



**REVIEW ARTICLE**

**A SYSTEMATIC STUDY OF THE IMPACT OF FOOTWEAR ON GAIT OF TODDLERS**

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**ARTICLE INFO**

**Article History:**

Received 30<sup>th</sup> July, 2014  
Received in revised form  
15<sup>th</sup> August, 2014  
Accepted 04<sup>th</sup> September, 2014  
Published online 25<sup>th</sup> October, 2014

**Key words:**

Shod condition,  
Unshod condition,  
Impact of footwear,  
Gait, Ill- fitting footwear

**ABSTRACT**

Shoes are known to be direct contributing factor for foot ills. Approximately for two third of life of an individual, the feet are housed in footwear. Studies have shown that shoes are a contributing factor to the foot ills like corns and callus. Because footwear and fit are importantly involved in healthy foot growth in children, it is essential to devote special attention to the effects of footwear on foot especially during the early years of life when the feet are soft and moldable. The paper analyses the secondary research on development of feet among toddlers, function of footwear and the importance of shoes for healthy feet development. It also deliberates on different viewpoints of various researchers on bare feet versus shod condition being good for toddlers. The study compares foot size of toddlers to the inner lengths of footwear been worn by a sample of 20 urban Indian toddlers and the effect of wrong footwear on gait of toddlers. Scientific gait experiments using pressure plate scanners of 4 toddlers and video recording of gait of 10 toddlers, in shod and unshod condition, confirm that footwear affects the natural gait of toddlers. The researchers are able to study the impact of footwear on gait of toddlers and argue upon the detrimental effects of footwear.

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**INTRODUCTION**

Foot wear are functional gears for protection of feet. Historical evidences show that humans adopted footwear as a protection against hot, cold, rough or slippery surfaces. The footwear is meant to perform tasks that allow the feet to be in their natural shape and form and they provide support and balance to the feet. Footwear history dates back to 10,000 years where the historical evidence point out that footwear was first worn by Egyptians and Mesopotamians. They were initially worn to protect the sole of the feet (Stewart, 1972). Shoes were sized from the 14<sup>th</sup> century. Initially worn to protect feet against injury, shoes became a status symbol in Greece, Rome and Europe. Pointed shoes and heels were introduced in Europe in the 16<sup>th</sup> century (Cavangh, 1980). Early European heels were largely flat but French started elevating these heels to lend height to the wearer (Stewart, 1972). For the past 2000 years, adult shoe design has been primarily determined by fashion. Therefore, fashion driven shoes exist from around 2000 years back. During the past 200 years, shoe design for children has been determined by the impression that the child's foot required "support" (Staheli, 1991). In recent times, footwear, including those of children have been perceived as fashion statement rather than a technical and functional object that is required for assisting the gait of an individual. Due to this, the foot health of many individuals has been affected.

Little attention is given to the constructional and architectural requirements of footwear resulting in wrong, ill-fitting footwear being marketed.

**Development of Feet in Infants and Toddlers**

Babies' feet are extremely fragile. It has more flesh and cartilage than bones. The bones are soft as compared to those in adults. Also there are wide spaces between the bones due to which an infant's foot lacks joints (Rossi 2002). Babies have thick pad of fat under their feet which conceals the arch. The underfoot fat pad disappears and makes the arch visible as the child starts walking and performing normal functions of the feet. Relative to the foot size, the toes of the baby fete are much longer than those in the adult foot. The baby toes have enormous grip power, almost 10-15 times more than that of the adult which helps the baby for gait balance. The babies constantly wiggle their toes which are a natural way of exercising the feet. During the first three years the foot grows faster than at any other time in life. Children's feet do not grow at a steady pace. Spurt growth is very common in children.

**Function of Footwear**

A footwear should protect the foot from injury and improve performance. It is important that a shoe must be comfortable (Frey, 2000). It is generally perceived that the design of appropriate footwear should be matching the dynamic changes in foot shape. The design of a comfortable shoe must correlate

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to the function and dynamic shape of the foot. According to this, the footwear has three important functions.

1. Provide protection to the foot and ankle.
2. Help prevent injury by decreasing the stress on the leg.
3. Enhancement of performance.

The production of footwear across the world is done as mass production due to the fact that footwear is a product that offers the possibility to address all the requirements that make it suitable for being mass produced like: fit (shape, measurements, and size) functionality and aesthetic design (taste, forms). As the lifestyles changed over a period of time, footwear also became a fashion victim and lost its functionality to aesthetics.

### Importance of Shoes

Shoes are responsible for prevention of injury, foot health and maximizing performance of the foot. Each component of a shoe, like each part of human foot, has to work to fulfill its role in helping to make the walk comfortable and effortless. Though shoes protect feet, but when incompatible in size and shape, result in inflammatory conditions of the foot e.g. bunion. Feet endure tremendous pressures of daily living.

### Footwear significantly influences;

- The frequency of overuse injuries,
- The energy expenditure
- The comfort level of the users.

According to the American Podiatric Medical Association, an average day of walking brings a force equal to several hundred tons on footwear. Since a person takes approximately 5,000-10,000 steps each day, mostly on hard surfaces, a person's entire musculoskeletal system is being punished if their shoes do not fit correctly. The main function of modern footwear is to provide feet with protection from hard and rough surfaces, as well as climate and environmental exposure.

To the wearer the appearance of their footgear is often more important than its (mis)function. This causes foot injuries. According to a research by Rossi, almost all (95 percent or more) of these physically deprived feet of adult Americans and Europeans begin in childhood with the wearing of faulty designed and constructed footwear, since infancy (Rossi, 2002).

### Toe Shape

The natural shape of the toes of toddlers is broad as compared to the heel or the mid foot (Fig 1.1). There is more of flesh and cartilage than bones and the foot appears to be flat without any well- formed arch. Toddlers generally keep their phalanges apart and keep wiggling their toes even when the feet are static.

### Bare Foot Versus Shod Foot

The shoe experts and podiatrists have always argued about the bare foot condition and the shod condition for toddlers; one being better than the other.

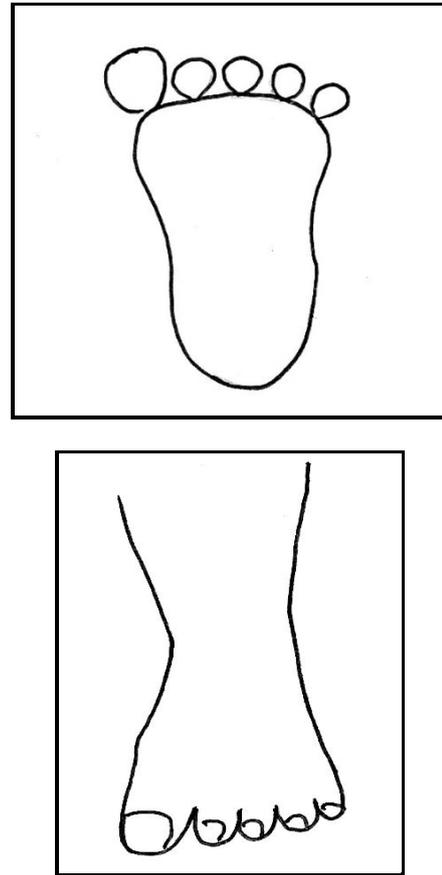


Fig 1.1. Natural Broad Shape of Toes of Toddlers

Studies supporting shod condition suggest that shoes render stability and children walk faster in shod condition. The increased stride length in shod condition is attributed to the increase in mass of the shod foot. Shoe provides a perception of protection giving confidence to the wearer to take longer steps. The increased sole width of shoes results in increase in base of support due to increased length and breadth of the shod foot leading to longer ground contact time during the gait cycle. (Wenger, 2011).

At the same time there are other studies that argue that the natural state of the foot is the best condition to be for toddlers who are developing the gait and their soft bones of the feet are vulnerable enough to get molded according to the footwear they are housed in thereby having a long term effect on the gait. Studies have shown that unshod foot is characterized by excellent mobility, thickening of the plantar skin, absence of static deformity, alignment of phalanges with metatarsals causing toes to spread and variability in arch height. (Staheli, 1991). Effects of footwear on children were studied by Emslie who noted that 80% of 281 shod children aged 2 years to 4 years had some deformity of the toe which was absent among toddlers who were left unshod. Further studies also showed that the foot shape of 74% of the 1000 children studied did not conform to the conventional shoe lasts being used for manufacturing shoes. (Bleck, 1971). Toddlers left bare feet have stronger and healthier feet with fewer deformities as compared to the ones who are habitual footwear users.

## Gait of a Toddler

The entire inner metatarsal region of the foot of toddlers is composed of soft pliable structure, incapable of bearing strains. In walking more weight is borne by the mid tarsals than any other area of the foot. The toddler has a broad base gait for support, and appears to be high stepped and flat footed, with arms outstretched for balance. The legs are externally rotated, with a degree of bowing. Heel strike develops at around 15 to 18 months with reciprocal arm swing. Running and change of direction occur after the age of 2 years. The study was undertaken to show that the footwear affects the gait of early walkers. These effects have a long term bearing on their gait and foot shape. Experiments were conducted using pressure plate scanners and gait of toddlers was recorded to establish the relation between the changing pattern in gait and footwear of an individual.

## MATERIALS AND METHODS

20 toddlers were contacted through a play school to measure the footwear and their feet lengths. Footwear inner lengths were compared to the lengths of the feet of toddlers at a given time to see if the toddlers were wearing correct sizes of footwear. The gait of the toddlers was recorded by using observation technique and pressure plate scanner. Gait of 10 toddlers in shod and unshod conditions on different surfaces like marble floor, tiled floors, on grass and while climbing stairs was recorded. The toddlers were made to wear similar style of closed shoe with the toe room of 15mm for each toddler (Mahajan, 2014). Experiments of gait analysis were conducted on 4 toddlers using plate scanners (Fig 1.2) to establish scientific data for comparing the gait of an individual in shod and unshod condition.



Fig. 1.2. Toddler on the plate scanner

The sample consisted of kids from northern India living in urban area who belonged to different economic backgrounds.

Photo documentation of feet of toddlers wearing wrong footwear and of grown ups showing tendencies of intoeing was done to further establish the long term effect of wrong or ill fitting footwear on the shape of the feet.

## RESULTS AND DISCUSSION

### Comparison of Foot Size and Inner Length of Footwear

Inner length of the footwear with respect to the feet measurement of toddlers at a given location and time were also recorded to see if the toddlers were wearing the correct size of footwear. The records are compiled in the Table 1.1 below.

Table 1.1. Comparison of the Foot length and the Footwear Inner length Worn by Toddlers

S. No	Foot Length (cm)	Inner Length of Shoe (cm)
1	14.2	14
2	13.3	15.4
3	13.6	17.4
4	15.6	15.2
5	16.3	15.4
6	13.4	17.5
7	14	15.6
8	13.2	17.6
9	15.2	14.6
10	16.3	14.8
11	17.4	15.8
12	18	16.4
13	12.6	14.2
14	15.6	18
15	10.5	14.2
16	13.4	17.6
17	14.6	17.8
18	17.4	21.6
19	16.6	21.5
20	14.7	13.8

It was found that most of the toddlers were either wearing footwear that was too tight or too loose for their foot size. Because of the tight footwear the toddlers were trying to curl up their toes in the closed toe shoe as shown in Figure 1.3 or their toes were running out of the sole in case of open toe shoes as shown in Figure 1.4.



Fig. 1.3. Curling of toes due to Tight Footwear



**Fig. 1.4. Narrow toes running out of ill-fitting footwear**

85% of the toddlers were wearing footwear that was either small or too big for their foot size. In some cases the toes were running out of the sole in case of open toe shoes as shown in Figure 1.4. Smaller size footwear (Figure 1.5) or footwear restricting the foot (Figure 1.6) affected the gait among the toddlers. The skin of toddlers' feet is soft. Wrongly fitted footwear can impact the foot resulting in blisters and peeling off of the tender skin. (Fig 1.7)



**Fig. 1.5. Tight footwear affects the gait of a toddler**

#### **Impact of Footwear on Shape of Foot**

Hallux angles were studied in children in the age group of 8-10 years and teenagers. It was found that many of the grown up individuals had hallux angle deformity. The deformity is attributed to restrictive footwear worn in their early childhood which has over the time, resulted in bunion or permanent deformity of the feet. With the small sample size of 50 individuals, it was found that the bunion was more common among girls who were fond of wearing closed toe ballerina style shoes.



**Fig. 1.6. Restrictive Footwear**



**1.7. Toddler's feet showing signs of blisters, an Impact of wrong footwear**

Figure 1.8 and Figure 1.9 show how the ill-fitting footwear affects the shape of the feet, resulting in problems like bunion. The earlier study on Austrian kids establishes a relation between the length of the footwear and hallux angle. According to the study, the shorter the shoe, the greater is the hallux valgus angle. (Klein *et al.*, 2009)



Fig. 1.8. Photograph showing the beginning of deformity due to wrong footwear in a 9 year old girl



Fig. 1.9. Photograph showing deformity due to wrong footwear in a teenage girl

**Gait Videos**

During the recording of the videos it was seen that the toddlers moved around with much ease when they were unshod. Footwear changed their gait and restricted the free movement among individuals. The toddlers felt difficulty in walking on tiled floor and lost their balance easily as compared to walking on marble floor or on grass. The toddlers walked with maximum ease on grass in shod as well as unshod condition. While climbing stairs, their speed decreased considerably in shod condition. The movement also altered with the type of footwear. Footwear with a counter at the back, rendered better stability to the foot making it easier for the toddler to balance. Children with correct footwear sizes were able to walk with greater stability and could perform actions like running with greater ease than those wearing footwear that was either loose or tight for them.

**Gait analysis through plate scanner**

The impact of the footwear on the gait of the toddler was scientifically measured using Pressure plate scanners. Readings were noted in shod and in unshod condition and gait was compared between the experimental footwear as well as branded commercial footwear. (Fig 2)

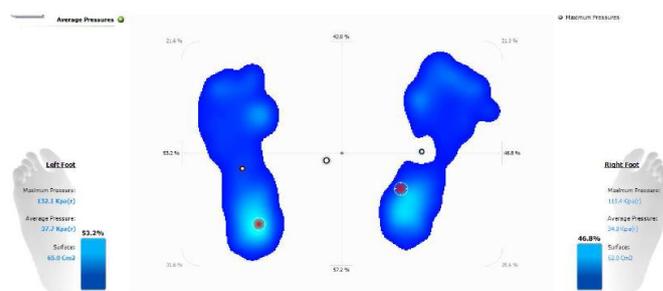


Fig. 2. Dynamic Gait Analysis in Unshod Condition

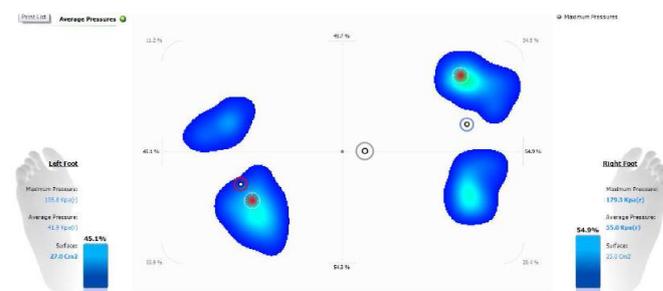


Fig. 2. Dynamic Gait Analysis in shod Condition

Table 1.2. Comparing difference in pressure exerted and Center of Gravity in shod and unshod condition

Condition	Pressure		Center Of Gravity
	Left Foot	Right Foot	
Unshod	53.2%	46.8%	2.31°
Shod	45.1%	54.9%	10.40°

The scanning shows that the pressure points of the feet in shod and unshod conditions have shifted significantly among the toddlers. With the shift of the pressure points the COG has also changed considerably thereby affecting the gait of each individual (Table 1.2). As the foot gets housed in wrongly fitted footwear, the toddler changes the gait pattern in order to adjust to the fit of the alien object covering the foot. This forces an individual to transform the natural gait into a gait which is not the characteristic of his bare feet. Study by Rossi also supports the fact that an average shoe wearing foot has few problems fitting into conventional shoes, in contrast to the difficulties experienced by the habitually unshod foot fitting into the same shoes. The shoe-wearing foot has been anatomically conditioned from infancy to acquire the faulty shape to adapt to the faulty shoe.

**Conclusion**

The study systematically and scientifically investigates the impact of footwear on gait of toddlers. Little research has been done in the area of toddlers' footwear which continues to be a neglected segment in research and development due to the short span of product use and limited market share. The researchers have tried to compare the shod and unshod condition scientifically to emphasize the fact that footwear plays a significant role in gait formation and foot health during the early years and that unshod condition is the best condition for the tender feet during the years when the gait is still

immature. Footwear impacts the gait and the shape of the feet. Hence, for attaining natural gait, the early walkers should be left bare feet on the ground.

### Acknowledgements

I thank National Institute of Fashion Technology for the encouragement and support given to carry out the research. I express my sincere gratitude to the retailers and manufacturers of the toddlers' footwear who have helped me collect relevant facts and data for my research. I specially thank DIERSPedoscan and Hospamedica for sponsoring the pressure plate scan experiments for the study.

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