Reliability of Three-dimensional Kinematic Measurement during Sit-to-stand in Healthy Young Adults and Typical Children

ความน่าเชื่อถือของการวิเคราะห์การเคลื่อนไหวในท่านั่งลุกขึ้นยืน ด้วยเครื่องวิเคราะห์การเคลื่อนไหว 3 มิติ ในผู้ใหญ่ตอนต้น และเด็กปกติ

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ABSTRACT

The motion analysis system was a famous system to assess kinematic movement. However, the errors can influence from variability of people during repeatedly performed movement analysis, placement of markers, and movement of markers over the skin. Therefore, this study aimed to standardize the motion analysis protocol and determine the inter- and intra-tester reliability of three dimensional kinematic measurement of sit-to-stand (STS) in healthy young adults and inter-tester reliability in typical children. A motion analysis system was used to assess kinematic data of peak hip, knee, and ankle motion during STS movement for analyzing reliability. The intra-class correlation coefficient (ICC) was calculated the reliability. The result showed that all variables were good reliability for inter- and intra-tester reliability in both groups. This protocol was feasible analysis of three-dimensional motion of STS with minimize errors.

บทคัดย่อ

เครื่องวิเคราะห์การเคลื่อนไหว 3 มิติ เป็นที่นิยมอย่างมากในการวิเคราะห์การเคลื่อนไหว แต่อย่างไรก็ตาม ความหลากหลายของการเคลื่อนไหว ตำแหน่งการติดจุดสะท้อนแสง และการเคลื่อนไหวของจุดสะท้อนแสงบนผิวหนัง สามารถทำให้เกิดข้อผิดพลาดในขณะเก็บข้อมูลได้ ดังนั้นในการศึกษานี้ต้องการสร้างมาตรฐานของวิธีการวิเคราะห์การเคลื่อนไหวแบบ 3 มิติ และการศึกษาความน่าเชื่อถือของผู้ประเมิน ความน่าเชื่อถือระหว่างผู้ประเมิน ในการวิเคราะห์การเคลื่อนไหวในท่านั่งลุกขึ้นยืนของผู้ใหญ่ตอนต้น และการศึกษาความน่าเชื่อถือระหว่างผู้ประเมินในเด็กปกติ โดยใช้เครื่องวิเคราะห์การเคลื่อนไหว 3 มิติ (Motion analysis system) ในการหาค่าสูงสุดของมุมข้อสะโพก ข้อเข่า และข้อเท้า เพื่อนำมาใช้วิเคราะห์ค่าสัมประสิทธิ์สหสัมพันธ์หาค่าความน่าเชื่อถือ ผลการศึกษาพบว่า ค่าสัมประสิทธิ์สหสัมพันธ์ของความน่าเชื่อถือของผู้ประเมิน และระหว่างผู้ประเมินทุกค่าตัวแปรอยู่ในเกณฑ์ดี ดังนั้นวิธีการวิเคราะห์การเคลื่อนไหวแบบ 3 มิตินี้สามารถใช้วิเคราะห์การเคลื่อนไหวในท่านั่งลุกขึ้นยืนโดยเกิดความคลาดเคลื่อนของการวัดในระดับต่ำ

Keywords: Reliability, Sit-to-stand, Motion analysis
คำสำคัญ: การหาความน่าเชื่อถือ นั่งลุกขึ้นยืน เครื่องวิเคราะห์การเคลื่อนไหว 3 มิติ

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Introduction

Over the years, three-dimensional motion analysis has become the most tools for both research and clinical assessment to describe kinematics of movement. However, the errors of motion analysis can influence by two main factors (Hopkins, 2000; Tsushima et al., 2003). The first factor is variability of people during repeatedly performed movement analysis. The second factor may occur in a part of measurement such as placement of markers across sessions (intra-tester) and across testers (inter-tester); movement of markers over the skin; and accuracy of motion analysis system (Hopkins, 2000; Tsushima et al., 2003; Stagni et al., 2005; Benoit et al., 2006; Peters et al., 2010). The errors caused by the second factor could be minimized by training the researcher and conducting inter- and intra-tester reliability test. For several studies, they have been investigated the reliability of kinematic data from three-dimensional motion analysis in various movements such as walking, running, etc. (Kadaba et al., 1989; Ferber et al., 2002; Tsushima et al., 2003; Collins et al., 2009).

Previous studies have showed that the movement of markers over the skin was affected by the tasks. The marker movement was greater in sit-to-stand and stand-to-sit tasks than stair climbing or step up/down movement (Stagni et al., 2005). Accordingly, for using the motion analysis system in sit-to stand (STS) movement in our further study, the motion analysis protocol has been developed. Hence, the inter- and intra-tester reliability three dimensional kinematic measurement should be determined to minimized errors associated with marker placement methods and procedure before performing the study. Therefore, the purpose of this study was to standardize the motion analysis protocol and determine the inter- and intra-tester reliability of three dimensional kinematic measures of STS movement in healthy young adults. After the reliabilities in healthy young adults were met the good level, the inter-tester reliability in typical children during STS movement was further evaluated.

Objectives of the study

To standardize the motion analysis protocol and determine the inter- and intra-tester reliability of three dimensional kinematic measures of STS movement in healthy young adults.

To standardize the motion analysis protocol and determine the inter-tester reliability of three dimensional kinematic measures of STS movement in typical children.

Methodology

This study was cross-sectional study design. All study protocols were approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University. The study procedure was fully explained to the participants. Then, the informed consent was obtained from them. All test in this study were carried out at the Motor Control and Motion Analysis Laboratory, department of Physical therapy, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok, Thailand.

Participants

A convenience sample of ten healthy young adults (5 females and 5 males) and ten typical children (6 females and 4 males) participated in this study (Collins et al., 2009). In young adult participants, Body mass index (BMI) were normal ($\leq$ 23 kg/m^2) (World Health Organization [WHO], 2000). Their mean age, body weight and body height were 25.4±3.89 years, 56.03±4.17 kg and 166.75±7.15 cm, respectively. For typical children, their weight and height were appropriated with aged (Bureau of nutrition, department of health, ministry of public health, 1999). Their mean age, body weight and body height were 7±1.89 years, 24.57±6.07 kg and 124.21±13.38 cm, respectively. None of participants had a history of obvious musculoskeletal, neurological or any visual problem which affected ability to complete the STS task.

Instrument

Motion analysis system (Motion Analysis Crop., Santa Rosa, CA) and Cortex software version 2.6.2 were used to capture the STS movement. The motion analysis consists of eight Raptor E cameras with frame rate at 120 Hz and speed shutter 1/1000 sec.

Procedures

In healthy adult group, the test composed of 4 sessions with the same protocol conducted by tester 1 and tester 2, respectively. Both testers were physical therapists and be well trained the whole process of the three dimensional motion analysis of STS movement. Participants were required to wear tank top, shorts and swim cap. Each session started with marker placement. Twenty-nine reflective markers were attached on the body landmark of each participant by the tester. The positions of all reflective markers were described as Helen Hays marker set model including top, front and back of the head, bilateral tips of acromion process, bilateral lateral epicondyles of humerus, bilateral center between styloid process of radius and ulna, right scapular, bilateral anterior superior iliac spines (ASIS), superior aspect at L5 sacral interface, bilateral thighs, bilateral lateral femoral condyles, bilateral shanks, bilateral lateral malleoli, bilateral posterior calcaneus, bilateral center of foot between 2nd and 3rd metatarsals, bilateral median malleoli and bilateral medial femoral condyles (Orthotrack, 2009).

The participants were required to sit on adjustable height bench with arms crossed and feet shoulder width apart placed on the floor (Khemlani et al., 1999; Gillette, Stevermer, 2012). The height of bench was set at 100% of participant's lower leg length. The seat depth was set at 25% of participant's thigh length (Khemlani et al., 1999). Then, the participants were instructed to stand up from the chair with self-selected speed and did not allow to move their feet. After standing up, participants had to stand still for 5 seconds and then sit down. The three successful trials were collected. All markers were removed when finishing the data collection. In the 2nd session, the tester 2 repeated the whole process again after thirty minutes breaks within the same day. The 3rd and 4th sessions were conducted in an identical manner for the same participant on the other day within one week.

After the inter- and intra-tester reliability in adult population was achieved a good level, the 1st and 2nd sessions were performed again in typical children group by tester 1 and tester 2, respectively.

Data processing and data analysis

The fourth order Butterworth digital filter at cut of frequency 6 Hz was filtered the kinematic data. The peak of hip flexion-extension, knee flexion-extension and ankle dorsiflexion-plantarflexion were computed for all further analyses. Two-way random intra-class correlation coefficient (ICC) was used to evaluate inter-tester reliability. Two-way mixed intra-class correlation coefficient was used to evaluate intra-tester reliability. The ICC values were interpreted as follows: the values less than 0.25 indicated no reliability, 0.25-0.50 indicated fair reliability, 0.51-0.75 indicated good reliability, and more than 0.75 indicated high reliability.

Results

The mean and standard deviation (SD) for peak hip, knee, and ankle motion in healthy young adults and typical children were presented on table 1 and table 3 respectively. For the result of inter-tester reliability in healthy adults and typical children were presented in table 2 and table 3 respectively. All joint angle motions, the inter-tester reliability showed that no systemic differences ($p > 0.05$). The adult group, the ICC $_{(2,3)}$ values data were between 0.86 and 0.98 as presented in table 2. The typical children group, the ICC $_{(2,3)}$ values data were between 0.80 and 0.95 as presented in table 3.

For the intra-tester reliability, All joint angle motion were showed that no systemic differences ($p > 0.05$). The adult group, the tester 1, the ICC $_{(3,3)}$ values data were between 0.83 and 0.96. The tester 2, the ICC $_{(3,3)}$ values data were between 0.85 and 0.96 as presented in table 2.

Table 1 Mean ± SD of peak hip, knee, and ankle motion in sagittal plane in healthy young adults.

Joint angle motion	Tester 1		Tester 2	
	Day 1	Day 2	Day 1	Day 2
Peak hip flexion (˚)	82.87±9.50	83.58±9.42	82.93±9.10	84.7±8.63
Peak hip extension (˚)	6.95±4.75	6.86±5.05	7.23±5.73	8.12±4.74
Peak knee flexion (˚)	82.55±3.66	81.82±3.14	83.18±3.39	83.62±3.67
Peak knee extension (˚)	-5.41±2.79	-5.96±3.65	-4.43±3.54	-4.18±3.13
Peak ankle dorsiflexion (˚)	83.58±2.42	83.62±2.29	82.64±2.62	83.82±2.93
Peak ankle plantarflexion (˚)	100.48±2.56	100.61±3.37	99.50±2.29	100.73±2.94

Table 2 Intra-class correlation coefficient of intra-tester reliability and inter-tester reliability in healthy young adults.

Joint angle motion	Intra-tester reliability				Inter-tester reliability	
	Tester 1		Tester 2		ICC (2,3)	P-value
	ICC (3,3)	P-value	ICC (3,3)	P-value		
Peak hip flexion	0.96	0.535	0.96	0.130	0.98	0.926
Peak hip extension	0.95	0.890	0.94	0.255	0.96	0.686
Peak knee flexion	0.83	0.396	0.85	0.590	0.94	0.228
Peak knee extension	0.88	0.428	0.95	0.575	0.90	0.111
Peak ankle dorsiflexion	0.85	0.935	0.96	0.070	0.86	0.068
Peak ankle plantarflexion	0.89	0.824	0.94	0.120	0.90	0.051

Table 3 Mean ± SD and Intra-class correlation coefficient of inter-tester reliability in peak hip, knee, and ankle motion in sagittal plane in typical children.

Joint angle motion	Typical children		Inter-tester reliability	
	Tester 1 (°)	Tester 2 (°)	ICC (2,3)	P value
Peak hip flexion	88.19±10.29	88.85±11.51	0.95	0.674
Peak hip extension	9.48±8.32	10.97±6.10	0.80	0.460
Peak knee flexion	78.54±5.04	78.89±4.99	0.88	0.754
Peak knee extension	-6.53±8.60	-5.35±6.30	0.88	0.476
Peak ankle dorsiflexion	88.36±5.57	88.15±5.07	0.85	0.868
Peak ankle plantarflexion	102.68±4.17	102.20±3.54	0.82	0.634

Discussion and Conclusions

The purpose of this study was to standardize the motion analysis protocol and determine the inter- and intra-tester reliability of three dimensional kinematic measures of STS movement in healthy young adults. Moreover, this study was determining the inter-tester reliability in typical children during STS movement. From the results of present study, the inter- and intra-tester reliability of peak hip, knee, and ankle joint motions were good when measuring in young adult populations. Therefore, this protocol was acceptable for analysis of three dimensional motion of STS with minimized errors. Then, we tested the inter-tester reliability in typical children. The results were good reliability as well. Other investigators have reported similar results during running and walking in adults. Reed et al. reported good intra-tester reliability in running movement when measuring peak hip, knee, and ankle motions in sagittal plane (Ferber et al., 2002). In walking movement, Kadaba et al (1989) reported that the intra-tester reliability were good level of joint angle motion in sagittal plane. In addition, Tsushima et al. (2003) reported good inter- and intra-tester reliability of joint angle motion in sagittal plane.

In this study, inter- and intra-tester reliability in healthy young adults were good reliable. Meanwhile, in typical children, inter-tester reliability was good level as well. Previously, no known study reported the reliability of STS movement in children and adult population. Since children were different from adults such as the shorter period of attention, the variability of movement across the trials, and the body anthropometrics (Cahill et al., 1999). Therefore, a highly trained physical therapist to perform the whole the process of three dimensional motion of STS in this study could minimize error associated with data collection. This finding supported that the protocol was suitable for analysis of three dimensional motion of STS with minimize errors in young healthy adult and typical children population. In addition, the motion analysis system gives the kinematic information of STS movement. The peak values of joint angle motion in sagittal plane were feasible analysis of three-dimensional motion of STS with minimize errors.

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