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An investigation of the factors affecting flatfoot in children with delayed motor development

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ABSTRACT

This study investigated the prevalence of flatfoot in children with delayed motor development and the relevant factors affecting it. In total, 121 preschool-aged children aged 3–6 with delayed motor development (male: 81; female: 40) were enrolled in the motor-developmentally delayed children group, and 4 times that number, a total of 484 children (male: 324; female: 160), of gender- and age-matched normal developmental children were used as a control group for further analyses. The age was from 3.0 to 6.9 years old for the participants. The judgment criterion of flatfoot was the Chippaux-Smirak index >62.70%, in footprint measurement. The results showed that the prevalence of flatfoot in children with motor developmental delay was higher than that in normal developmental children, approximately 58.7%, and that it decreased with age from 62.8% of 3-year-olds to 50.0% of 6-year-olds. The results also showed that motor-developmentally delayed children with flatfoot are at about 1.5 times the risk of normal developmental children (odds ratio = 1.511, $p = 0.005$). In addition, the prevalence of flatfoot is relatively higher in overweight children with delayed motor development, and that in obese children is even as high as 95.8% (23/24). Children with both excessive joint laxity and delayed development are more likely to suffer from flatfoot. The findings of this study can serve as a reference for clinical workers to deal with foot issues in children with delayed motor development.

1. Introduction

Developmental delay refers to children's failure in at least 1 of 5 fields (motor, proprioception, language, cognition, and behavior) to achieve a normal developmental milestone, which leads to delays in physical and mental developmental (Petersen, Kube, & Palmer, 1998). According to the World Health Organization, the incidence rate of developmental delay in preschool-aged children is 6–8% (Hardan & Sahl, 1997). Motor developmental delay is defined as a delay in gross motor or

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fine motor skills, and previous studies have found that 13.9% of children with developmental delay in Taiwan suffer from delayed motor development (Chen et al., 2002). Moreover, the incidence rate of delayed motor development has increased year by year (Lin, Yen, Wu, & Kang, 2009).

The main characteristic of flatfoot is a collapsed medial longitudinal arch (Fabry, 2010; Magee, Zachazewski, & Quillen, 2008; Staheli, Chew, & Corbett, 1987). The preschool stage is the main developmental stage of the medial longitudinal arch (Forriol & Pascual, 1990; Volpon, 1994). Children with developmental delay often have flatfoot, according to clinical observation; however, whether delayed motor development leads to flatfoot has never been studied. The formation of the arch is associated with the complete development of the foot bones, ligaments, and muscles, and it also plays a role in static and dynamic stability. Previous studies have indicated that flatfoot may lead to abnormal gait, and even to motor dysfunction (Lin, Lai, Kuan, & Chou, 2001). Moreover, the lack of a stable foot structure to support and maintain posture may lead to delayed motor development (Westcott, Lowes, & Richardson, 1997).

Footprint measurement is frequently used clinically to determine whether children exhibit the symptoms of flatfoot, as it is convenient and rapid to use (Cavanagh & Rodgers, 1987; Forriol & Pascual, 1990; Chen, Yeh, Kuo, et al., 2011). Even for children who are less cooperative, footprints can be collected with some assistance. The high reliability of footprint analysis has been verified. Many studies have demonstrated it to be a reliable approach (Cavanagh & Rodgers, 1987; Forriol & Pascual, 1990; Kanatli, Yetkin, & Cila, 2001; Staheli et al., 1987). Some studies have found that footprint analysis has good correlation with radiological measurements and can be as effective as radiological measurements (Kanatli, Yetkin, & Cila, 2001; Villarroya et al., 2009). A previous study found that the prediction accuracy of the Chippaux-Smirak index (CSI) is as high as 90% in preschool-aged children (Chen, Yeh, Kuo, et al., 2011) and recommended using the CSI for screening of symptoms of flatfoot in children (Chen, Yeh, Kuo, et al., 2011; Kanatli et al., 2001). Footprint analysis is a simple, reliable, low-cost, and noninvasive technique that can be used for screening studies, and it does not have the potentially hazardous effects of X-rays.

Early intervention refers to early discovery, diagnosis, and provision of professional medical rehabilitation to fully develop children's abilities (Chen et al., 2002). Therefore, with understanding of the foot development of children with delayed motor development, proper intervention can be provided (e.g. foot orthotics and exercises) to improve the movement and stability of the lower limbs. The possible deformation of the foot structure and resultant pain in the future can also be prevented (Anderson et al., 2003; George & Elchert, 2007). Therefore, this study aimed to investigate the prevalence of flatfoot in preschool children with delayed motor development and identify the relevant factors affecting it. The results can serve as a reference for clinical workers to deal with movement issues in children with delayed motor development.

2. Methods

2.1. Participants

This study was approved by the Institutional Review Board of the Chung Shan Medical University Hospital, and the study complied with the tenets of the Declaration of Helsinki. Before participants were included, the parents or legal representatives of the participants fully understood the objectives of the study, agreed to participate in the study, and signed the informed consent. This study enrolled participants from hospitals and residential institutions in Taichung, Taiwan. The preschool-aged children, aged 3–6, were diagnosed with delayed motor development according to the assessment of functional development by physicians, defined as a delay in gross motor or fine motor skills. The exclusion criteria were: (1) lower extremity injuries within 6 months; (2) a medical history of musculoskeletal or neurological diseases affecting their lower limb structure or movement; (3) previous or current treatment with foot orthotics; (4) uncooperativeness in the collection of footprints. We also enrolled 4 times the number of gender- and age-matched normal development children from kindergartens as a control group.

2.2. Data collection

The basic information of the participants, including age, gender, body height (to the nearest 0.1 cm), body weight (to the nearest 0.1 kg), body mass index (BMI), and Beighton score were recorded. The BMI calculation formula was BMI = weight (kg)/height^2 (m^2). The participants were divided into 4 categories: underweight, normal, overweight, and obese (Table 1), according to the definition of obesity for children and teenagers from the Ministry of Health and Welfare, Taiwan. The Beighton score was divided into 9 items for scoring, wherein 1 item was assigned 1 point, for a total of 9 points. The participants with scores $\geq$4 points were defined as children with excessive joint laxity.

Two physical therapists were responsible for collecting the footprints of the participants. The participants were asked to stand on one foot on the Harris-Beath mat to make ink footprints (Shores, 1980). The collected footprints were scanned into image files, and computer software was used for the measurement and calculation of the length of the images in pixels. In this study, the CSI was used as the judgment criterion for flatfoot. The CSI is defined as the ratio of line B, a parallel line to A at the narrowest point on the foot arch, to line A, the maximum width at the metatarsals (B/A $\times$ 100%) in the footprint (Fig. 1). The ratio was used for judging whether the participants suffered from flatfoot. In previous studies using the CSI as a judgment criterion, preschool-aged children with CSI $>$ 62.70% were deemed flatfooted, and those with CSI $\leq$ 62.70% were deemed normal (Chen, Yeh, Kuo, et al., 2011).