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Reliability and Validity of the Postural Balance Application Program Using the Movement Accelerometer Principles in Healthy Young Adults

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Abstract

The purpose of this study was to determine the reliability and validity of the postural balance program which uses the movement accelerating field principles of posture balance training and evaluation equipment and smartphone movement accelerometer program (SMAP) in healthy young adults. A total of 34 people were appointed as the subject among the healthy young adults. By using Biodex stability system (BSS) and SMAP on the subject, the posture balance capability was evaluated. For the test-retest reliability, SMAP showed the intra-class correlation (ICC: .62～.91) and standard error measurement (SEM: .01～.08). BSS showed the moderate to high reliability of ICC (.88～.93) and SEM (.02～.20). In the reliability of inter-rater, ICC (.59～.73) as to SMAP, showed the reliability of moderate in eyes open stability all (EOSA), eyes open stability anterior posterior (EOSAP), eyes open stability medial lateral (EOSML) and eyes open dinamic all (EODA), eyes open danamic anterior posterior (EODAP), and eyes open danamic medial lateral (EODML). However, ICC showed reliability which was as low as .59 less than in other movements. In addition, BSS showed the reliability of high as ICC (.70～.75). It showed reliability which was as low as ICC (.59 less than) in other movements. In correlation to the balance by attitudes between SMAP and BSS, EOSML (r=.62), EODA (r=.75), EODML (r=.72), ECDAP (r=.64), and ECDML (r=.69) shown differ significantly ($p<.05$). However, the correlation noted in other movements did not differ significantly. Therefore, SMAP and BSS can be usefully used in the posture balance assessment of the static and dynamic condition with eyes opened and closed.

Key Words: Accelerometer; Postural balance; Reliability; Validity.

Introduction

Balance is an essential component for performance of movements in daily life and it is an ability that maintains one's body in a state of balance (Shumway-Cook and Horak, 1986). The ability to manage balance of postures is defined by an ability to maintain the center of gravity of one's body with minimum agitation of posture on a base of support in reaction to external force or when one moves one's own body voluntarily (Nichols et al, 1995).

Damage in balance control can cause injury in stability, delay in reaction time and irregular pattern of posture reaction (Boucher et al, 1995). Nitz and Choy (2004) considered decline in proprioceptional sense function, delay in reflexes, blurring in posture due to muscular weakness, decline in coordination of knee and ankle, and decline in flexibility. As a result of these, injury from falling can be accompanied by psychological and sociological damage and there are many studies being performed to prevent and treat injuries caused by falling (Barnett et al, 2003; Gardner et al, 2000).

In order to assess postural balance, Biodex stability system (BSS) has been recently adopted to assess postural balance objectively under static and

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active stress. In precedent research, interclass correlation (ICC) of assessment with fixed stability ranged from .44 to .95 (Cachupe et al, 2001; Hinman, 2000; Pincivero et al, 1997), and ICC of one-leg standing assessment by Arnold and Schmitz (1998) ranged from .42 to .82.

There do exist disadvantages that postural ability assessing equipment is high-priced and assessment methods are complicated which requires specialized knowledge and separate programs. However, utilization of postural balance application through smart phones can complement such advantages. With such drastic growth in the smart phone market, large numbers of applications are being used. Recently developed smart phones have various motion acceleration systems installed within the device which can perform the functions of postural assessment. A motion accelerometer attached at the waist records and saves information regarding energy consumption and the number of steps every minute. Energy consumption is estimated according to the level of physical motion (Pambianco et al, 1990). In measuring energy consumption, a motion accelerometer consisting of a single axis appeared to be significantly correlated when compared to a standard parameter (r=.94) and a motion accelerometer (r=.99) consisting of three axis displayed r range from .86 to .96 during consistent walking (Jakicic et al, 1999; Levine et al, 2001). In contrast to a single axis accelerometer which physical motion can be assessed in multiple directions measured acceleration of a perpendicular plane, an accelerometer consisting of two and three axis senses two-dimensional and three-dimensional motion (Montoye et al, 1983). A method to attach a motion sensor to a subject's waist or ankle to estimate energy consumption can allow data be processed with computers by assessing hourly energy consumption, intensity, frequency, duration, and steps. By perceiving the motion of a passometer that assesses vertical motion by attaching sensors to waist, wrist and ankle as well as an actometer which measures a rotary motion by perceiving the motion of spring, data related to active mass can be obtained but it carries the disadvantage of its inability to obtain information relating to postural condition of a body (Welk et al, 2000). On the other side, if an acceleration sensor that measures gravity acceleration and velocity acceleration is used, acute measurement of postural condition of the body and degree of activity can be measured and various studies are being conducted on this subject (Najafi et al, 2003).

Postural balance assessing application that utilizes a motion accelerometer program that can be purchased for a cheap price or without any fee and controls are simple so its applicability is high in assessing postural balance. However, there exists no precedent studies related to this subject. Therefore, a smartphone movement accelerometer program (SMAP) that uses the principles of a motion accelerometer, which has its base in a smart phone, is tested for reliability and validity with the intention of using it as convenient tool to assess postural balance in daily life.

Methods

Subjects

This study investigated 34 subjects (male; 17, female; 17) who agreed to the study that are not currently using medicine and composed of people in similar age groups in order to minimize any disparity in postural ability. Also subjects consist of adults who carry established proprioceptical function, visual and vestibular centripetalism. We asked for the agreement of all participants in this study after we explained the purpose of the study. Common characteristics of study subjects are as follows in Table 1.

Table 1. Characteristics of the subjects (N=34)

Variables	Mean±SD	Range
Age (yrs)	28.5±3.5	23～38
Height (㎝)	167.8±7.9	153～184
Weight (㎏)	62.5±10.7	43～87

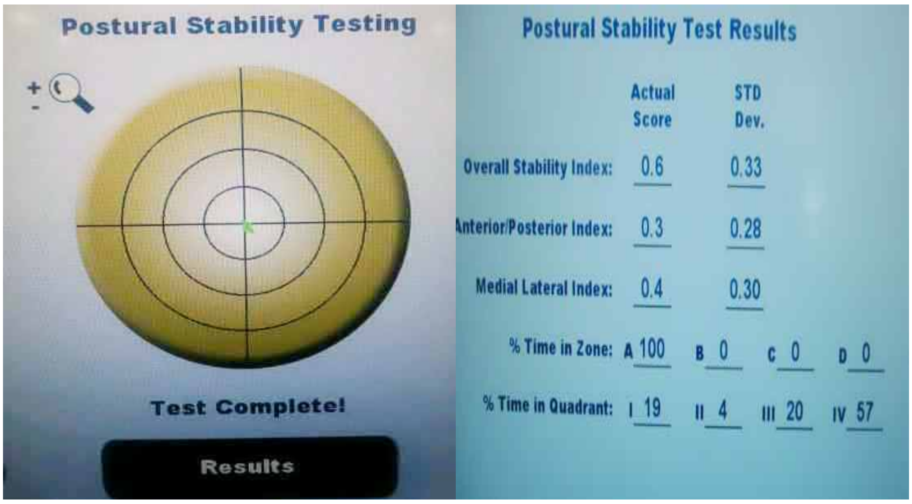

Figure 1. Biodex stability system.

Instruments and Measurement

Biodex stability system

The Biodex stability system (Biodex Medical Systems Inc., NY, USA) used in this study contained four strain gauges under a circular platform in order to measure the displacement of center of pressure (COP) at a sampling rate of 20 Hz. For the overall stability index (OSI), medial lateral stability index (MLSI) and anterior posterior stability index (APSI) stability scores, these indices were the measures of standard deviation, which were assessed along the path of sway around the zero point from the center of the platform of BSS. The units were recorded in degrees. The foot displacements that occurred on the medial-lateral (ML) axis were labeled as x-direction, while those on the anterior-posterior (AP) axis were labeled as y-direction, and these variables were measured as the MLSI and APSI respectively (Figure 1).

Smartphone movement accelerometer program

Each program which is installed separately in each smart phone is motion accelerometer programs (Balance test, Y-medical, Gwangju, Korea) based on the Android operating system. These programs utilized momentary acceleration of a cellular phone to conduct assessment using the built in accelerometer

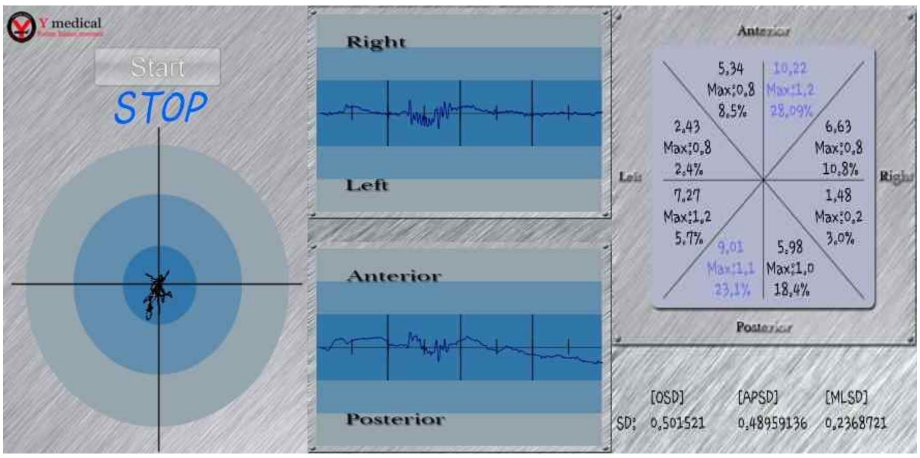

Figure 2. Smartphone movement accelerometer program.

Figure 3. Biodex stability system and Smartphone measurement.

based on the x, y, and z axis. It records one dot every 60 ㎳ and 1000 dots per minute. The data process is conducted by dividing a horizontal plane into eight planes and data is processed in each plane. The data process includes sum of data points distributed from each plane, distance between origin and furthest data point, and percentage of dots located in particular plane (Figure 2).

Procedures

Assessment of balance capability is conducted with BSS (ICC .44~.95) (Cachupe et al, 2001; Hinman, 2000; Pincivero et al, 1997) and motion accelerometer program. These measures represent the amount of deviation from the baseline position (Arnold and Schmitz, 1998). BSS can assess subject's maintenance of balance and movement of weight while an subject stands on a foothold that swings vertically and horizontally which consists of twelve levels according to level of difficulty. In order to have an identical assessment environment at stage 12, the most static stage, and at stage 6, the most kinetic stage, the smart phone which was placed at the center of the foothold is attached using velcro and both units were started simultaneously (Figure 3). The posture was categorized into a static posture with eyes opened and closed and a kinetic posture with eyes opened and closed. Scores of overall status, rear and front, and left and right were assessed separately for each category. The Intra-rater experimental method was measured through test-retest to obtain ICC and standard error of measurement (SEM). For inter-rater method, different examiners were divided into rater A and B Rater B then conducted experiment three days after rater A conducted the experiment in order to prevent learning effect when assessing reliability. Prior to experimentation, subjects conducted 5 sets of practices and had meetings to ensure standardization of experiment execution.

Statistical Analysis

In processing data, a commercialized window SPSS (Statistical Package for the Social Sciences) ver. 18.0 program was used. In order to test reliability between intra-rater and inter-rater of the motion accelerometer program ICC was obtained. Munro's classification for reliability coefficcients was used to report the degree of reliability .00 to .25 little, if any correlation .26 to .49 low correlation, .50 to .69 moderate correlation .70 to .89, high correlation, and .90 to 1.00 very high correlation (Domholdt, 2005). For validity, pearson correlation was calculated for correlation between Biodex and the motion accelerometer program. The level significance was set at $p<.01$ for all statistical tests.

Results

Intra-rater reliability

Intra-rater reliability was tested with subjects that stand with two-legs with eyes opened and closed in the most static stage, level 12 and level 6 which gives most dynamic task (ICC .60~.95) (Pincivero et al., 1997; Schmitz and Arnold, 1998). As a result, eyes open stability medial lateral (EOSML) had lowest ICC of .62 and eyes open dynamic anterior posterior (EODAP) had highest ICC of .91 for SMAP indicating highest level reliability. SEM ranged from .01 to .08. Also for BSS, EOSML and eyes close dynamic medial lateral (ECDML) had lowest ICC of .88 and eyes open stability all (EOSA) carried ICC of .93 displaying highest level of reliability. SEM ranged from .02 to .20 (Table 2).

Inter-rater reliability

The reliability between SMAP and BSS was assessed by two physical therapists that have over 10 years of clinical experience. As a result, ICC of EOSA, EOSAP, EOSML, ECSA, ECSAP, and ECSML ranged from .59～.73 displaying a reliability for SMAP and ICC of rest actions was below .59 indicating a low level of reliability (Table 3).

Validity

Validity related to standards was measured through coefficient of correlation of each BSS and SMAP. As a result, EOSML (r=.62), EODA (r=.75), EODML (r=.72), ECDAP (r=.64), ECDML (r=.69) displayed significant correlation ($p<.001$) and no significant correlation was found in rest of actions (Table 4).

Discussion

In this study targeting 34 adults male and female in healthy condition, validity and reliability were assessed through inter-examiner and intra-examiner test-retest method that assessed subjects in two leg standing static position with eyes opened and closed (BSS stage 12) and in two leg standing kinetic position with eyes opened and closed (BSS stage 6). This was conducted through comparison between assessment tools of BSS and SMAP which uses a principle of motion accelerometer. Originally, a force plate was used to measure fluctuations in center of pressure in order to standardize balance control and assess static and kinetic balance as well. Also a force plate is used to train postural balance control through bio-feedback (Goldie et al, 1989; Goldie et al, 1992; Hamman et al, 1992; Hocherman et al, 1984). BSS is used to assess postural balance under stimulation given anterior, posterior, medial and lateral axis of the circular platform (Arnold and Schmitz, 1998; Griend and Testerman, 1999). Also among

Table 2. Intra-rater reliability for the Smartphone movement accelerometer program and Biodex stability system (test and retest) (N=34)

Movements	SMAP[l]		BSS[m]	
	ICC[i] (95%CI[j])	SEM[k]	ICC (95%CI)	SEM
EO[a]/SA[c]	.85(.72∼.92)	.01	.93(.87∼.96)	.03
EO/SAP[d]	.75(.55∼.86)	.01	.92(.85∼.96)	.02
EO/SML[e]	.62(.36∼.79)	.01	.88(.78∼.94)	.02
EO/DA[f]	.88(.77∼.93)	.02	.92(.85∼.96)	.03
EO/DAP[g]	.91(.83∼.95)	.02	.92(.84∼.96)	.03
EO/DML[h]	.89(.80∼.94)	.02	.90(.82∼.95)	.02
EC[b]/SA	.69(.47∼.83)	.01	.92(.85∼.96)	.10
EC/SAP	.85(.72∼.92)	.02	.91(.84∼.95)	.10
EC/SML	.76(.57∼.87)	.02	.90(.82∼.95)	.04
EC/DA	.77(.60∼.88)	.05	.90(.80∼.94)	.20
EC/DAP	.90(.82∼.95)	.08	.90(.82∼.95)	.17
EC/DML	.84(.71∼.92)	.07	.88(.77∼.93)	.13

[a]eyes open, [b]eyes close, [c]stability all, [d]stability anterior posterior, [e]stability medial lateral, [f]dynamic all, [g]dynamic anterior posterior, [h]dynamic medial lateral, [i]intraclass correlation coefficient, [j]confidence interval, [k]standard error of measurement, [l]smartphone movement sccelerometer program, [m]biodex stability system.

Table 3. Inter-rater reliability for the smartphone movement accelerometer program and Biodex stability system (N=34)

Movements	SMAP[k]		BSS[l]	
	ICC[i]	95% CI[j]	ICC	95% CI
EO[a]/SA[c]	.65	.48~.81	.75	.56~.86
EO/SAP[d]	.59	.32~.77	.45	.13~.68
EO/SML[e]	.64	.39~.80	.53	.23~.73
EO/DA[f]	.08	-.25~.40	.16	-.18~.47
EO/DAP[g]	-.01	-.34~.32	.19	-.14~.49
EO/DML[h]	.06	-.38~.28	.13	-.20~.45
EC[b]/SA	.73	.52~.85	.70	.48~.84
EC/SAP	.72	.51~.85	.37	.04~.62
EC/SML	.62	.36~.79	.56	.29~.75
EC/DA	.09	-.24~.41	.26	-.81~.54
EC/DAP	.03	-.29~.36	.15	-.19~.46
EC/DML	.08	-.25~.40	.46	.15~.69

[a]eyes open, [b]eyes close, [c]stability all, [d]stability anterior posterior, [e]stability medial lateral, [f]dynamic all, [g]dynamic anterior posterior, [h]dynamic medial lateral, [i]intraclass correlation coefficient, [j]confidence interval, [k]smartphone movement sccelerometer program, [l]biodex stability system.

Table 4. Pearson correlation for the smartphone movement accelerometer program and Biodex stability system

Movements	Correlation with SMAP[i] and BSS[j]
EO[a]/SA[c]	.31
EO/SAP[d]	.08
EO/SML[e]	.62*
EO/DA[f]	.75*
EO/DAP[g]	.44
EO/DML[h]	.72*
EC[b]/SA	.25
EC/SAP	.12
EC/SML	.16
EC/DA	.32
EC/DAP	.64*
EC/DML	.69*

[a]eyes open, [b]eyes close, [c]stability all, [d]stability anterior posterior, [e]stability medial lateral, [f]dynamic all, [g]dynamic anterior posterior, [h]dynamic medial lateral, [i]smartphone movement sccelerometer program, [j]biodex stability system, *p<.01.

many precedent studies, many studies conducted their investigations on postural balance and standing position. Ku et al (2012) reported in his study which examined postural balance using BSS targeting 30 adults in normal condition that there existed some disparity between OSI, APSI, and MLSI and significant disparity observed between OSI and APSI, OSI and MLSI, and APSI and MLSI as a result of posterior tests. This indicates that stability of posture can be affected according to position of the toes. Also studies on the importance of knee location in body stability are conducted by some researchers. According to reliability test of BSS scales, OSI, APSI, and MLSI of those female subjects out of 21 female subjects who maintained overall knee straight without spatial feedback for thirty seconds (OSI ICC=.88, APSI ICC=.87, MLSI ICC=.79) created better results in bland and altman assessment than those with subjects who bent their knees slightly (OSI ICC=.93, APSI ICC=.90, MLSI ICC=.89) and had higher OSI and APSI than those with subjects who bended their knees at right angles which indicated by values OSI (p=.001) and APSI (p=.024) (Pereira et al, 2008). As shown above, it is indicated that stability can change according to alterations of knee locations. In this study, ICC ranged from .88 to .93 under conditions with opened and closed eyes in BSS. This result displays an outcome similar to that of Arnold and Schmitz (1998) which displayed ICC of .82. Also when validity was tested with SMAP under identical condition as BSS, other positions displayed very high levels of reliability indicated by r=.92 even though EOSML carried moderate levels of reliability indicated by ICC (r=.62). Therefore it is assumed that SMAP can also be used as a tool for postural assessment in clinical experiments. However, results of reliability tests between BSS and SMAP carried moderate levels of reliability (ICC, r=.59∼.73) only among EOSA, EOSAP, EOSML, ECSA, ECSAP and ECSML, and the level of ICC is as low as that reliability was in doubt under conditions of posture with eyes closed. This indicates that the condition of closed eyes cannot be used for postural balance assessment through SMAP due to low reliability. For correlation between assessment results of SMAP and BSS, there appeared to be moderate to high correlations in EOSML (r=.62), EODA (r=.75), EODML (r=.72), ECDAP (r=.64), and ECDML (r=.69) and low correlations were present in rest of the postures. This indicates that when SMAP is used to assess EOSML, EODA, EODML, ECDAP, ECDML postures, results that are similar to that of assessments conducted through BSS will be displayed. Likewise, it can be assumed that reliability related to assessed posture and postural fluctuation are affected by various environmental factors of assessment tools, age, gender and etc. (Baker et al, 1998). In this study, even though those factors mentioned above were not completely controlled, this assessment, which used BSS and SMAP based on the principle of motion accelerometer, is a reliable one that offers varied information about the postural balance of normal adults.

Conclusion

This study demonstrated that validity and reliability were assessed through inter-examiner and intra-examiner test-retest method that assessed kinetic position with eyes opened and closed in healthy subjects. This was conducted through comparison between assessment tools of BSS and SMAP which uses a principle of motion accelerometer. Obtained coefficients of intraclass correlation of SMAP through intra-examiner test-retest methods based on built in SMAP displayed high levels of reliability in both static and kinetic balance while displaying high levels of reliability with BSS indicated by coefficient of intraclass correlation. Based on this result, it is assumed that the program will be practical considering that SMAP created results similar to that of BSS through balance assessment in EOSML, EODA, EODML, ECDAP, and ECDML and it has an ability to assess overall, rear and front, and left and right balance in static and kinetic condition with eyes opened.

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