B5-3 ID192

EFFECT OF FOOTWEAR ON LOWER LIMB KINEMATICS IN CHILDREN DURING SIDESTEP

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Wearing shoes has been shown to affect children's gait and neuromuscular development. This study aims to evaluate the effect of supportive shoes and flexible shoes on children's lower limb kinematics during sidestep. Fourteen children aged 6 to 13 years, with no foot deformity were recruited. A motion analysis system and a force plate were used for motion capture. Compared to jogging, sidestep has increased sagittal plane motion and a different frontal plane movement pattern. The supportive shoes allowed smaller midfoot sagittal range of motion (ROM) and higher peak knee flexion whereas flexible shoes showed increased motion in the first metatarsophalangeal joint (MPJ), midfoot and hip with increased ankle eversion velocity and knee less internally rotated. Conventional supportive school shoes allowed less motion in healthy children's feet, thus affecting negatively on long term lower limb functional development.

KEY WORDS: Footwear; Kinematics; Lower Limb; Children; Side-step.

INTRODUCTION: Physical activity in children is highly recommended with its lifelong benefit, however, Spinks et al., (2006) found that almost 90% of children's injury was directly related to physical activity. A study in Dutch children found that injuries that occur during leisure time physical activities lead to the highest medical costs compared to other organised physical activities. Since lower extremities seemed to be the most commonly injured body parts in youth sports and leisure time physical activities, preventive measures should be focussed on lower limb injuries.

Extrinsically, footwear impairs foot position awareness (Robbins et al., 1995), thus during school hours, children's school shoes would be affecting their lower limb proprioception and functioning. Neuromuscular factors and lower limb strength are developing in children and considered modifiable. Since different footwear were shown to have effects in sport, gait or running kinematics, proprioception, neuromuscular control and muscle activities and injury rate, there is increasing concern about the biomechanical effect of shoes on the long-term growth and development of children with normal feet. School-aged children spend more time in their school shoes than any other footwear, so it is imperative that footwear should be fitted correctly and should allow maximum mobility and foot function to occur besides providing physical protection (Staheli, 1991). Stiff shoes might also limit children's activities and discourage the children to be socially and physically active.

Children play patterns can be highly variable. Besides running and walking, side-stepping is one of the characteristic motions that school children will encounter during physical activities. The internal rotation loads on the knee experienced during sidestepping were up to five times the load experienced during running (Besier et al., 2001). Sidestep cutting manoeuvre is very often used in popular school sports such as soccer and basketball. Its specific movement patterns is considered to be one of the risk factors responsible for one of the most frequent and debilitating/catastrophic injuries, non-contact ACL injuries, with high chance of recurrence and high medical expense worldwide. Therefore, investigation in sidestepping is highly warranted.

In this study, we will look at the difference between running and sidestep and the effect of different footwear on the lower limb kinematics of healthy children's feet during sidestepping. We will use barefoot as a reference for comparison as barefoot walking was considered to be desirable for normal functioning and healthy growth of children's feet. We hypothesized that unsupportive shoes should have a larger range of motion than supportive shoes, especially in the forefoot and midfoot region. We expect that in sidestepping, the angular velocity in the loading phase would be larger in order to dissipate a larger load. The knee and hip joint kinematics may also be affected as a compensation of limitation of motion in the foot.

METHODS: *Subjects:* Fourteen healthy children aged 6 - 13 years were recruited in Sydney, Australia, by advertisements in local print media. Study participants were excluded if they had neurological or orthopaedic conditions, foot or leg pain in the previous six months or a Foot Posture Index outside two standard deviations of the age-relative mean[34]. All participants and their parent/caregivers gave informed written assent/consent in accordance with the requirements of the University of Sydney Human Research Ethics Committee.

Motion Analysis

45 retro-reflective markers of 15 mm diameter were attached on each participant. In the beginning of each test session, a static calibration trial with the barefoot marker placement was captured in which the participant stood with their feet parallel and shoulder-width apart. The leg, rearfoot and forefoot segments were defined by three non-collinear retro-reflective markers. The hallux was defined by two markers, hence resultant motion of the hallux was reported with one angular degree of freedom, primarily plantarflexion/dorsiflexion. Motion at a joint was defined as motion of the distal segment relative to the proximal segment in the sagittal, frontal and transverse planes. Each segment was modelled as a rigid structure. The utilisation of surface markers overlying the navicular and first metatarsal head to model forefoot motion has been validated with fluoroscopy (Wrbaskic and Dowling, 2007). For both the barefoot and shod conditions, motion of the rearfoot segment was defined by a detachable wand with a marker triad which is a valid and reliable method of obtaining in-shoe motion (Wegener et al., 2011). For the shod condition, motion of the forefoot and hallux segments was determined from markers placed on the shoe at locations corresponding to those for the barefoot condition.

To ensure a natural gait pattern, the children were then asked to run at a self-selected speed while focusing on a distant object. For sidestepping trials, the subject continued the movement by changing direction to 45^o to the left after landing his/her right foot on the force plate, with his/her left foot towards a target which was hanging a few steps in front of them oriented 45^o from the line of progression. Five successful trials were recorded for each participant for barefoot and two shod conditions. Three-dimensional kinematic data were collected on the right foot, shank and thigh, using a motion capture system sampling at 200Hz. Raw data of the coordinate trajectories of the markers were filtered at 20 Hz with a zero lag fourth order low-pass Butterworth filter. The processed data were then time-normalised by linear interpolation to stance phase and ensemble-averaged across trials and participants. The 95% confidence intervals were calculated from the standard deviations. Frontal plane velocity at different joints are calculated from 0 to 20% stance as this is the time when foot and knee exert the largest stress during the deceleration phase with the knee in less than 40^o of flexion.

Statistical Analysis

Analyses were undertaken in SPSS 19.0 (SPSS Inc, Chicago, Illinois) to a predetermined plan. A nested repeated measures ANOVA was undertaken on all parametric data. Significance levels were set at $p \leq 0.05$.

RESULTS: Generally, compared to barefoot jogging, barefoot sidestep had increased sagittal plane motion (Figure 1a), reduced transverse plane motion and a different frontal plane movement pattern (Figure 1b). ROM was increased in the sagittal plane in all the lower limb joints including the first MPJ, midfoot, ankle, knee and hip. Peak values in the sagittal plane were also greater in all joints during sidestep except at the ankle joint.

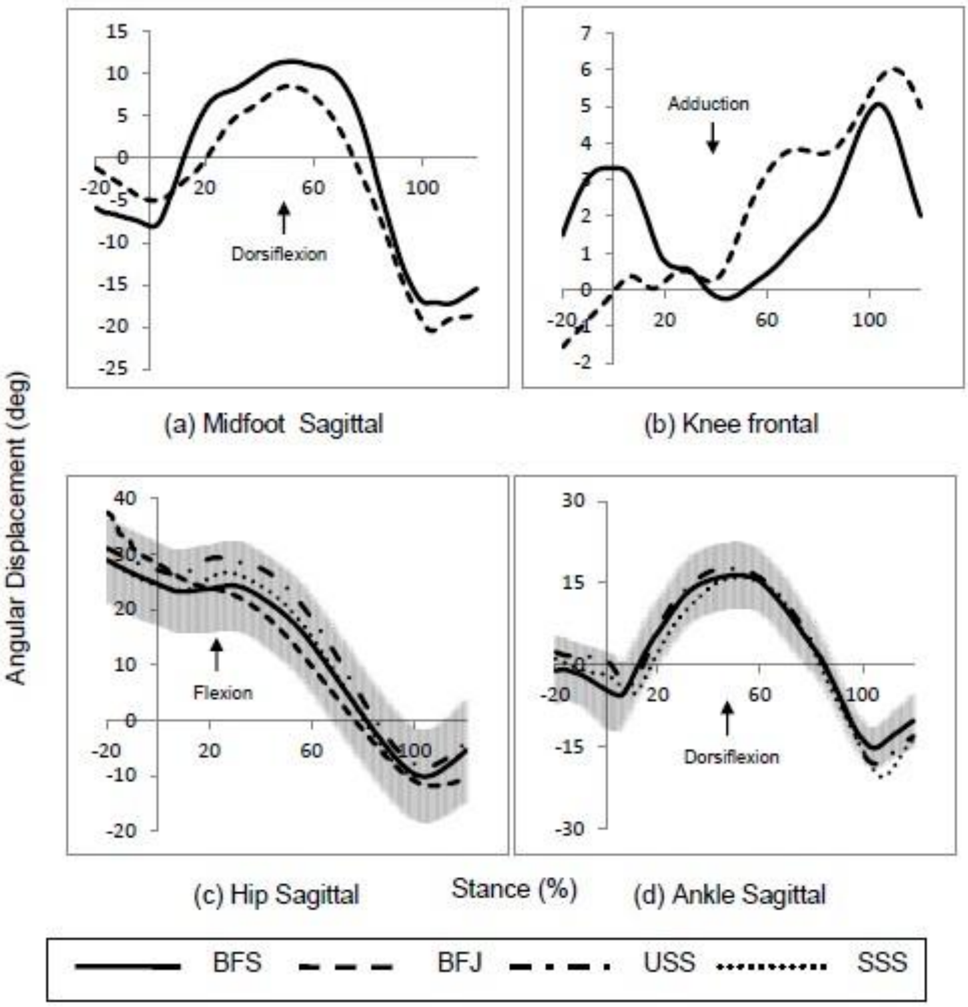

Figure 1. Difference between barefoot jogging (BFJ) and sidestep (BFS) and effect of footwear on ensemble lower limb kinematic patterns during stance. Arrows indicate the convention for the joint angles. USS represents unsupportive shoes and SSS represents supportive shoes. Shading area represents error bars of BFS.

Comparing the two shoes, in supportive shoes, the midfoot had a smaller sagittal ROM, higher peak knee flexion, a less inverted midfoot and a less external rotated hip throughout the stance. Whereas in flexible shoes, the first metatarsophalangeal joint (MPJ) was more plantarflexed, the midfoot was more inverted and the hip more flexed throughout the stance (Figure 1c). The ankle eversion velocity and hip abduction during propulsion were also increased. However, the midfoot transverse ROM decreased and the knee was in a less internally rotated position throughout stance.
There was also a larger difference in foot position at heel strike and toe-off than midstance in first MPJ, midfoot and ankle joints (Figure 1d).

DISCUSSION: Wearing shoes provides protection against trauma and acts as a status symbol in modern society (Staheli 1991). For healthy development of children's feet, there is a need to understand the biomechanical effect of different footwear in order to produce optimal biomechanical footwear. Also, kinematic data on different joints was compared to alternative movement strategies such as sidestepping with a view to gaining specific insight into the biomechanics of this particular sidestep movement and thereby enhance our understanding of its effect on children.

Sidestep is different kinematically from straight jogging, with a larger ROM or peak angular displacement in sagittal plane of all joints. Generally, sidestep has less motion on transverse plane but very different in frontal plane motion compared to jogging straight.
Compared to adult side-stepping, the children had less knee flexion, abduction and rotation in a relatively erect posture. However, this might be due to children running at slower speed (Beiser 2001).Therefore, in future investigations the speed could be controlled. Lateral step width will increase the peak knee angles and moments. During real play there might be more significant difference in variables as the speed could be higher and the movement more unanticipated and more severe than the experimental situation described here.

CONCLUSIONS: We have compared how sidestep is biomechanically different to jogging. We also compared how during both activities supportive shoes are different from unsupportive shoes and barefoot.
Specifically, children wearing supportive shoes exhibited smaller ROM in first MPJ, smaller ROM in midfoot dorsiflexion, smaller mean midfoot inversion, larger mean midfoot abduction, smaller mean ankle dorsiflexion, larger mean ankle eversion, larger peak knee flexion, larger mean knee internal rotation, smaller mean hip extension, smaller mean hip abduction and smaller mean hip external rotation than children wearing unsupportive shoes.
Generally for sidestepping, shoes decrease the range of motion in the First MPJ and midfoot and ankle but increase or make no change to knee or hip angles. Sagittal movement show bigger differences than frontal and transverse planes.
For parents, coaches, physicians, footwear designers and manufacturers, it will be useful to understand how different types of footwear affect the lower limb kinematics of young children during play. This information could be beneficial for parents or professionals when selecting shoes for physical activities.
Future research should focus on a longitudinal study of changes in lower limb dynamics and injuries in children with normal feet while wearing different types of footwear to identify the most appropriate and effective footwear for facilitating neuromuscular training and preventing injuries.

REFERENCES:

Besier, TF; Lloyd, DG; Cochrane, JL; Ackland, TR: External loading of the knee joint during running and cutting maneuvers. Med Sci Sport Exer. 33: 1168-1175, 2001.

Robbins, S; Waked, E; McClaran, J: Proprioception and stability - foot position awareness as a function of age and footwear. Age Ageing. 24: 67-72, 1995.

Spinks, AB; Macpherson, AK; Bain, C; McClure, RJ: Injury risk from popular childhood physical activities: results from an Australian primary school cohort. Injury Prev. 12: 390-394, 2006. 38. Staheli, LT: Shoes for children - a review. Pediatrics. 88: 371-375, 1991.

Wegener, C; Hunt, AE; Vanwanseele, B; Burns, J; Smith, RM: Effect of children's shoes on gait: a systematic review and meta-analysis. J Foot Ankle Res. 4, 2011.

Wrbaskic, N; Dowling, JJ: An investigation into the deformable characteristics of the human foot using fluoroscopic imaging. Clin Biomech. 22: 230-238, 2007.

Acknowledgements:

The authors wish to acknowledge the financial support of the Australian Research Council (LP0455177) and Clark's Shoes and the support of Ray Patton, Biomechanics Laboratory Manager.