
RESEARCH

Comparisons of Foot Pressure between Teenager Girls and Young Female Adults

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Background: Increase age is one of the main factors influencing spatiotemporal and pressure parameters. Adolescence and young adulthood are unique periods in the life span that present opportunities and challenges in improving health. Meantime, this age span involve significant growth and development. But the previous studies seldom examine the adolescents gait characteristics and pay attention to the plantar pressure changes between this age span.

Purpose: Given the complex variation of these transitional ages and their implications to the foot care, the primary aim of this study was to investigate plantar pressure differences between teenager girls and young female adults during walking using an EMED pressure plate (Novel, Germany).

Method: Nineteen young female adults (YFA) age at 24.7 (± 2.21) and nineteen teenager girls (TG) age at 18.25 (± 1.23) were participated this study. Data collections including peak pressure, contact area, pressure time integral were performed with an EMED pressure plate. The measurement protocol was barefoot walking across the platform along a 10m long straight trail. Pressures were evaluated for seven plantar areas on the foot according to the anatomical structure.

Result and Conclusion: The result showed that walking speed was similar in both teenager girls and young female adults. The teenager girls shown higher peak pressure in the first metatarsals (FM), fourth and fifth metatarsals (FAFM), middle foot (MF) and rear-foot (RF) areas while the YFA shown larger pressure time integral at big toe (BT) and other toes (OT). Contact area was lower in the YFA for the several foot regions compared to the TG BT, OT, FAFM and MF. Greater pressure time integrals of the FM, FAFM and MF were found in the TG compared to the YFA, while the YFA shown larger pressure time integral at BT, OT and RF. The TG shown greatest peak pressure and pressure time integral in the FM while the YFA shown biggest peak pressure and pressure time integral in the BT. This normative data will provide a basis to assess pediatric pathologic foot deformities more accurately and to distinguish dynamic foot deformities from anatomic foot deformities.

Keywords: foot pressure; Gait analysis; teenager; adult

1. Introduction

With advancing age the foot might experience changes in appearance, joint mobility, perception, muscle and plantar fat pad atrophy (Jahss, Kummer, & Michelson, 1992; Kernozek & Lamott, 1995). Increase age is one of the main factors influencing spatiotemporal and pressure parameters (McKay et al., 2017). Adolescence and young adulthood are unique periods in the life span that present opportunities and challenges in improving health, meantime, this age span involves significant growth and development (Mulye et al., 2009). Many investigations have been undertaken to explore the relationship between gait characteristics and plantar pressure in adults and to a lesser extent in children and they found comparable results between the various group (Shiavi, Hunt, & Waggoner, 1988). Many studies have investigated the foot function, characteristics and plantar pressure in children (Bosch, Gerß, & Rosenbaum, 2010; Bosch, Gerß, & Rosenbaum, 2007; Bosch, Nagel, Weigend, & Rosenbaum, 2009) and in adults (Bosch et al., 2009; Putti, Arnold, Cochrane, &

Abboud, 2008). But there were few studies to examine the adolescents gait characteristics and pay attention to the plantar pressure change between the adolescents and young female adults.

During walking, foot pressure is generated as body weight is transferred onto the stance limb (Burnfield, Few, Mohamed, & Perry, 2004; McKay et al., 2017). Plantar pressure analysis refers to the measurement of the magnitude and distribution of force that is applied to the plantar surface of the foot during walking (Stephen, 1999) and is one of the predominant techniques that are used to investigate the interaction between foot posture and lower limb biomechanics (Buldt, Allan, Landorf, & Menz, 2018; Landorf & Keenan, 2000). Plantar pressure measurement technology can provide the important information for the podiatric physicians to assess the changes in foot function over time or the effects of therapeutic intervention (Alexander, Chao, & Johnson, 1990; Bryant, Tinley, & Singer, 2000). The variations in pressure are associated with alterations to moments acting on joints proximal to the foot, such as the ankle, thus altering stress placed on tissues that influence the joint (Buldt et al., 2018). Previous study shown that gait velocity was stable during the adolescents aged 10–19 and adulthood aged 20–59, they found that the adolescents demonstrated highest peak pressures beneath the rear-foot while adults and older adults demonstrated highest pressures at the forefoot (McKay et al., 2017). Given the complex variation of these transitional ages of YFA and TG and their implications to the foot care, the primary aim of this study was to research the plantar pressure difference among the middle school girl students and college young female adults.

2. Methods

2.1. Subjects

Two groups with similar height and body mass but different regarding age were participated in our study (details shown in the **Table 1**). The young female adults consisted of 19 college students coming from Ningbo University. The teenager girls included 19 middle school girl students coming from Zhenhai middle school (a local middle school in Ningbo). They all have the normal foot free from history of traumatic injury of lower extremity and without any surgeries within 6 months before this study. Participants with diabetes, hallux valgus, pes cavus, flat foot or polyneuropathy diagnosed by a physician were excluded from this study. These participants were not menstruating within the test period. All participants signed a consent form in agreement with participating in this research and this research was approved by the Ethics Committee of the Ningbo University.

2.2. Procedure

Experiments were conducted in the laboratory of research academy of great health at the Ningbo University. The EMED pressure plate (Novel, Germany) was used to record the plantar pressure data of the TG and YFA during walking at a frequency of 100 Hz. They were walking at their comfortable speed. Peak pressure, contact area and pressure time integral were included in this study. Participants were instructed to step on the plate with their dominant foot for 7 times during walking. Participants were provided with 30-second rests between trials, respectively, to minimize the effect of fatigue.

2.3. Data analysis

All statistical analyses were performed with the SPSS 19.0 (SPSS Inc. v. 19.0, USA). An independent sample test was used for the plantar pressure comparison among the TG and YFA. For the pressure measurement trial, seven anatomical sites under the feet were identified: big toe (BT), other toes (OT), first metatarsal (FM), second and third metatarsals (SATM), fourth and fifth metatarsals (FAFM), mid-foot (MF) and rear-foot (RF). The toe area was subdivided into two regions consisting of the BT and OT. The metatarsal areas were divided into three parts including FM, SATM, and FAFM. The rest of the foot was subdivided into MF and RF. Significance level was set at 0.05.

Table 1: Characteristics of participants.

	N (Mean ± SD)	Age (Mean ± SD)	Weight(Mean ± SD)	Height(Mean ± SD)
TG	19	18.25 ± 1.23 years	57.45 ± 2.56 kg	1.65 ± 0.46 cm
YFA	19	24.7 ± 2.21 years	58.69 ± 2.26 kg	1.67 ± 0.62 cm

3. Results

When comparing the two groups, in this study, the walking speed was found to be similar in both TG and YFA. We found high peak pressure under FM ($P = 0.00$), FAFM ($P = 0.00$), MF ($P = 0.00$) and RF ($P = 0.01$) in TG than YFA, while the YFA shown larger pressure time integral at BT ($P = 0.00$) and OT ($P = 0.00$) (**Figure 1a**). Contact area was lower in the YFA for the several foot regions at BT ($P = 0.00$), OT ($P = 0.01$), FAFM ($P = 0.14$) and MF ($P = 0.079$) compared to the TG (**Figure 1b**). Greater pressure time integrals of the FM ($P = 0.00$), FAFM ($P = 0.01$) and MF ($P = 0.00$) were found in the TG compared to the YFA, while the YFA shown larger pressure time integral at BT ($P = 0.00$), OT ($P = 0.00$) and RF ($P = 0.01$) (**Figure 1c**).

4. Discussion

In this study we mainly analyzed the peak pressure, contact area and pressure time integral difference between the YFA and TG during walking using an EMED pressure plate (Novel, Germany). The main finding of this study was that the TG shown greatest peak pressure and pressure time integral in the FM while the YFA shown biggest peak pressure and pressure time integral in the BT. When comparing the two groups, the walking speed was found to be similar in both TG and YFA which was consistent with the result that the gait velocity was stable from adolescence through to adulthood and there was no difference in the self-selected gait velocity of children and older adults (McKay et al., 2017).

Peak plantar pressure refers to the maximum pressure value recorded in a predetermined region of the foot during the gait cycle (Melai et al., 2011). For the YFA the highest peak pressure under the plantar foot has been found at BT area which was in line with to previous the previous study (Kernozek & Lamott, 1995; McKay et al., 2017) that the maximum pressures and maximum pressure changes occurred in the forefoot (Soames, 1985). But the result of this study also found some difference with the previous study. As this study shown high peak pressure under FM, FAFM, MF and RF in TG while the YFA shown larger pressure time integral at BT and OT but previous study indicated that adolescents demonstrated highest peak pressures beneath the rear-foot while adults demonstrated highest pressures at the forefoot (McKay et al., 2017). This might because the difference of the walking speed, condition and the description of the foot areas. As to the TG the greatest peak pressure of the foot was the FM area. In this study the participants were walking under barefoot condition which was different to their real walking condition with shoes. Increased plantar pressures under the heel and forefoot regions have also been documented during barefoot compared to shod walking (Perry et al., 1995; Sarnow et al., 1994; Soames, 1985). As the significant difference plantar pressure distribution among TG and YFA under barefoot walking, there might be some difference in shod walking among them which deserved the shoe manufactures and shoe developers to focus on. And further research is required to determine the effect that shoe design has on plantar pressures among them in plantar foot.

Pressure-time integral, also referred to as impulse, is a measure of the cumulative exposure to pressure over time in a predetermined region of the foot (Melai et al., 2011). Pressure-time integrals are thought to be important in the pathogenesis of skin lesions and have been proposed to be a potentially valuable measurement parameter in clinical practice (Putti et al., 2008; Soames, 1985). The contact area of the foot change might induce the redistribution of the pressure in all the areas of the foot (Claire Jeanne Louise, Roeland, Hilde, & Ruoli, 1995). The higher contact areas of TG in the FAFM and MF area which might result the greater pressure time integrals of the FM, FAFM and MF. But the increased contact area under BT and OT of the TG shown lesser time pressure integrals and peak pressures this might due to the TG shown lesser

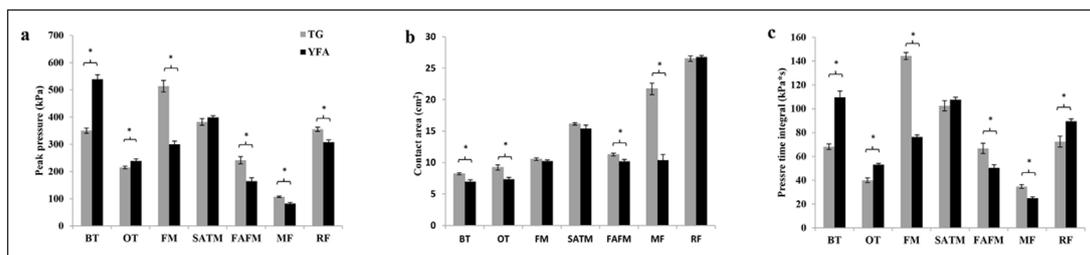


Figure 1: The plantar pressure comparison among the TG and YFA (* indicates $P < 0.05$). **a** represents the peak pressure in seven anatomical areas. **b** shows the contact area in seven anatomical areas. **c** illustrates pressure time integral in seven anatomical areas.

ankle plantar flexion angle at the stance phase while the YFA existed high toe grip function during the push-off phase. Future study need to explore the influence in details to clarify the difference.

5. Conclusion

The main finding of this study was that the TG shown greatest peak pressure and pressure time integral in the FM while the YFA shown biggest peak pressure and pressure time integral in the BT, and the walking speed was found to be similar in both TG and YFA. This normative data will provide a basis to assess pathologic foot deformities more accurately and to distinguish dynamic foot deformities from anatomic foot deformities.

Competing Interests

The author has no competing interests to declare.

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