FOOTFALL PATTERN DURING RUNNING IN PRESCHOOL CHILDREN ACCORDING TO AGE AND FOOTWEAR

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The aim of this study was to compare the footfall pattern (FP) in different age groups of preschool children while they ran in standard running shoes (SRS) and barefoot. Forty-eight children aged 3-6 years participated in the study and were split into 4 age groups (n=12). All children performed a simple running game (based on the shuffle run) in SRS and barefoot. The length of the runway was adjusted for each age group. Kinematic and kinetic data were collected using 3-D motion capture system. We analyzed strike index (SI) and sagittal plane ankle angle (AA) at initial contact (IC) from 6 successful running trials for each child in each condition. We found differences between conditions in both SI (p=0.000, η^2=0.448) and AA (p=0.000, η^2=0.259) respectively, but we did not find any differences among age groups. Moreover, we found an interaction between age and conditions in AA (p=0.019, η^2= 0.201). In preschool children, FP changed differently in certain age groups according to the footwear condition.

KEY WORDS: foot, ankle, fundamental skills, running, shoes, barefoot, development.

INTRODUCTION: Running skill develops very dramatically during preschool age (Fortney, 1983; Payne & Isaacs, 2007). One of the most important characteristics of running technique is footfall pattern (FP), which can determine tissue loading of the lower limb (Almonroeder et al, 2013; Gruber et al., 2014) and in turn, could affect the development of the musculoskeletal system. For example, gait pattern has shown to be associated with morphological changes in toddlers (Dam et al., 2010). Previous studies have reported strong evidence that FP is affected by using different types of footwear or a different type of surface (Gruber et al., 2013; Lieberman et al., 2010). A recent prospective study indicated fewer overall musculoskeletal injuries in adult barefoot runners, but similar incidence rates of running related injuries in comparison with habitually shod runners (Altman & Davis, 2016). Nevertheless, most adults in high economically developed countries have been wearing shoes for their whole life. Nowadays, we still know very little about how young children adapt to wearing running shoes during running. Very little attention was paid to investigate this phenomenon in school aged children (Hollander et al., 2014; Hollander et al., 2018) and in preschool children (PSCH) respectively (Latorre-Román et al., 2018; Latorre-Román et al., 2019). The studies dedicated to running biomechanics in PSCH (Latorre-Román et al., 2018; Latorre-Román et al., 2019) showed that, when compared with older groups, there were fewer rear foot strikers in the younger group (3-4 years old). However, there are several limitations in the methods of these studies due to the uncontrolled running speed, footwear and running distance. In addition, their qualitative assessment of FP may be limited and the authors may not have detected the real differences among age groups. Therefore, the purpose of this study is to compare FP among age groups of preschool children in different footwear conditions. We hypothesize that younger children will show less differences in FP (depending on footwear) than older groups.

METHODS:

Participants and Protocol: In this cross sectional study, 48 healthy children from 3 and 6 years old were divided into 4 groups by age (see Table 1 below). Besides biomechanical measurement, each child completed the Movement Assessment Battery for Children-Second Edition (MABC-2) to reveal possible developmental coordination disorders. Parents of the children also completed the Barefoot Questionnaire (BFQ) (Hollander et al., 2016), modified for preschoolers in this study. All children performed a simple running game based on shuffle run in two different conditions (barefoot and SRS). During shod running condition children wore cushioned running shoes with drop from heel to toe (Adidas, Germany). The length of the runway was adjusted for the age for each group (10, 11, 12 and 13 meters). Before each running condition children were instructed about the continuous movement task based on running between two ends of the runway (to run inside the band created by blue cones). They also had to relocate four tennis balls from red cones to the green cones at the same end of the runway (during one running trial was allowed to relocate only one ball). Children ran through the runway 20 times at a self-selected speed in each condition. For familiarization and warm up were performed four running trials and then 16 recorded trials (2 stages x 8 trials).

Table 1: Participant Characteristics

	3.0 – 3.9 years		4.0 – 4.9 years		5.0 – 5.9 years		6.0 – 6.9 years		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age (y)	3.58	0.27	4.56	0.34	5.58	0.32	6.52	0.37	0.000*
Height (cm)	100.23	3.78	107.66	3.09	115.53	4.62	122.85	5.95	0.000*
Weight (kg)	15.48	1.56	17.34	1.29	21.12	3.79	24.06	4.13	0.000*
BFQ	13.42	1.83	14.25	2.45	14.67	1.87	14.58	1.24	0.366
MABC-2	67.75	28.42	66.91	26.21	71.50	19.57	62.00	22.08	0.769
Sex (male/female)	5/7		7/5		5/7		9/3		
N	12		12		12		12		

Note: SD – standard deviation, MABC-2 – Movement Assessment Battery for Children-2nd ed., BFQ – Barefoot Questionnaire.

Data collection and analysis: Retro-reflective markers were placed on the right lower limb of the participant according to the recommendation of Visual 3D (C-motion, USA). A synchronized system of 10 optoelectronic cameras (Qualisys, Sweden) and three force plates (Kistler, Switzerland) were used for collection of kinematics (250 Hz) and kinetics (1200 Hz) data. Both kinematics and kinetics data were processed by using Qualisys Track Manager and Visual 3D software. The threshold for resultant of ground reaction forces was set at 15 N. Six successful trials were analyzed based on pelvis velocity (the closest 6 trials to median). A low–pass Butterworth filter was used for ground reaction forces with a cut-off frequency of 50 Hz and 10 Hz for the kinematic data. The key independent variables for this study included strike index (SI) and sagittal plane ankle angle (AA) at IC (Gruber et al., 2013) with pelvis velocity and Froude number (Alexander, 1989) used as control variables. All statistical analyses were conducted in SPSS 24 (IBM, USA). Strike index (SI) was determined as the center of pressure location during the first initial foot contact with the force plate and reported as a percentage of foot length from the posterior calcaneus (Cavanagh & Lafortune, 1980). Ankle angle was determined as relative position of foot and shank during the first initial foot contact with force plate. One-way ANOVA were used to compare characteristics of participants (age, height, weight, MABC-2 total score, BFQ). Two factorial repeated measures ANOVA (2x4) were performed for analysis of all biomechanics dependent variables.

RESULTS: SI and AA at IC as main dependent variables are presented in Figure1 and Table 2.

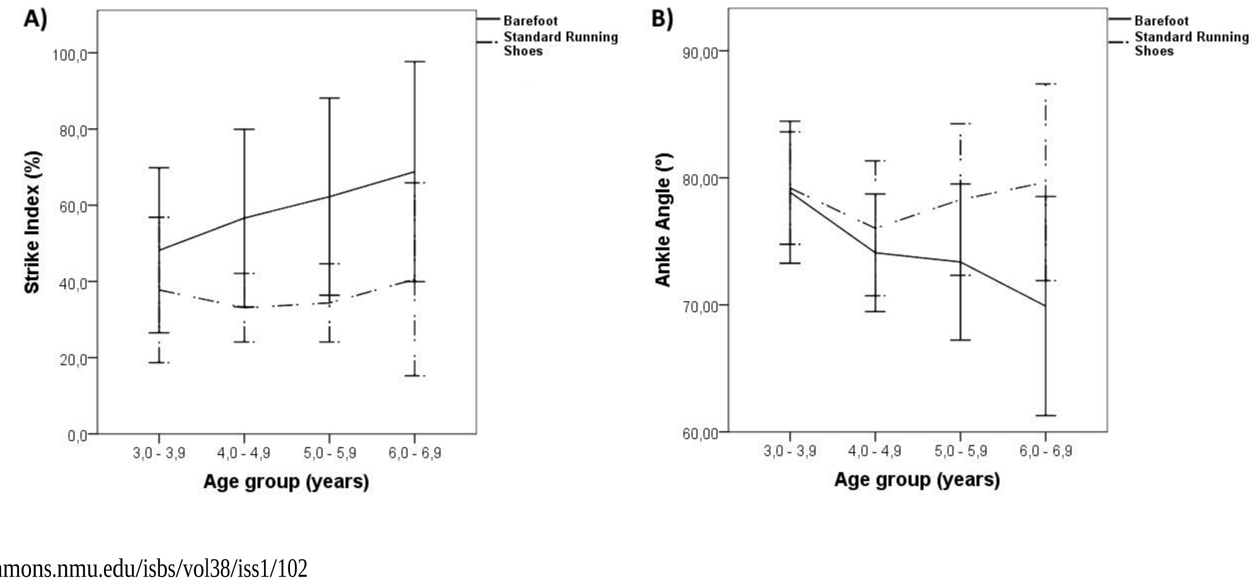

Figure 1: Means and standard deviation of Strike Index (A) and Sagittal Ankle Angle at IC (B) for 3 – 6 years old children during running in SRS (dash) and barefoot (solid).

Table 2: Two way repeated measures ANOVA (2x4).

	Footwear Condition (B x SRS)		Age Group		Condition x Group	
	p	η^2	p	η^2	p	η^2
Strike Index (%)	**0.000***	0.448	0.364	0.069	0.312	0.077
Ankle Angle IC (°)	**0.000***	0.259	0.149	0.113	**0.019***	0.201
Pelvis Velocity (m/s)	0.927	0.000	**0.001***	0.314	0.116	0.124
Froude Number	0.858	0.001	0.414	0.062	0.101	0.131

Note: Bolded values with * represent significant statistical differences between conditions across groups, significant difference among groups across conditions and as well as interactions ($p<0.05$). η2 represents partial eta-squared - as trivial effect were considered values <0.01, as small 0.01-0.06, as medium 0.07-0.14 and large >0.14 (Cohen, 1990).

DISCUSSION: We hypothesized that younger children would show fewer differences than older children in their FP with different footwear. The main finding of our study is that younger children do not change their ankle angle as much as older children depending on footwear condition (Table 2, Figure 1). It seems that children react differently in FP during running to changing conditions at certain ages. According to classification of SI (Cavanagh & Lafortune, 1980), PSCH are rear-foot and mid-foot strikers when running in shoes. However, they became mid-foot and forefoot strikers when running barefoot (Figure 1, Table 2). These findings are in compliance with studies published in population of adult runners (Bonacci et al., 2013; Fuller et al., 2016), as well as in school aged (Hollander et al., 2014, 2018), adolescents (Hollander et al., 2018) and PSCH (Latorre-Román et al., 2018). The research to date has tended to focus on running footwear of a single age group preschoolers (Latorre-Román et al., 2018) rather than study concurrently effect of footwear condition and aging in PSCH during over-ground running. While the preschool age is the crucial period for the development of running skill. When preschoolers ran in SRS, their FP did not substantially change according to age (Figure 1, Table 2). However, in the study of Latorre-Román et al. (2019) showed fewer rear foot strikers in 3-4 age group than in 5-6 age and older groups of children. On the other hand, when our preschoolers ran barefoot their AA became more plantar flexed with increasing age. It could be explained that three years old children transferred their rear-foot strike skill from walking to one of the first running attempts. In addition, the coordination level during maturation of central nervous system is not able to adapt to the changed footwear condition (Malina et al., 2004). Alternatively, three years old children are unable to adapt to the changed footwear condition because they are less used to wearing shoes than older groups and tend to display a similar FP in both conditions (Figure 1, Table 2). There is little prior literature that has focused on running biomechanics in PSCH (Fortney, 1983). Nevertheless, Fortney (1983) analyzed sprinting which is considered a different type of locomotion.

The strength of the current study is that we used an appropriately designed movement task with a running velocity for PSCH adjusted for age and controlled by using the Froude number. Moreover, we controlled for motor competences in each age group via MABC-2 tests. Both a strength and a limitation could be observed using of uniform footwear (controlled footwear). In terms of a limitation, every child may not have had previous experience with SRS. The main limitation of this study could be found in cross sectional design, for better understanding to changes of FP future research should adopt a longitudinal study design.

CONCLUSION: Footfall pattern is affected by footwear condition in preschool children. When the children get older their FP becomes more non rear-foot during barefoot running. On the contrary, the FP did not change according to age when they wore SRS. For example, three years old children do not change their FP to the same extent as six years old children depending on the footwear condition.

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