Gait & Posture 47 (2016) 68–73

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Postural seated balance in children can be assessed with good reliability

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ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form 9 March 2016
Accepted 7 April 2016

Keywords:
Seated balance
Reliability
CONFORMat
Pressure sensor
Postural control

ABSTRACT

Background: Seated postural stability can be measured using Tekscan, CONFORMat. Standing postural stability has gained great clinical and, research value by use of different force platforms with mostly good reliability. No reliability testing or biologic variation assessment has been documented regarding seated balance. This study determines the reliability of the parameters of seated balance in healthy children using the Tekscan CONFORMat equipment.

Methods: Sixty-six healthy children completed six measurements of seating position the first three with the child seated in a relaxed normal back position and the next three with the child seated in a complete up-right back position. The SAM software calculated five default parameters of balance (area, distance, variability, antero-posterior (AP) excursion and left–right excursion).

Results: Reliability parameters were assessed by one-way analysis of variance intra-class correlation (ICC) proving excellent reliability for relaxed and up-right back position with respect to distance (0.75/0.84) and good reliability with respect to variability (0.61/0.62) and area (0.61/0.60). AP excursion (0.41/0.59) and left–right excursion (0.54/0.24) showed fair to poor reliability.

Conclusion: In conclusion, two of the five default parameters of balance used in the Tekscan CONFORMat system are direction-independent parameters and have been found reproducible for measuring seated balance in children. This study can be used as reference for comparisons of seated balance in children with affected seated postural control and for evaluating a clinical treatment effect.

1. Introduction

Postural stability is defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity and consequently avoiding a fall [1]. This term normally refers to the standing position, but with the increasing technological development measurements of the seated postural stability are becoming feasible. The mechanical definition of balance or equilibrium is derived from Newton's first law, which states balance as the state of an object, when the resultant load actions acting upon it are zero. In the scope of human balance the body's global Centre of Force (CoF) or center of gravity must remain inside the body's base of support in order to maintain postural stability [1]. Balance, and most importantly balance control, is a fine adjustment between sensory neuro-input and neuromuscular output, and this active neural control keeps the CoF positioned inside the body's base of support by using tiny oscillatory movements known as postural sway [2].

Children with motor disorders as for example cerebral palsy (CP) suffer from postural control dysfunction due to their primary brain injury contributing to limitations in the gross motor skills that require balance. Maintaining postural control is often a major challenge for children with CP and interferes with upper limb activities, oral motor activities and speaking – limitations which all restrict activities of daily living (participation) [3,4]. Studies investigating postural balance in children find that, among others, children with Autism Spectrum Disorder [5], Attention Deficit Hyperactivity Disorder [6], bilateral sensorineural hearing loss [7], myelomeningocele [8], and CP [9,10] have impaired postural balance of varying degrees and consequences. In adults, trunk training exercises have been found to improve dynamic sitting balance in patients after stroke and trunk postural control was affected during a seated task in lower-limb amputees [11,12].

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http://dx.doi.org/10.1016/j.gaitpost.2016.04.007
0966-6362/

Interventions aimed at improving postural balance in children with CP are targeted towards anticipatory and reactive postural adjustments as well as sensory and musculoskeletal components of postural control and may comprise of hippotherapy, gross motor task training, functional electrical stimulation, treadmill training, trunk-targeted training, upper limb interventions, visual biofeedback or virtual reality [3]. Studies show, that postural control interventions, can improve the seated postural balance of children with CP [3,4,13,14]. Liao et al. [13] found a significantly worse seated balance in children with diplegic CP compared to healthy children and Park et al. [14] found a positive effect on trunk control after physical therapy based on the Neuro-Developmental Technique (NDT) and electrical stimulation in young children with CP. In a review by Zadnikar and Kastrin [4] a positive effect of hippotherapy and therapeutic horseback riding on postural balance in children with CP was indicated.

Different tests or equipment have been used to investigate both standing balance and seated balance, but evidence on the reliability and variability is sparse and including both dynamic sitting and quiet sitting [2,7,14–21]. Some clinical tests measure seated postural balance, including the Rivermead Stroke Assessment, which tests the ability of a patient to sit unsupported; the Motor Assessment Scale (MAS), that analyzes the voluntary movements from a seated person [1] or the sitting score of the Gross Motor Functional Measure (GMFM) for children with CP [14]. Equipment used for assessing seated balance include force plates where Karlsson et al. [8] analyzed postural sway in seated children using the VIFOR system with a Kistler force plate and Liao et al. [13] have used the Chattex Balance System to test seated postural sway. Other equipment includes the Prototype Trunk Training System for sitting balance developed by Jeong et al. [22] training trunk muscle strength and movements. However, these studies have not reported testing of the psychometric properties of the equipment.

The Tekscan CONFORMat system is easy to use and able to provide seated postural balance data with high clinical feasibility; but no studies on reliability, intra-variability or biologic variation in children have been published. Dewar et al. [3] reviewed 45 studies on exercise interventions to improve postural control in children with CP and highlighted the importance of selecting appropriate postural balance measures and call for reliable outcome measures validated for use in children. At present the reliability and intra-variability of the parameters of seated balance in children using the Tekscan CONFORMat system have not been assessed. Hence, the primary aim of this study is to test the reliability and intra-variability of the parameters of seated balance in healthy children using the Tekscan CONFORMat system. The secondary aim is to describe seated balance in healthy Danish children, in order to make comparisons to children with postural control dysfunction.

2. Methods

2.1. Participants

Sixty-six healthy children (33 boys and 33 girls) aged 7–14 years participated in the present study. Demographics are listed in Table 1. Permission to conduct the project in a local primary school was obtained; the parents of children in a 1st, 3rd, 5th and 7th grade were invited to participate in the study and accepted the participation of their child. Only children with informed consent were included. Inclusion criteria were informed consent by the parents and exclusion criteria were previous diagnosis of any orthopedic condition regardless of treatment or status.

The hypothesis behind the primary aim of the present study is that healthy children aged 7–14 years old have reproducible seated balance parameters with low biologic variation assessed by intraclass correlation. In addition, it is hypothesized that reproducibility is correlated to the age of the child. Secondary, the seated balance is described and it is hypothesized that seated balance improves in the up-right seated position compared to normal position, that seated balance changes with age or body mass index (BMI) and that a gender difference is present as previous studies have shown.

2.2. Equipment

The Tekscan CONFORMat Seat Sensor (#5330) with a sensor resolution of one sensor per cm^2 was used and the measurements of normal seated position and seated in the up-right position were analyzed with Tekscan Sway Analysis Module. A 10 points pressure calibration of the CONFORMat sensor with the VB5A Vacuum Pressure Calibration System was performed with S-23 sensitivity (range 1–40) and saturation pressure of 580 mm Hg. The same calibration file was loaded into all measurements of seated position. Each recording was set to 2000 frames in a 30 s recording, equivalent to a capturing frequency of 66 frames per second.

The Tekscan CONFORMat is a flexible pressure sensor mat and bases measurements of balance on the CoF at a specific point in time and can be described as the point on the ground where a pendulum through the body points to (Fig. 1) [2].

2.3. Procedures

Each child included in the study successfully completed six consecutive measurements of seated position and received identical instructions. The instruction was to sit on the pressure sensor with unsupported feet and the hands placed on the thighs looking straight forward. The pressure sensor was placed on the same examination bed for all measurements in order to maintain identical underground properties. First, three recordings of 30 s were done with the child seated with a relaxed normal back position (normal) assessed as the most comfortable position for the individual child, followed by three recordings with the child in a complete up-right back position (upright), defined as an active pelvic anterior tilt combined with an increased lumbar lordosis straightening the back position. This position was reached by motivating the child to sit as up-right as physically possible. The seated position was checked prior initiation of the measurements. Between measurements the children were encouraged to stand up and move or shake their legs in order for the measurement to reflect the intra-variability of the child rather than the reliability of the mat. The time between measurements was approximately 1 min and was used for saving the previous recording and initiating the next recording. All measurements were conducted in a closed room in order to minimize any disturbances.

Table 1
Participant demographics both total and by age. Values are mean (SD).

	Total	Age 7–8 yrs	Age 9–10 yrs	Age 11–12 yrs	Age 13–14 yrs
N	66	15	14	19	18
Height/cm (SD)	148.5 (*14.2*)	129.8 (*6.7*)	143.7 (*5.6*)	151.7 (*7.0*)	164.5 (*7.0*)
Weight/kg (SD)	37.6 (*10.3*)	26.1 (*2.9*)	32.5 (*3.5*)	39.5 (*7.3*)	49.0 (*7.3*)
Age/yrs (SD)	10.4 (*2.3*)	7.2 (*0.4*)	9.1 (*0.4*)	11.1 (*0.5*)	13.3 (*0.5*)
Body mass index (SD)	16.7 (*2.1*)	15.5 (*1.5*)	15.7 (*1.1*)	17.1 (*2.2*)	18.1 (*2.4*)