medial and lateral foot stability and postural sway [18–20]. The way the sole is constructed and the sole material properties have been shown to influence stability and comfort in elderly populations with a thick-soled shoe reducing stability and a thinner firmer sole material being more preferable [21]. For heeled shoes though, increased instability is observed when there is a change of heel shape with narrowing of the heel impacting on the medial and lateral centre of pressure progression angle in the frontal plane [22]. Centre of Pressure (CoP) has been identified as the instantaneous point of application of the ground reaction force and the progression of CoP indicates the advances that this point makes during dynamic heel to toe walking [23]. Alterations in CoP progression from the longitudinal axis of the foot can be used to assess foot posture and motion during gait with a medial deviation being associated with a pronated foot type [24]. Motion of the foot whilst wearing shoes is known to provide challenges as the shoe inhibits motion capture [25]. CoP progression can be easily calculated from plantar pressure measurements and has been shown to identify deviations away from the midline of the foot and can be used as a measure of foot function identifying an altered pathway of motion [22,23].

To minimise discomfort and the potential for harm, it is important that a good fitting shoe is essential for everyday wear. The relationship of subjective comfort and the fit of a shoe clearly warrant investigation. Therefore, the primary aim of this paper is to examine the relationship between the perceived comfort whilst wearing three different flat ballet shoes which have an altered forefoot shape, volume and cantilever bending stiffness. Additionally, this study will investigate the impact of CoP progression during walking across these styles.

2. Method

2.1. Participants

Twenty-seven healthy females, from a convenience sample with an average age of 22.5 (±4.5) years, body mass of 63.3 (±8.9) kg, height of 1.64 (±6.5) m, UK shoe size 5.5 (±0.8), foot length 24.03 cm (±1.3) cm, foot girth – circumference of forefoot – 22.89 (±2.39) cm, and foot posture index 4 (±2), were recruited and provided full informed consent to participate in the study. Ethical approval was sought and granted from the university ethics committee. All subjects included in the study were asymptomatic at the time of testing and were excluded if any musculoskeletal foot and ankle pathologies were present. Foot sizing length and breadth measurements, for correct shoe size allocation, were taken using a Brannock device® (The Brannock Device Company, NY, USA).

Fig. 1. Three footwear styles investigated: A4L = square shoe left size 4, B4L = pointed shoe left size 4, C4L = round shoe left size 4.

2.2. Footwear characteristics

The style of shoe chosen to investigate was a slip on flat ballet pump. The three toe box shapes were round, square and pointed. This shoe was selected as it has been highlighted as the everyday shoe of choice by young females [11]. All the shoes were black in colour, leather uppers and design on the toe box was matched with a feature of a bow or buckle styling (Fig. 1). The brand of each shoe varied between shoe conditions, with each shoe being purchased from a different retail outlet, and was blinded by covering the logo inside the shoe with micro lining top cover material (Algeos, Liverpool, UK). These features were controlled to minimise preference in brand and design that may influence comfort scores. The heel height on all shoes was standardised to 5 mm, weight of shoe was measured as Square = 192 g, Point = 164 g and Round = 145 g and the sole unit had a smooth tread pattern for each shoe style. The toe box shape and volume of the shoe upper varied between each style