Original Article

A Reliability of the Prototype Trunk Training System for Sitting Balance

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Abstract. [Purpose] Cerebral palsy is a disorder that affects balance in the sitting position. Cerebral palsy patients need trunk muscle strengthening and balance training. In order to improve trunk control sensory-motor control training is carried out on an unstable surface. We have developed a Trunk Training System (TTS) that can provide visual feedback using a tilt sensor for balance training in the sitting position. Before using the TTS for training children with cerebral palsy experiments were conducted with healthy adult subjects and the TTS to gather basic data for its improvement. [Subjects] The subjects were 11 healthy men (n=3) and women (n=8). [Methods] Subjects trained at two levels (5°, 10°), in four different directions (anterior, posterior, left, right), three times each. TTS outcome indices (stability index, performance time) were measured. [Results] The stability index and performance time showed high correlation ($-0.6 < r < 1$). The measurements of the different task levels and directions showed high reliability ($0.9 < \alpha$). [Conclusion] The TTS may be used to evaluate the range of motion and execution capabilities of sitting balance. Additional experiments will be needed to investigate the validity of the TTS measurements.
Key words: Trunk training system, Reliability, Cerebral palsy

INTRODUCTION

Cerebral palsy is a non-progressive brain disease that affects motor function and posture changes during childhood growth. Disorders of motor function, muscle weakness, fatigue, involuntary behavior, and physical postures are accompanied by body imbalance and stiffness[1]. Abnormal development of the skeletal muscles needed for weight-bearing ability delays the development of movement functions. Also, sit, stand or walk will not develop normally causing deformity of the spine, as well as poor balance and trunk control. Therefore, therapeutic approaches for functional improvements are needed[2].

The standing posture is controlled by the ankle, knee and hip joints. In the sitting posture no positional adjustment occurs. Postural control of the sitting position can be used to assess spinal instability, trunk muscle weakness, and activities of daily living impairments in cerebral palsy[3–5]. Dynamic control measurements on an unstable board are suitable for balance control and postural maintenance assessments[6]. In addition, exercise on an unstable support surface provides a superior environment for trunk muscle exercises[7].

Numerous researchers have attempted to improve the balance and strength of cerebral palsy patients, and as a result, various training devices have been proposed. Hwang et al.[8] reported the reliability and validity of a hemisphere (dome-shaped) unstable balance training device. In addition, a dynamic system of therapeutic interventions for children with cerebral palsy and motor function has been improved[9]. A survey of children with cerebral palsy showed that a horse riding program may improve motor function[10]. Recently, the evaluation of the sitting and standing device have been developed, but for children with cerebral palsy were not developing properly. Access to treatment is limited in the case of horse riding, and requires a lot of manpower to provide safety. Control of trunk muscle strength and power in the seated position and the use of visual information, as well as the elimination of the shortcomings of existing equipment are needed for safe training interventions.

In this study, the shortcomings of the existing TTS (Trunk Training System, Korea, NRC) was investigated. The TTS is made of an elastic band and a chair and it can be easily produced at low cost. The TTS, can be used to train the user in smooth and natural movements. Before using the trunk training system to train children with cerebral palsy, an experiment involving normal healthy subjects was required. The purpose of this study was to investigate the reliability of the trunk training system.

SUBJECTS AND METHODS

This study used a cross-sectional design. Eleven healthy adults were recruited at the National Rehabilitation Hospital in Seoul, South Korea. This study was approved by the Institutional Review Board of Korea National Rehabilita-
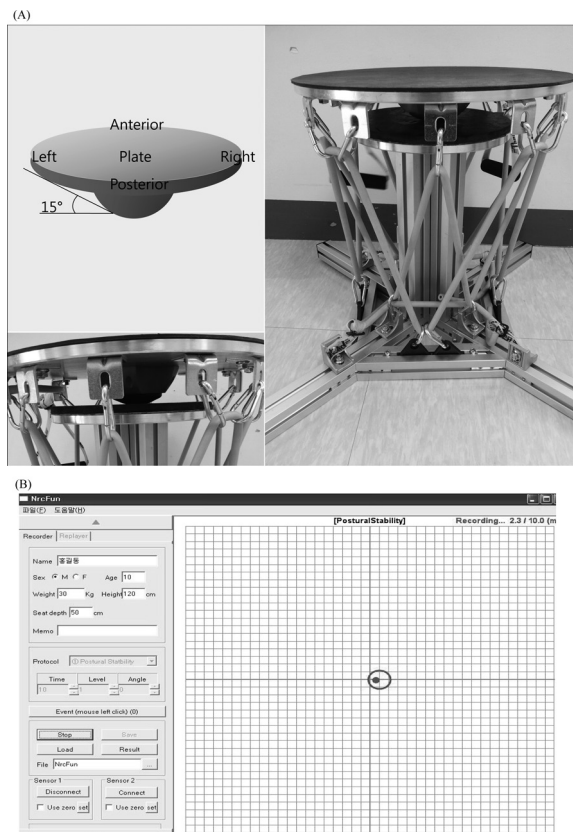
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Fig. 1. The trunk training system
(A) general view, (B) Interface of TTS software and quantifies the tilt of the plate

(A)

$$SI\ (°) = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(\sqrt{(x_i - mean\ x^2 + (y_i - mean\ y^{2)}} - mean\ xy}$$

(B)

$$Performance\ Time\ (\%) = \frac{Time\ spent\ in\ the\ target\ zone}{Total\ time} * 100$$

Fig. 2. Formulae of stability index (A) and performance time (B)

Table 1. Correlation coefficients of SI and PT

Level	Variables	Correlation (r)			
		Right	Left	Anterior	Posterior
5°	SI & PT	−0.925	−0.732	−0.688	−0.865
10°	SI & PT	−0.719	−0.639	−0.697	−0.603

SI, Stability Index; PT, Performance Time

tilt. The red point moves in tandem with the sensor tracking the seat or trunk movement angles (Fig. 1B). The stability index (SI) and performance time (PT) were calculated using the tilt values. SI is a measure of the deviation of the red mark from the target, and PT is a measure of the time spent in the target zone. The formulae used to calculate SI and PT are shown in Fig. 2.

SPSS version 18.0 software was used for statistical analysis. The relationship between SI and PT was analyzed, using Pearson's correlation coefficient. The training was performed a number of times in order to analyze the internal consistency and reliability using Cronbach's α. Statistical significance was accepted for values of p<0.05.

RESULTS

Eleven subjects (male 8, female 3) participated in this study. The ages of the participants ranged from 25 to 38 years and they had a mean (SD) age of 30.18 (3.62) years. The average height and weight of the participants were 172.3 cm for males and 162.8 cm for females, and 70.3 kg for males and 50.2 kg for females.

At the 5° target level, stability index and performance time values were lower than their respective values at the 10° level and a significant correlation was found between them (−0.6<r<1) (Table 1). Reproducibility of the performance time are shown in Table 2 (0.9<α).

DISCUSSION

The ability to balance of the trunk in human activities, in order to straighten posture, is an important ability because it improves stability[1]. In children with cerebral palsy, control and stability of the trunk are low and result in poor balance ability[2]. In this study, we examined an interactive trunk training system, which we developed, which uses visual feedback to improve the postural balance and trunk control of cerebral palsy children.

The TTS is comprised of a chair and elastic band for trunk training, tilt sensor and evaluation software. The software includes some clinical assessment tools, which are

tion Institutions. Before the experiment, all the participants were provided with sufficient explanation about the study. Participants signed a consent form agreeing to the terms and conditions of the experiment. Inclusion criteria were as follows: 18 to 40 years old, and a weight of less than 80 kg. Exclusion criteria were visual acuity too poor to recognize the change of a character on a computer screen.

The TTS has three components: hardware for seated trunk training, a tilt sensor, and software (sitting balance training protocol). The TTS hardware is attached to a hemispherical dome (diameter 13 cm) under the seat plate (Fig. 1A). A tubing band for resistance connects the foot plate to the seat plate. The angle of sitting tilt is measured. The maximal possible seat plate tilt is 15° in all directions.

TTS software ver1.0 (Korea, NRC) includes programs to train and evaluate seating balance. A red point (Fig. 1) moves according to the tilt of the seat. For each test, the subjects were asked to place their hands on their chest and to maintain the target posture for as long as possible. Maintaining the target angles was repeated three times for each direction and the direction was randomly determined. For the participants' safety, two physical therapist attended the experiment.

Measures were repeated three times for each of the four directions (anterior, posterior, left, right) and target tilt angles (5°, 10°). In the graphic user interface of the TTS software, one unit on the screen grid represents one degree of

Table 2. Performance time and its reliability of measurement (Chronbach's α)

Level	Direction	Trial			Chronbach's
		1	2	3	α
5°	Right	69.06 (21.82)	73.59 (22.26)	76.90 (23.27)	0.980
	Left	71.89 (22.89)	75.75 (22.67)	74.57 (22.41)	0.978
	Anterior	71.98 (24.65)	72.98 (21.87)	74.77 (23.69)	0.962
	Posterior	64.02 (20.90)	72.03 (21.88)	71.07 (22.34)	0.911
10°	Right	55.99 (19.97)	63.97 (22.99)	62.14 (23.87)	0.911
	Left	55.81 (24.68)	59.86 (24.99)	66.24 (22.48)	0.972
	Anterior	55.38 (24.45)	65.33 (20.55)	64.26 (21.85)	0.932
	Posterior	43.26 (25.62)	57.93 (23.44)	56.85 (22.43)	0.934

Values are mean (SD)

generally used in hospitals, such as the gross motor function measure (GMFM)[12], the berg balance scale (BBS)[13], the pediatric balance scale (PBS)[14], the fugl-meyer assessment (FMA)[15], the trunk impairment scale (TIS)[16], the sitting balance scale (SBS)[5], and the pediatric reach test (PRT)[17]. In this study, protocols for static and dynamic balance training for improving postural stability were used. The protocols were performed in the four major directions at two tilt angles to examine the correlation between variables and to evaluate the internal consistency and reliability.

At the 5° level, the correlation between SI and PT was higher than at the 10° level. Also, at the right direction, the correlations between SI and PT were r=−0.925 (5° level) and r=−0.719 (10° level). These results show that SI is highly correlated with PT, level increases, the difficulty of the task more difficult. The protocol was repeated three times in all the directions and at both tilt angles and a Chronbach's α value of 0.9 or more showed a high internal consistency. In a similar study, Cholewicki et al.[6] examined a device for quantifying the postural control of the lumbar spine in unstable sitting. In this study at the 10° level the tasks were difficult to perform. However, the balance ability and the high correlation between SI and PT show that the balance ability can be quantified. TTS has a relatively low cost. The equipment's ease of use and its portability make it an ideal device for rehabilitation. The software of this newly developed training system is easy to use in conjunction with other hardware, which makes it easy to use in most locations. In addition, the software can be used to evaluate the progress of a program, a feature which is useful in research. The TTS may be used to evaluate the range of motion and execution capabilities of sitting balance. In the near future, we need to investigate the reliability and validity of the TTS. Also, a future study should be conducted on patients with neuropathic or low back pain. The TTS can be used for the evaluation and training of sitting balance.

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