

Effect of Different Types of Footwear on Gait Pattern – A Scoping Review

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Abstract: **Background:** Footwear has a big influence on how we walk and our overall foot health. Various elements, such as environment, culture, fashion trends, and technical breakthroughs, have impacted the evolution of footwear over time. Many investigations on the impact of footwear on muscular activity, balance, posture, energy consumption, and biomechanical alterations have been conducted. A study of the impact of various types of footwear on gait patterns might aid in improving quality of life. **Objective:** To review the available evidence on the effects of various available footwear on gait patterns to make specific recommendations for practice and future studies. **Design:** Scoping review. **Literature Search:** PubMed, Google Scholar, Science direct. **Study Selection criteria:** Inclusion criteria-RCTs, meta-analysis, clinical trials, reviews and systemic reviews done after 2013 were included. **Exclusion criteria-**Articles before 2013 were excluded. **Result:** The gait pattern of a person is influenced by a variety of factors, including their body mechanics, muscle strength and flexibility, and the way their joints move. These factors can vary between individuals and can also be influenced by the type of footwear they are wearing. **Conclusion:** Footwear has a substantial influence on walking patterns. The design, fit, and type of footwear can impact body alignment and modify joint action during walking. To maintain a healthy gait pattern, footwear that is suited for the activity and gives proper support and comfort should be chosen.

Keywords: footwear, flip flops, bionic shoes, high heels, formal shoes, sports shoes, gait pattern.

1. Introduction

Walking is one of the most common activities of daily living that involves alternating periods of limb movements in order to perform locomotion. It is a complex mechanism that involves the body's nervous, musculoskeletal as well as cardiorespiratory systems [1]. Normal walking patterns should be both steady and flexible, allowing for adjustments in pace and maneuvering across various terrains while being energetically efficient. This locomotory mechanism occurs in a specific pattern called 'gait'. Gait is the term for a person's cyclical walking pattern, which is characterized by repeated heel strikes [2]. It includes the timings, sequence, and coordination of various joint motions by involving an interplay between various internal and external factors [3]. A normal gait can be interpreted in terms of a gait cycle that involves a period from heel contact of one foot on the ground followed by release of that same foot from the ground,

termed as stance and swing phase respectively [4]. With an increase in speed, gait can be classified as- walking, jogging, running, and sprinting [5].

Gait is affected by various factors like an individual's age, health status, and fitness. Thus, an abnormality in gait pattern can help to diagnose various diseases and conditions which can be the cause of falls and thus injuries [6]. Individual's limitations in walking, stair climbing, and squatting are typical complaints that severely interfere with activities of daily living, thus the capacity to conduct a safe, efficient, and effective gait may assist to forecast an individual's quality of life [7]. The gait pattern of an individual may help the clinician or examiner to understand the underlying pathology or present condition of the individual. Every phase of the gait cycle involves different and specific actions of muscles and joints [8]. It is also an effective method for forecasting health-related outcomes such as falls and the development of future health deterioration [3].

A person's gait pattern might be disrupted by a variety of causes. These factors might be external or internal. Internal influences may include a person's health, sense of balance and coordination, age, and pathological asymmetry in the body. On the other hand, clothing, floor surface, surroundings, and footwear are a few examples of external factors. If neglected, these factors might contribute to asymmetrical gait behavior, which can lead to serious biomechanical and structural complications in the long term and thus, affect the activities of daily living (ADLs). Several physiological changes occur with growing age, which may have a negative impact on one's lifestyle. These changes are not only physical but also psychological and social. Individuals commonly experience chronic health issues, joint and muscle weakness, fear of falling, and depression which are some of the key contributors to an altered gait pattern [9]-[11]. In this study, we are focusing on one of the external factors that affect gait pattern, "footwear".

Various types of footwear have different effects on the gait pattern of an individual. Footwear plays an important role in protecting the feet of an individual who is in direct contact with the floor most of the time. The type of footwear worn by the individual can stimulate touch receptors on the plantar surface of the foot and thus, enhancing balance and proprioception [12].

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2. Methodology

A literature search was conducted across PubMed, Science Direct, and Google Scholar databases, including the reference lists of relevant articles which ranged in duration from 2013 to 2022. The specific terms used for identifying relevant pieces of literature were “Footwear”, “Flip flops”, “Sports shoes”, “Bionic footwear”, “High Heels”, “Foam Footwear”, “Gait patterns”, “Balance”, and “Musculoskeletal Disorders”. A reference list of articles obtained from this search was also examined for additional relevant articles. The inclusion/exclusion criteria for studies were based on their potential relevance to the footwear in the Gait Patterns. Articles published before 2013 were excluded.

3. Discussion

Various floor conditions may impose harm to bare feet or the individual as a whole by disrupting balance leading to falls or causing injury to the skin in contact [13]. The type of footwear worn by an individual has a direct impact on various parameters that affect gait pattern. The ground reaction forces, the center of pressure (COP), weight distribution, and ankle-knee-hip joint kinematics are directly affected because of footwear as suggested by a study done by Zhang *et al.* (2013) which involved walking trials performed on healthy male subjects [14]. Sanno *et al.* (2021) in their research on different footwear found that in fatigue conditions, performing a gait can require even more energy expenditure on distal muscles and tendons of lower extremities if proper footwear is not worn by the person; and major changes can be observed in initial phases which may subside because of habituation [15]. Footwear with improper fittings like being too narrow and having less depth can cause gait abnormalities and might even be responsible for foot deformities, thus creating more walking and balancing problems in the long run. Research has shown that a significant fraction of people wear footwear that is not the proper size, which is concerning. It might also lead to pain, various types of skin lesions, corns, and calluses. These factors not only contribute to changes arising in the standing posture and gait of the individual but also the activities of daily living [16], [17].

Sports and running shoes are made with internal and external cushioning. This cushioning provides comfort and reduces the level of fatigue in the users. Cushioning in shoes helps to reduce the muscular expenditure required while performing gait by dissipating the impact force at the time of contact with the ground. The cushioning effects of shoes studied by Tung *et al.* (2014) by measuring VO₂ max values in each subject concluded the positive impact of the same on muscle energy expenditure which was reduced as compared to that in bare feet or other footwear [18]. Sports shoes are elastic, lightweight, and comfortable and have an overall positive impact on the gait pattern [18], [19]. However, according to research done by Hesses *et al.* (2017) on adult males, static and dynamic tests conducted revealed that sports shoes that have higher heel lift are found to cause significant problems like postural imbalance, muscle overuse and may even become a cause of altered gait pattern [20].

A 3D motion analysis system was used to assess the gait parameters in a study by Silva *et al.* (2020), which involved a group of healthy male subjects. The findings indicated that gait characteristics such as stride length, walking speed, cadence, and stance time are considerably influenced by heel height and shoe material. In order to avoid pain or injury, the authors advised carefully weighing factors like heel height and shoe material when choosing men's dress shoes. They also recommended that more research be done to determine how various dress shoe types affect gait patterns [21]. Long-term use of such shoes may cause discomfort and even deformities in the foot [16]. To understand the effects of formal shoes on lower extremities, joint biomechanics, and gait pattern, N. Paul *et al.* (2019) conducted a study that revealed that the shape and weight of formal footwear worn by men could create an unnecessary buildup of stress over the skin, muscles, and joints of foot and leg because of increased venous pump activity in the distal lower limb and higher pressure on muscles which further leads to more fatigue and discomfort, hence affecting the gait pattern. Moreover, greater comfort and reduced energy expenditure were observed when low-heel and low-weight formal shoes were used [22].

Wearing flip-flops or slippers seems to be enticing to the wearers as it imitates a more barefoot-like environment as compared to the other footwear and thus, feels more comfortable. Flip flops are distinguished by a thin, flat, and flexible sole linked to a few straps in the forefoot region thus exposing a major portion of the dorsal foot's skin. Flip-flop users also expose their hind foot and receive no support to the heel and ankle which is frequently found in closed-toe shoes [23]. This lack of posterior support has a direct impact on individuals' balance and pattern of gait. A cross-sectional study on gait analysis by Sharpe *et al.* (2016) revealed that despite being lightweight and convenient, flip flops may have less stability because of their lack of adherence to the foot causing an increase in knee flexion and ankle dorsiflexion in the swing phase. This may cause a loss of balance which may further lead to falls and thus, injuries. It has been observed that people wearing flip-flops have a different gait as compared to those wearing shoes [24]. Flip flops provide less shock absorption on contact with the ground as compared to that in other footwear. There is a lack of support and an increased need for ankle dorsiflexion in these types of footwear which may lead to heel pain and might worsen a pre-existing biomechanical or musculoskeletal condition of the foot [25].

A study to determine the effect of flip flops on plantar pressure done by Carl *et al.* (2008) on women subjects with a normal Body mass index (BMI) suggested that the pressure on the plantar side of the foot increases while wearing flip flops as compared to that in shoes but is still lower than that of bare feet [26]. Another study on assessing the effect of flip flops on the ground reaction forces (GRF) by Tan *et al.* (2021) revealed no significant change in GRF however, it may help to decrease ankle angle thereby preventing the chances of ankle sprain. It also focused on determining how various flip-flop styles affected certain gait characteristics, by taking three different varieties of flip-flops into consideration— foam, rubber, and

leather—the researchers assessed the gait metrics of each one in all involved subjects. Step length, step width, cadence, velocity, and stance duration were all measured gait variables. According to the study, people's choice of flip-flops significantly affected their gait metrics. People who wore foam flip-flops specifically had shorter steps and wider steps than people who wore rubber or leather flip-flops. In addition, compared to people wearing rubber or leather flip-flops, people wearing foam flip-flops had a lower cadence and velocity and a longer stance time. Overall, the study indicated that footwear selection, particularly the kind of flip-flops worn, can change gait metrics. This finding may have consequences for those who have disorders connected to their gait [27].

The usage of high-heeled shoes results in an apparent gain in height boosts confidence, and also creates an attractive appearance to female wearers [28] Footwear with high heels has been found to have various negative impacts on lower extremity joint mechanics, gait pattern, the center of gravity, balance, and impact force distribution [20], [29]. A higher lifetime risk of osteoarthritis in women has been linked to the wearing of high-heeled shoes. A gait analysis study using different heel-length shoes was performed on healthy female subjects by Matthew *et al.* (2014) revealed that wearing high heels on a daily basis is harmful and can increase the risk of OA in women since the changes observed in joint biomechanics found to be similar as that in OA and it also causes other gait irregularities because of increased knee flexion angle during high heeled gait [30]. Muscle energy expenditure while performing gait also significantly increases with an increase in heel height along with the overall increase in pressure over metatarsals [31]. To understand and evaluate changes in different parameters while performing high-heeled gait, Enrica *et al.* (2018) performed a study on healthy women subjects and observed a significant decrease in step length, step width, joint range of motion, and duration of swing phase [32]. Ankle instability can occur as a result of prolonged wearing of high heels because of excess stress over ligamentous structures between the foot and ankle. A gait analysis study using a three-dimensional model done by J. Yu *et al.* (2016) deduced that during high-heeled walking, the plantar fascia's tensile strain and tension force sharply increases which adds as a risk factor for ankle injuries. Moreover, the changes observed in the same were observed to be even greater for subjects in a static standing position [33].

The Centre of pressure is observed to be significantly affected by different footwear. A study to explore the impact of various unstable footwear constructions by Plom W *et al.* (2014) focused on postural control during standing by analyzing the center of pressure motion. The results indicated that the different types of unstable footwear significantly affected postural control, thus demonstrating the importance of considering footwear design in the management of balance-related issues. Overall, the study underscores the need to recognize the role of footwear in maintaining balance and stability, particularly in populations susceptible to balance disorders [34].

A type of footwear known as "bionic shoes" uses cutting-edge technology to enhance comfort, support, and performance

for the user. The article Huiyu Zhou *et al.* (2021) details a study that looked into how bionic shoes affected gait patterns when running and walking. In order to lessen the strain on the lower limb muscles and joints, the bionic shoes utilized in the study contained an integrated assistive mechanism that gave the foot a spring-like effect during the stance phase of walking and running. It was also found that bionic shoes significantly altered gait patterns, leading to a more dorsiflexed ankle position during the stance phase of walking and a more extended knee position during the stance phase of running. The muscle forces needed in the ankle dorsiflexors during the stance phase of walking were also dramatically decreased by the bionic shoes. Overall, the research indicated that assistive bionic shoes may have a positive effect on gait patterns by increasing gait efficiency and stability [35].

4. Limitations

There has been less research done on various types of footwear, despite the fact that there is a growing body of knowledge about how footwear affects gait patterns. For instance, the impact of high-heeled boots or clogs on gait patterns has received comparatively little attention.

Drawing meaningful conclusions could be difficult because there may be a lot of variation in the techniques, demographics, and results reported between researches.

5. Clinical Implications

Selection of footwear: Healthcare professionals may need to take into account how footwear affects gait patterns when advising individuals on suitable footwear. For instance, people who have a history of ankle sprains would benefit from avoiding high heels, while others who suffer from foot pain might benefit from footwear with more padding.

Injury prevention: Healthcare professionals may be better prepared to give individuals injury prevention advice if they are aware of how various footwear options affect gait patterns. For instance, to lower the risk of injuries associated to running, it may be suggested to runners to use footwear that supports their natural foot striking pattern.

Research and development: The results of studies on how footwear affects gait patterns may help create innovative footwear styles that are intended to encourage good gait mechanics and lower the risk of injury.

6. Conclusion

The purpose of this study was to look at the impact of different types of footwear on gait patterns. It is important to note that footwear selection can have a considerable influence on gait patterns and may increase the risk of injuries and even chronic problems. Clinicians and individuals should be aware of the dangers associated with specific types of footwear, particularly when participating in activities that demand continuous walking or running. Wearing good and comfortable footwear provides multiple benefits like minimizing the impact of surfaces between foot and ground, protection from cold and wet conditions, and improving friction on a slippery floor hence

reducing the possibility of falls. Thus, in order to optimize the gait pattern and limit the risk of injury, footwear should be carefully selected depending on the activity and individual demands which may vary depending on the age, gender, or condition of the individual. More study is needed to examine the long-term impact of various forms of footwear on gait pattern and injury risk in bigger and more varied groups.

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