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Inter-rater Consistency Reliability of the Inertial Measurement Units as a Balance Evaluation Tool

Jeong-hee Jang[1], Myung-chul Kim*[2], Hang-sik Park[3], Hae-in Kim[4], Jean-kyung Paik[5]

[1] *M.D. Student, Dept. of Physical Therapy, Eulji University*

[*2] *Professor, Dept. of Physical Therapy, Eulji University*

[3] *Professor, Faculty of liberal art, Eulji University*

[4] *Ph.D. Student, Dept. of Physical Therapy, Eulji University*

[5] *Professor, Dept. of Food & Nutrition, Eulji University*

Eulji University, Sanseongdaero 553, Sujeonggu, Seongnamsi, Gyeonggido, (13135), South Korea

Cjjh81130@gmail.com[1], ptkmc@eulji.ac.kr*[2], parkhs@eulji.ac.kr[3],
khi920119@gmail.com[4], jkpaik@eulji.ac.kr[5]

Abstract

Background/Objectives*: This study aim to evaluate the inter-rater consistency of static standing balance measurement equipment using inertial measurement system.*

Methods/Statistical analysis*: 45 residents over 50 years old of Seongnam-si were recruited. The participants were randomly divided into 2 groups, and their static standing balance ability was measured by 2 physical therapists for 2 days. The measurements were performed on standing with open eyes, with closed eyes, standing on an unstable surface. The measured items were 3 parts, right and left trunk shaking, anterior and posterior trunk shaking, trunk rotation.*

Findings*: For the open eyes part of the test, right and left trunk shaking's Cronbach alpha was .552, and anterior and posterior trunk shaking's Cronbach alpha was .626. And for the closed eyes part of the test, right and left trunk shaking's Cronbach alpha was .409 and anterior and posterior trunk shaking's Cronbach alpha was .623. Finally, for the unstable surface part of the test, only anterior and posterior trunk shaking data was able to be checked and the result was .570. The trunk rotation of all standing posture didn't give significant Cronbach alpha data. Reliability of anterior and posterior trunk shaking in the all position was confirmed. And the right and left trunk shaking showed that there is reliability in the partly position. And there is no reliability in the trunk rotation of all standing position.*

Improvements/Applications*: The results of this study shows the IMUs as a balance evaluation tool has moderate reliability in partial items.*

Keywords: *Static Standing Balance, Trunk Shaking, IMUs(Inertial Measurement Units), Reliability, COG(Center Of Gravity)*

1. INTRODUCTION

The balance is defined as an ability to keep COG(Center Of Gravity) in BOS(Base Of Support)[1]. A deficit of balance is the one of common problems that is treated by physical therapists[2]. The imbalance was defined by the variation of center of mass that is outside the standard age-matched reference limitation[3]. Physical therapists need to be able to distinguish between the people who have balance problems, after that, decide the optimal way for rehabilitation[2]. Balance is important factor of daily life and performance, it is used for therapy and evaluation in major of orthopedics, sports medicine, gerontology, neurology, rehabilitation[4]. Loss of balance causes problem in therapeutic intervention or rehabilitation, in addition, it causes disability that makes difficult to conduct daily life. And it causes the other injury like fall-down or fracture. Thereby, balance evaluation is important[5].

Clinically, the balance is evaluated using functional movement test(timed up and go test, functional reach, romberg test) or evaluation tool(berg balance scale, activity-specific balance confidence scale), balance measuring equipment[6]. The equipment that evaluates balance ability provides objective information, but most of the equipment is expensive and needs wide space to keep it[5].

Recent research started to depend upon wearable sensor to measure acceleration or velocity of human body during balance exercise[7]. And, recent study addresses that center of gravity is near the middle height of human body should be considered[8].

The 4th industrial revolution began recently. Ubiquitous and mobile internet and cheaper and small and stronger sensor, artificial intelligence and machine learning are feature of the 4th industrial revolution[9]. Along with start of industrial revolution, thanks to recent development of technology of microelectromechanical system, wearable sensor is becoming applicable to field of health and bio-medical technology in terms of price, size, power consumption. An example of this technological trend is the Inertial Measurement Units(IMUs)[10]. The inertial sensor device consists of an accelerometer and a gyroscope and electromagnetic machine[6]. The inertial measurement unit integrates 3-axis gyroscope and 3-axis accelerometer to measure angular velocity and acceleration, and perceives magnetic field of earth using 3-axis magnetic sensor[10].

The inertial measurement units has been used to estimate the motion of human body like motion capture[6],[10], recently it was developed for balance training and measurement[7]. Precedent research about balance training has been conducted, but there is no study that check the reliability that is essential to use that device as a measurement tool. This study aims to check the reliability of inertial measurement unit as a balance evaluation tool to utilize in this field.

2. MATERIALS AND METHODS

2.1. *Participants*

The participants of this study were 45 adults over 50 years old who use the welfare center in Seongnam-si. They fully understood and agreed on the contents of this experiment. They are able to stand independently and no

psychologic disease, and able to understand and perform the verbal indication of experimenter.

The characteristics of participants is showed in the table[Table 1].

Table 1. Physical characteristics of subjects

Issue	Mean±SD
Age(years)	21.0±1.4[a]
Body weight(㎏)	62.5±12.4
Height(㎝)	167.0±8.8

[a]Mean±SD

2.2. *Experimental method*

The participants were divided into two groups and the experimenters consisted of physical therapist "a" and "b" who has worked as a physical therapist for 10 years. Before the participants get involved, they listen about the experiment and totally understood.

The static standing balance was conducted with open eyes, closed eyes, and on an unstable surface. Each item was measured three times for 10 seconds and the next measurement was made after 3 seconds of rest after each measurement. To provide against emergencies of participants because of a fall, the experimental assist always standed-by the participants during the experiment.

To make the environment the participants can concentrate on the experiment, the experiment was conducted in enclosed area. To block the any compensation of vision, a sticker was affixed to the wall. During the experiment, the participants stood on the floor with bare foot, and they participated in the experiment after being educated to not speak except when there was discomfort.

At the first day, "A" group conducted the experiment with the physical therapist "a", and "B" group conducted the experiment with the physical therapist "b". They visited the laboratory at the next day same time, and "A" group conducted the same experiment with the physical therapist "b", "B" group conducted the same experiment with the physical therapist "a". The experimental method is shown in figure 1[Figure 1].

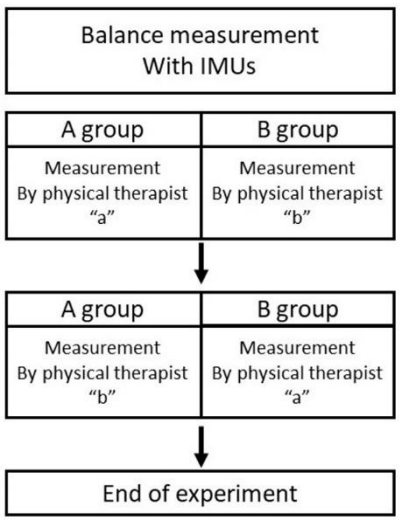

Figure 1. Experimental diagram

2.2.1. Inertial Measurement Units(IMUs)

"Balance gear(Alexia, Taiwan)" was used as an experimental tool. Balance gear is a small evaluation tool with a built-in inertial measurement units(IMUs). It is a wearable device that is used to connected to computer or laptop without any wire.

Balance gear consists of an angular velocity measurement unit contained 2 gyroscopes that could measure angular velocity and an accelerometer and a bluetooth for wireless and a dongle that accept the information from the sensor[7]. Except for these, there are a strap that could fix the balance gear on someone's back, and

locking key for shutting off the power supply, and recharging cable. The figure 2 shows part of balance gear[Figure 2]

Figure 2. Composition of balance gear

The program consists of stability test and training mode, posture control mode, limitation of stability mode. And level 1 test of stability test was used for this experiment. The figure 3 shows the balance gear screen for selecting a program[Figure 3].

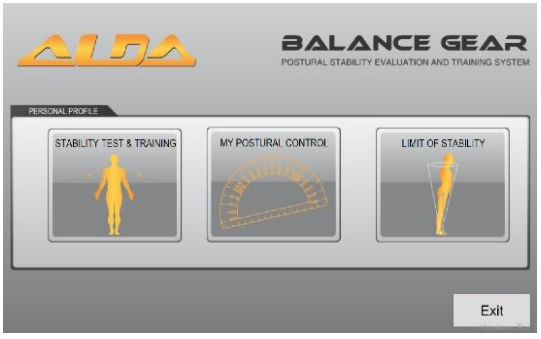

Figure 3. The programs of balance gear

The proper limitation ranges of shaking following age in each mode is provided. When the sensor over the limitation, warning horn rings. But in this experiment, to block the feedback, during the experiment, the warning horn turned off.

2.2.2. Balance pad

To provide unstable surface to participants, Balance pad(Airex, Switzerland) was supplied. Balance pad is a training tool that made with 6cm plasticized polyvinyl chloride cellular. At this experiment, the tool was used for more difficult standing test. The participants measured their standing ability as if they stand on normal floor

with staring the indicated point[Figure 4].

Figure 4. The balance pad

2.3. *Analysis method*

The collected data was statistically processed using SPSS ver. 21. The general characteristics of the subjects were analyzed using the mean and standard deviation. The angular deviation value of COG that were measured for 10 seconds were calculated the average, and the median data of 3 sets was picked as a representative data. The inter-rater consistency reliability of the selected data for each items was analyzed using the intraclass correlation coefficient. The statistical significance level was set at $\alpha < 0.05$.

3. Results And Discussion

At the standing with open eyes, the Cronbach's α coefficient for reliability between the experimenter "a" and "b" is follow as. The right and left trunk shaking(Roll) was .552, and the anterior and posterior trunk shaking(Pitch) was .626. But at the trunk rotation(Yaw), the statistical significance was .485, it was dismissed under the significance probability.

At the standing with closed eyes, the Cronbach's α coefficient for reliability between the experimenter "a" and "b" is follow as. The right and left trunk shaking(Roll) was .409, and the anterior and posterior trunk shaking(Pitch) was .623. But at the trunk rotation(Yaw), the statistical significance was .689, it was dismissed under the significance probability.

At the standing on an unstable surface, the Cronbach's α coefficient for reliability between the experiment "a" and "b" is follow as. The anterior and trunk shaking(Pitch) was .570. But at the right and left trunk shaking(Roll) and the trunk rotation(Yaw), the statistical significance were each .212, .102, it were dismissed under the significance probability.

The table 2 shows the Cronbach's α data and P-value of all items[Table 2].

Table 2. Reliability of all items

Item		Cronbach's α	P-value
Standing with open eyes	Right and left trunk shaking	.552	.004*
	Anterior and posterior trunk shaking	.626	.001*
	Trunk rotation	.011	.485
Standing with closed eyes	Right and left trunk shaking	.406	.042*
	Anterior and posterior trunk shaking	.623	.001*
	Trunk rotation	-.161	.689

Standing on an unstable surface	Right and left trunk shaking	.299	.212
	Anterior and posterior trunk shaking	.570	.003*
	Trunk rotation	.320	.102

*<0.05

4. CONCLUSION

Klaus schwab mentioned about 'Moore's Law(Generally, it means that the processor speed or the amount of transistors in central processing unit are increased doubly every 2 years)', and addressed that if anything connects to the internet, it would be possible without financial burden because of continuous growth of computing power and price reduction of hardware. Lots of people are able to purchase an intelligent sensor with reasonable price already. Over time the sensor size is getting smaller, and the amount of processing information is increasing, and the price is getting cheaper. This technique is using in a lot of area, but it hasn't affected in the field of physical therapy yet. Meanwhile, IMUs was used in the field of animation for estimation of motion of human, It was not often used for estimating and training balance ability by estimating human shaking. But, recently, precedent research addressed that the height of COG is near the human's lumbar spine, and a tool that evaluates the human's posture maintenance ability using wireless wearable sensor has been developed. There have been researches used the IMUs as a balance training tool, but no research used the IMUs as a balance evaluation tool. There was no study to use the IMUs as an evaluation tool, and therefore the purpose of this study was to check the reliability of the IMUs as a balance evaluation tool.

This study checked the inter-rater consistency reliability of IMUs as a balance evaluation tool with 45 adults over 50 years old. The participants measured their static standing balance ability with each different physical therapists using IMUs for 2 days. The measured posture was 3 type, standing with open eyes, standing with closed eyes, standing on a unstable surface, and the measured item was 3 items, right/left trunk shaking, anterior/posterior trunk shaking, right/left trunk rotation. At the result, for the anterior/posterior trunk shaking of the open eyes part and closed eyes of the test showed that the intraclass correlation coefficient was over 0.60. And for the right/left trunk shaking of standing with open eyes part of the test and anterior/posterior trunk shaking of standing on an unstable surface part of the test showed that the intraclass correlation coefficient wasn't over 0.60, but each data was 0.552, 0.570, it is close to the standard 0.60. Biorescue(RM Ingénierie, Marseille, France) is the one of general equipment that measures balance using pressure foothold. In the precedent research that checked the reliability of Biorescue shows that only partial item was over 0.60. Considering this, it is difficult to consider that there is no reliability of IMUs as a balance evaluation tool.

However, the number of participants was too small to generalize. And the experiment was conducted for 2 days, so the change of participants's body condition couldn't be considered. Besides, the precedent research by Shin joong-dal that researches sampling time for measuring balance using pressure foothold presented 60 seconds as a proper sampling time for significant value. Considering this, the sampling time of 10 seconds was considered to short to get significant value. Therefore the follow-up study needs to be progressed with consideration with this limitation.

IMUs doesn't need the wide space for storage, so it is easy to keep. And IMUs doesn't have any wire and be able to wear easily, so when the participants measure their balance, they could attend evaluation

comfortably. And the price of IMUs is lower compared to general pressure foothold sensor, it is easy to popularize.

The general balance evaluation tool using the pressure foothold estimates the straight line motion of center of gravity. But IMUs traces the center of gravity directly and measures the angular motion. Because of this, the data was from IMUs is considered to be different with existing balance measuring data. To get high reliability, it is considered to be requested to choose properly with these 2 balance measurement method.

If the follow-up study is actively carried out by adding additional research or improve upon the limitation that was mentioned, it is expected that the field of physical therapy evaluation could be developed more by utilizing various IMUs.

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