ISB 2013 BRAZIL

XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

XV BRAZILIAN CONGRESS OF BIOMECHANICS

EFFECT OF SPORTS SHOES ON CHILDREN'S MULTI-SEGMENT FOOT KINEMATICS DURING PROPULSION OF WALKING AND RUNNING

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SUMMARY
Midfoot motion plays an important role in propulsion. This study investigated the effect of conventional children's sports shoes on multi-segment foot motion during propulsion of walking and running in 20 children. The sports shoes reduced motion at the 1st metatarsophalangeal joint and midfoot during propulsion, which was partially compensated by increased motion at the ankle joint during propulsion.

INTRODUCTION
During propulsion of children's walking, midfoot plantarflexion generates 39-48% of the total power from the foot and ankle [1-3]. Previous research on children's walking has identified that shoes reduce midfoot and 1st metatarsophalangeal joint (MTPJ) motion during propulsion of walking [4, 5]. However, research on the effect of children's midfoot kinematics during shod gait has been limited to walking in Oxford style shoes [4, 5]. Further research on other shoe styles is now required to establish if the splinting effect of shoes extends to shoe styles that might be considered more suited to walking and running. The aim of this study was to investigate the effect of conventional sports shoes on children's midfoot kinematics during propulsion of walking and running.

METHODS
Twenty healthy children aged between 8 and 12 years were recruited for the study. Participants were excluded if they had foot or leg pain in the previous six months or a Foot Posture Index outside two standard deviations of the healthy population mean for children [6]. All participants and their guardian gave informed written assent/consent in accordance with the University Human Research Ethics Committee requirements (Protocol No: 11139).

Children were fitted with an appropriately-sized conventional children's sports shoe [ASICS Gel Kanbarra 5 (Asics Oceania Pty Ltd, Sydney, Australia)]. The shoe has a single density ethylene vinyl acetate (EVA) midsole (shore 55 ± 3) with an encapsulated GEL cushioning unit (silicon/polyurethane composite) in the heel. The sole height was 33mm at the heel and 23mm at the MTPJ region for a size 5 shoe. A US size 5 shoe weighed 246 grams.

A 14-camera motion analysis system (Cortex 1.1, Motion Analysis Corporation, USA) with a sampling rate of 200Hz was used to calculate three-dimensional marker trajectories. Ground reaction force data were recorded at 1,000Hz from a single force plate, Kistler™ (Model 9281B, Winterthur, Switzerland). Segment coordinate systems were embedded in the forefoot, rearfoot and shank using a standing reference position.

Motion at the 1st MTPJ, midfoot and ankle joints was calculated using a model based on that used by Rattanaprasert and colleagues [7]. The midfoot joint axis was redefined, on the basis of fluoroscopy research validating skin markers overlying the navicular and 1st metatarsal head to model sagittal plane forefoot motion [8]. The leg, rearfoot and forefoot segments were defined by three non-collinear 13mm diameter retro-reflective markers. The first ray and hallux segments were each defined by two markers. Motion of the rearfoot segment was defined by a detachable wand triad marker, which is a valid and reliable method of obtaining in-shoe motion of children [9]. In the shod condition the wand extended through a hole in the shoe. The navicular, hallux and 1st and 5th metatarsal heads markers were attached by self-centring magnets through holes in the shoe.

The stance phase was defined from the vertical ground reaction force data. The propulsive phase was defined from the anterior posterior force data as the period when a positive propulsive force was being produced (time of zero crossing force – toe-off).

Coordinate trajectories of the markers were filtered at 5Hz (walking) [10] and 20Hz (running) [11] with a low-pass zero phase shift 4th order Butterworth filter. The processed data were time-normalised by linear interpolation to the stance phase and ensemble-averaged across trials and participants. Range of motion was calculated for the propulsive phase.

To ensure a natural gait pattern and prevent targeting of the force plate, the children walked and ran at a self-selected velocity while focusing on a soft toy at the end of the laboratory. Five successful trials, in which the participant landed completely on the force plate, were recorded for each participant and condition. Participants were allowed a five minute acclimatisation period for each condition. Activities were undertaken in a predetermined order of walking followed by running to allow for a gradual warm up. Footwear testing order was randomised for each participant.

Statistical analyses were undertaken in SPSS 19.0 (IBM SPSS Statistics for Windows, Armonk, NY, USA). Nested repeated measures ANOVAs were undertaken to assess significance between conditions.

RESULTS AND DISCUSSION

Physical characteristics of the study participants are presented in Table 1. Gait velocity and the range of motion during propulsion for the ankle, midfoot and 1st MTPJ joints and for walking and running are presented in Table 2.

Table 1: Physical characteristics of participants (n=20)

Variable	Mean/Count	Range
Gender, male (%)	9 (45)	N/A
Age, years (SD)	10 (1.4)	8 –12
Height, m (SD)	1.43 (0.11)	1.21 –1.65
Body mass, kg (SD)	38.1 (12.1)	23.5 – 67.5
Body mass index, kg/m^2 (SD)	18.2 (3.3)	14.1 – 27.4
Foot Posture Index, score (SD)	4 (2)	0 – 8
Shoe size (US), mean (SD)	5 (2)	1–11

Children's sports shoes have a splinting effect on midfoot and 1st MTPJ motion consistent with results for other shoe styles reported in the literature [4, 5]. The similarities in the literature persist despite the differences in biomechanical foot models and shoe design. However, the splinting effect by the shoe in this study is greater at the midfoot and 1st MTPJ than previous studies [4, 5]. Smaller effects in previous studies may be due to the placement of some markers on the shoe [4, 5], rather than directly on the skin through holes in the shoe as was the case with this study.

Restriction of motion at one joint may require compensation at another joint. Wolf and colleagues [4] hypothesised that increased ankle plantarflexion during shod walking was compensatory for decreased midfoot plantarflexion. The current findings support the hypothesis that increased ankle plantarflexion compensates for a reduction in midfoot plantarflexion in children. Prospective studies are required to understand the effect of such an effect/ compensation on the foot development of children.

CONCLUSIONS

Children's sports shoes have a splinting effect on midfoot and 1st MTPJ motion during propulsion of walking and running. Children partially compensate for a reduction in midfoot plantarflexion during propulsion of shod walking and running by increasing ankle plantarflexion.

ACKNOWLEDGEMENTS

We are grateful for the financial support of an Australian Research Council Linkage grant (LP0883915) with ASICS Oceania (ASICS Oceania, Pty Ltd, Sydney Australia) for the purposes of this study. ASICS had no involvement in study design, data collection or results interpretation.

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Table 2: Walking and running gait velocity and range of motion (°) during propulsion for the 1st metatarsal phalangeal (MTPJ), midfoot and ankle joint complex. Values expressed as mean (SD) (n = 20).

Joint	Plane	Walking		Running	
		Barefoot	Sports shoe	Barefoot	Sports shoe
1st MTPJ	Resultant	36.0 (7.5)	10.7 (3.7)*	31.5 (7.5)	12.6 (4.1)*
Midfoot	Sagittal	22.5 (6.4)	6.2 (3.0)*	27.4 (7.3)	9.6 (4.1)*
	Frontal	6.3 (2.8)	2.6 (1.1)*	5.2 (3.7)	2.2 (1.4)*
	Transverse	8.1 (3.3)	3.5 (1.8)*	7.4 (3.7)	3.3 (1.9)*
Ankle	Sagittal	17.5 (4.9)	19.6 (4.9)*	26.7 (7.4)	34.1 (6.5)*
	Frontal	9.5 (2.9)	9.1 (3.4)	11.9 (3.6)	11.1 (4.1)
	Transverse	7.3 (3.4)	6.1 (3.0)	8.3 (3.9)	8.4 (3.3)
Gait velocity (m/s)		1.33 (0.13)	1.41 (0.14)*	2.30 (0.27)	2.40 (0.29)*

*Statistically significant compared to barefoot $P<0.05$