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Original Article

A study on the reliability of measuring dynamic balance ability using a smartphone

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Abstract. [Purpose] Evaluation of the reliability of smartphones as measuring equipment for dynamic balance ability was the goal of this study. [Subjects and Methods] Subjects were 30 healthy young students in their 20s. The first and second rounds of measurements were taken at a one-day interval to confirm test-retest reliability. The subjects stood on the footboard of the Biodex Balance System. Balance was measured using a smart phone. [Results] Acceleration rates corresponding to subjects with open eyes were 2.7 ± 2.2 (first measurement) and 3.3 ± 1.5 (second measurement), and the interclass correlation coefficient ICC (1,1) was 0.8. Acceleration rates corresponding to subjects with closed eyes were 4.1 ± 2.4 (first measurement) and 4.5 ± 1.8 (second measurement), and the ICC (1,1) was 0.9. Gyroscope rates corresponding to subjects with open eyes were 1.7 ± 1.2 (first measurement) and 2.3 ± 1.5 (second measurement), and the ICC (1,1) was 0.7. Gyroscope rates corresponding to subjects with closed eyes were 6.7 ± 2.4 (first measurement) and 6.6 ± 2.3 (second measurement), and the ICC (1,1) was 0.6. [Conclusion] The results of this study suggest that smartphones have sufficient potential as measuring equipment for dynamic balance ability.

Key words: Smartphone, Dynamic balance, Reliability

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INTRODUCTION

Balance is the ability to control and maintain the center of gravity of a body toward the base of support in a given environment[1)]. Even healthy individuals experience limited function once they lose their ability to balance, and evaluating balance ability makes it possible to predict the risk of falls. Therefore, objective measurement of balance ability is very important[2)]. The equipment used to measure balance ability includes Stabilometer[3)], Good Balance system[4)], BPM[5)], F-scan[6)], and Biodex Balance System[7)]. However, using such equipment requires a fairly large space and specialized training[8)]. In contrast, smartphones are readily available and do not have substantial temporal or spatial limitations. Moreover, as smartphones incorporate various sensor technologies, they may be used as measuring equipment for balance ability. Recent studies have reported on the reliability of smartphones for this function. Measurement of the shoulder range of motion using a smartphone was reported by Lim et al.[9)], and the measurement of heart rates using a smartphone was investigated by Matsumura and Yamakoshi[10)]. However, the reliability of measuring dynamic balance ability using a smartphone was considered in only a few studies. Therefore, the identification of the reliability of smartphones as measuring equipment for dynamic balance ability was the goal of this study.

SUBJECTS AND METHODS

The subjects in this study were 30 healthy young students in their 20s, attending Youngdong University in Chungbuk, South Korea. Absence of musculoskeletal or neurological disorders affecting the upper or lower extremities and lesions, and

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Fig. 1. The smartphone was attached to the skin between the third and fourth lumbar vertebrae using velcro made of spandex and a plastic bag

zero history of surgery of the spine or upper extremities were the criteria used for selecting the subjects. The subjects of the study were selected randomly from among those who met the aforementioned criteria. The mean age, height, and weight of the subjects were 22.0 ± 0.0 years, 169.2 ± 8.6 cm, and 61.9 ± 11.0 kg, respectively. Ethical approval for the study was granted by the Institutional Review Board of Youngdong University. All subjects were fully informed of the objectives and methods of the study beforehand, and informed consent to participate in the experiments was obtained from them.

The Biodex Balance System (Biodex Medical Systems, Inc., USA) was used for dynamic balance task in this study. The footboard of this system can be adjusted from Level 1 to 12 according to the level of difficulty. A lower level corresponds to a higher level of difficulty. The smartphone used in this study was a Galaxy Note 4 LTE (SM-N910 K, Samsung, Korea, 2014) with an Android 5.1.1v operating system and the application Sensor Kinetics pro (Ver.2.1.2, INNOVENTIONS Inc., USA, 2015).

The first and second rounds of measurements were taken at a 1-day interval to confirm test-retest reliability. In each round, the dynamic balance ability was measured thrice when the subjects kept their eyes open and thrice when they closed their eyes. During the measurement of balance ability, a smartphone was attached to the skin between the third and fourth lumbar vertebrae using Velcro made of spandex and a plastic bag. The subjects were instructed to stand on the footboard of Biodex Balance System with their bare feet together and each of their hands holding their opposite shoulder. The verbal order “start” was given 3 s after the application began running, and the verbal order “stop” was given around 40 s after the application stopped running (Fig. 1).

The interclass correlation coefficient (ICC) was identified using SPSS 12.0 for statistical analysis in this study. The values measured for 30 s, excluding the first and last 5 s, were extracted for use. All gyroscope values were multiplied by 1,000 because the extracted values were too small. For the acceleration and gyroscope values, the value for each of the three axes was raised to the second power, and the square root of the sum of the three resultant values was used.

RESULTS

When the eyes of the subjects were open, the acceleration rates were 2.7 ± 2.2 at the first measurement and 3.3 ± 1.5 at the second measurement, and the ICC (1,1) was 0.8. When the eyes of the subjects were closed, the acceleration rates were 4.1 ± 2.4 at the first measurement and 4.5 ± 1.8 at the second measurement, and the ICC (1,1) was 0.9. When the eyes of the subjects were open, the gyroscope rates were 1.7 ± 1.2 at the first measurement and 2.3 ± 1.5 at the second measurement, and the ICC (1,1) was 0.7. When the eyes of the subjects were closed, the gyroscope rates were 6.7 ± 2.4 at the first measurement and 6.6 ± 2.3 at the second measurement, and the ICC (1,1) was 0.6 (Table 1).

Table 1. Reliability study of dynamic balance abilities measure using a smartphone

		Mean ± SD		ICC
		First	Second	
Acceleration[1)]	Open eye	2.7 ± 2.2	3.3 ± 1.5	0.8
	Closed eye	4.1 ± 2.4	4.5 ± 1.8	0.9
Gyroscope[2)]	Open eye	1.7 ± 1.2	2.3 ± 1.5	0.7
	Closed eye	6.7 ± 2.4	6.6 ± 2.3	0.6

[1)] Acceleration: $\sqrt{x^2+y^2+z^2}$

[2)] Gyroscope: $\sqrt{\text{Yaw}^2+\text{Pitch}^2+\text{Roll}^2}$

DISCUSSION

The use of smartphones as measuring equipment is being continuously explored. Anterior and posterior stability were measured using the Biodex Balance System and a smartphone by Patterson et al.; no statistically significant difference was reported between the two sets of values[11)]. In agreement with this previous study, statistically significant conformity was confirmed in this study too when dynamic balance ability was measured using a smartphone. Timed up-and-go tests conducted using a smartphone were found to be sufficiently reliable and accurate by Galán-Mercant et al.[12)]; In contrast to the present study, an iPhone and a different set of tasks were used in the study of Galán-Mercant et al. Therefore, the two studies are not directly comparable. However, given that in both studies, an inertial sensor in a smartphone was used to identify the potential of a smartphone as the measuring equipment for determining balance ability, similar results have been obtained for both. Good Balance System's inter-examiner reliability for postural sway measurement in post-stroke patients was reported to be 0.69 to 0.93 by Ha et al[13)]. Biodex Balance System's intra-examiner reliability for dynamic balance ability when the subjects stood on one foot was reported to be 0.8 Arifin and Abu[14)]. The peak pressure over the metatarsal heads proved to have the best indices of reliability at approximately 0.8, and the equivalents for the heel, whole foot, and hallux ranged from 0.5 to 0.8 according to the study by Ahroni et al[15)]. In relation to this, in the present study, an index of at least 0.7 was obtained for all items, except the ICC of the gyroscope values, when the subjects closed their eyes. In particular, the ICC of all acceleration values was at least 0.8, showing a high level of conformity. This suggests that smartphones have sufficient potential as measuring equipment for dynamic balance ability. While the existing expensive devices designed to measure balance ability can provide more varied and specific data regarding balance ability, including sway length, sway area, and sway speed, this study indicates that using a smartphone can present highly limited data regarding balance ability. While the problem of limited data will be overcome to a certain extent with the future development of specialized applications, they are unlikely to replace the existing expensive devices entirely. However, smartphones may be highly useful in environments in which an expensive device has not been introduced or when dynamic balance ability should be measured in a few hours or immediately. Therefore, based on the findings of this study, specialized applications should be developed to measure dynamic balance ability using smartphones. In addition, future studies should address various dynamic tasks in terms of the level of difficulty, ages, diseases, and types of smartphones.

REFERENCES

1) Alabdulwahab SS, Kachanathu SJ, Oluseye K: Physical activity associated with prayer regimes improves standing dynamic balance of healthy people. J Phys Ther Sci, 2013, 25: 1565–1568. [Medline] [CrossRef]
2) Jarnlo N: Functional balance tests related to falls among elderly people living in the community. Eur J Geriatr, 2003, 5: 7–14.
3) Urushihata T, Kinugasa T, Soma Y, et al.: Aging effects on the structure underlying balance abilities tests. J Jpn Phys Ther Assoc, 2010, 13: 1–8. [Medline] [CrossRef]
4) Cho K, Lee K, Lee B, et al.: Relationship between postural sway and dynamic balance in stroke patients. J Phys Ther Sci, 2014, 26: 1989–1992. [Medline] [CrossRef]
5) Lee CW, Kim SG, Na SS: The effects of hippotherapy and a horse riding simulator on the balance of children with cerebral palsy. J Phys Ther Sci, 2014, 26: 423–425. [Medline] [CrossRef]
6) Park S, Ko YM, Park JW: The correlation between dynamic balance measures and stance sub-phase COP displacement time in older adults during obstacle crossing. J Phys Ther Sci, 2013, 25: 1193–1196. [Medline] [CrossRef]
7) Akbari A, Sarmadi A, Zafardanesh P: The effect of ankle taping and balance exercises on postural stability indices in healthy women. J Phys Ther Sci, 2014, 26: 763–769. [Medline] [CrossRef]
8) Chang WD, Chang WY, Lee CL, et al.: Validity and reliability of Wii fit balance board for the assessment of balance of healthy young adults and the elderly. J Phys Ther Sci, 2013, 25: 1251–1253. [Medline] [CrossRef]
9) Lim JY, Kim TH, Lee JS: Reliability of measuring the passive range of shoulder horizontal adduction using a smartphone in the supine versus the side-lying

position. J Phys Ther Sci, 2015, 27: 3119–3122. [Medline] [CrossRef]
10) Matsumura K, Yamakoshi T: iPhysioMeter: a new approach for measuring heart rate and normalized pulse volume using only a smartphone. Behav Res Methods, 2013, 45: 1272–1278. [Medline] [CrossRef]
11) Patterson JA, Amick RZ, Thummar T, et al.: Validation of measures from the smartphone sway balance application: a pilot study. Int J Sports Phys Ther, 2014, 9: 135–139. [Medline]
12) Galán-Mercant A, Barón-López FJ, Labajos-Manzanares MT, et al.: Reliability and criterion-related validity with a smartphone used in timed-up-and-go test. Biomed Eng Online, 2014, 13: 156. [Medline] [CrossRef]
13) Ha H, Cho K, Lee W: Reliability of the good balance system(®) for postural sway measurement in poststroke patients. J Phys Ther Sci, 2014, 26: 121–124. [Medline] [CrossRef]
14) Arifin N, Abu Osman NA, Wan Abas WA: Intrarater test-retest reliability of static and dynamic stability indexes measurement using the Biodex Stability System during unilateral stance. J Appl Biomech, 2014, 30: 300–304. [Medline] [CrossRef]
15) Ahroni JH, Boyko EJ, Forsberg R: Reliability of F-scan in-shoe measurements of plantar pressure. Foot Ankle Int, 1998, 19: 668–673. [Medline] [CrossRef]