

Dynamic pedobarographic classification of idiopathic toe-walkers for therapeutical indication



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ARTICLE INFO

Article history:

Received 17 March 2016

Accepted 11 July 2016

Available online 17 February 2017

Keywords:

Gait
Development
Equinus deformity
Evaluation
Children

ABSTRACT

Idiopathic toe-walkers (ITWs) pedobarographic analysis has not been described yet nor its possible relationship with orthopedical and developmental characteristics. The objective of this research is to develop a dynamic pedobarographic classification of ITWs to propose a specific therapeutical approach. Through an observational study, 56 ITWs aged 3–6 years were classified by their initial foot contact; differences between idiopathic toe-walking (ITW) types and with respect to 40 control children were calculated by means of ANOVA and Student *t*-tests. The results show that the three ITW types displayed different step models for pressure and impulse distribution and also for temporal development ($p < .05$). They also showed different orthopedic and developmental characteristics ($p < .05$). As a whole, they demonstrated different severity levels, which suggest different therapeutical indications. This study confirms the convenience of a specific orthopedic, developmental, and gait assessment in ITW to clarify therapeutical indication.

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Clasificación baropodométrica dinámica de los andadores de puntillas para la indicación terapéutica

RESUMEN

El análisis baropodométrico de la marcha de los andadores de puntillas (AP) no ha sido aún descrito en la literatura, ni tampoco su posible relación con sus características ortopédicas y neuromadurativas. El objetivo de este trabajo es desarrollar una clasificación baropodométrica dinámica de los AP para proponer un abordaje terapéutico específico. En un estudio observacional, 56 AP de 3 a 6 años han sido clasificados por su contacto inicial del pie, calculándose las diferencias entre los diferentes tipos de AP y con respecto a 40 niños que conformaron el grupo control, mediante los tests ANOVA y *t* de Student. Los resultados demostraron que los tres tipos de AP tenían diferentes modelos de paso en cuanto a la distribución de presiones e impulsos y también en su desarrollo temporal ($p < .05$). También se encontraron diferencias significativas en sus características ortopédicas y neuromadurativas ($p < .05$). En conjunto, los tres grupos de AP demostraron diferentes niveles de severidad que sugieren la indicación de abordajes terapéuticos diversos. Este estudio confirma la necesidad de una valoración específica de la marcha ortopédica y neuromadurativa en los AP para clarificar la indicación terapéutica.

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Palabras clave:

Marcha
Desarrollo
Pie equino
Evaluación
Niños

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<http://dx.doi.org/10.1016/j.clysa.2016.07.003>

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Idiopathic toe-walkers (ITWs) are children with a usual tiptoe gait (Fox, Deakin, Pettigrew, & Paton, 2006), but they are capable of heel-striking when they are asked to or when their attention is drawn to it, with an absence of gastrosoleus retraction (Brunt et al., 2004; Stricker, 2006; Westberry, Davids, Davis, & de Moraes, 2008). Idiopathic tip-toe gait is considered as an exclusion diagnosis in children older than 3 years (Engelbert, Gorter, Uiterwaal, van de Putte, & Helders, 2011; Williams, Tinley, Curtin, Wakefield, & Nielsen, 2013; Williams, Tinley, & Rawicki, 2014), once principal orthopedic and neurological conditions are discarded (Fox et al., 2006; Stricker, 2006). However, some authors have speculated that idiopathic tiptoe gait is a motor expression of a minimal cerebral dysfunction, as this kind of gait has been related to difficulties in psychomotricity, learning, behavior, speech, language, and sensory integration (Fox et al., 2006; Shulman, Sala, Chu, McCaul, & Sandler, 1997; Stricker, 2006; Williams, Tinley, Curtin, Wakefield et al., 2013; Williams et al., 2014). So, developmental evaluation is strongly recommended in ITW and a specific treatment could be implemented if necessary (Williams et al., 2014).

As biomechanical aspects, together with a progressive secondary triceps surae retraction in older children (Engelbert et al., 2011; Shulman et al., 1997; Williams, Tinley, Curtin, & Nielsen, 2013), compensations for long term tiptoe gait include valgus rearfoot, external tibial torsion, and an abducted gait pattern (McMulkin, Baird, Caskey, & Ferguson, 2006). For this reason, orthopedic evaluation is highly recommended (Williams, Tinley, Curtin, & Nielsen, 2013) and therapeutical approaches are focused on these alterations once established (van Kuijk, Kusters, Vugts, & Geurts, 2014). Some authors have studied kinetic and kinematic idiopathic toe-walking (ITW) gait characteristics to quantify them and Alvarez, Vera, Beauchamp, Ward, & Black (2007) have designed a specific classification for ITW. They classified ITW in three progressive severity types by the presence of a first ankle rocker, an early third ankle rocker, and a predominant first ankle flexor moment. This classification has showed its usefulness to select the best treatment option and evaluate its effectiveness (Engström et al., 2010), but it has not been related with orthopedic or developmental ITW characteristics.

A dynamic pedobarographic analysis has been suggested for children gait evaluation because of its sensitivity to detect light changes (Alvarez, Vera, Chhina, & Black, 2008; Bertsch, Unger, Winkelmann, & Rosenbaum, 2004; Bosch, Gerss, & Rosenbaum, 2010; Halleman, De Clercq, Van Dongen, & Aerts, 2006), but there is a lack of studies about ITW. It could be a valid instrument to reveal differential patterns of plantar pressure distribution in ITW, to indicate a therapeutical option (Bosch et al., 2010; Eiff, Steiner, & Zegar, 2006; Halleman et al., 2006).

The aim of this work is to develop a dynamic pedobarographic classification in ITW, linking these models with orthopedic and developmental characteristics, to propose a specific therapeutical approach depending on them.

Method

One hundred and fifty-one children (3–6 years old) were recruited for this prospective research via specific advertising. Two experienced physiotherapists conducted a developmental, orthopedic, and dynamic pedobarographic analysis. The inclusion criteria of ITW were being currently toe-walkers and starting since gait began (Engström & Tedroff, 2012; Williams, Tinley, Curtin, & Nielsen, 2013; Williams, Tinley, Curtin, Wakefield et al., 2013). The exclusion criteria for ITW and control type (CG) included trauma disorders, neurological or developmental ones, unilaterally tiptoe gait, and previous treatment for tiptoe gait. According to these criteria, 96 children (56 ITWs and 40 in the CG) were selected out

of those who fulfilled the inclusion criteria and whose parents had signed the informed consent. Excluded children were mostly affected by flatfeet, in-toeing gait, neurodevelopmental disorders, and inability to complete valuation. This observational study was previously approved by the Clinical Investigation Ethics Committee of the Faculty.

Dynamic Pedobarographic Analysis

Children's age, sex, height, and weight were firstly collected. Pedobarographic gait analysis was performed using Footscan USB Gait Clinical System® (2 m x 0.4 m x 0.02 m, 16,384 sensors, 500 Hz, and 3 sensors per cm²), embedded in a 9-meter walkway. Children were asked to walk onto the gait track at a comfortable speed and looking at the front, after they had been freely barefoot walking for a minute. At least 10 whole fingerprints of both feet were recorded and their average was considered for the analysis. The variables analyzed were calculated directly by the system by means of the automatic division in foot zones (Alvarez et al., 2008; Bertsch et al., 2004; Bosch et al., 2010; Crenna, Fedrizzi, Andreucci, Frigo, & Bono, 2005; Halleman et al., 2006; Liu, Thometz, Tassone, Barker, & Lyon, 2004). The variables studied were peak pressure, percentage of impulse, total foot impulse, percentage of contact time, and step duration.

Low Extremity Orthopedic Assessment

Physical evaluation included the measure of the popliteal angle, the passive ankle dorsiflexion, both with extended and flexed knee, the relaxed calcaneal stance position, and the pronation angle. Angular measurements were obtained using a handheld goniometer, with modalities which have demonstrated to range from moderate to high reliability (Evans, Cooper, Scharfbillig, Scutter, & Williams, 2003; Van Gheluwe, Kirby, Roosen, & Phillips, 2002).

Developmental Evaluation

Developmental evaluation was performed by the *Cuestionario de Madurez Neuropsicológica Infantil* [Child's Neuropsychological Development Questionnaire] (CUMANIN), a very complete test validated in Spain that evaluates all aspects of children development and enables us to compare them with reference values for the chronological age (Portellano, Mateos, Martínez-Arias, Tapia, & Granados, 2000). Global and specific scales results can be expressed as farthings with respect to the reference population and all of them have been considered for this study, and also the global indicator known as Development Quotient. CUMANIN has been described as an useful tool for developmental evaluation of different Spanish children samples, both with and without disorders (Portellano, 2004; Portellano et al., 2000).

ITW Types Configuration

ITWs were classified through an analysis of their initial foot contact and the step development during dynamic pedobarographic analysis by means of the initial contact time for each foot zone (Figure 1). Type 1 ($n=23$) included children who showed a clear initial hindfoot strike progressively followed by midfoot and forefoot in a roller from heel to toes. Type 2 ($n=27$) demonstrated an initial contact with the hindfoot together with other foot zones in a flatfoot contact, or a variable initial contact by the alternation of heel strike with the flatfoot contact. Type 3 ($n=6$) included children who demonstrated an initial forefoot contact followed by a retrograde hindfoot contact.

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