SMART PHONE AS A STANDING BALANCE ASSESSMENT DEVICE

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Abstract

Balance plays important role in postural control and force production in artistic gymnastics and can be used as injury prevention. Therefor balance should be monitored during the training process. Many different protocols have been used to assess balance. Recently there were proposals made to include new technologies such as smart phones in various assessment protocols. In present research, we compared a balance assessment protocol on a T shaped tilt board with smart phone application and G-weight goniometer balance assessment protocol. Thirty different positions in x-axis and thirty different positions in y-axis were used as a criteria acquired with two smart phones and one G-weight goniometer. We acquired also one real time measurement for 10 seconds on the T shaped tilt board. We found out a very strong and positive correlation between smart phone application and G-weight goniometer. Cronbach's alpha showed very high reliability of the smart phone measures. The limits of agreement showed that the measurement with the smart phone could be 0.85° below or 3.23° above in x-axis and 0.09° below or 2.96° above in y-axis the goniometer. Both smart phones share a very similar displacement-time curve. To sum up, the smart phones with its measurement characteristics are reliable and valid enough for monitoring balance on T shaped tilt board for practical use but are not precise enough for the research use.

***Keywords**: Artistic Gymnastics, Evaluation, Panel Judging, Bias.*

INTRODUCTION

Humans are from balance point of view quiet unstable system with multiple segments to control over a relatively small base of support. Balance can be defined as the ability to maintain the body's centre of gravity (COG) within the base of support that involves the use of sensory information and its integration with muscle contractions (Kirby, Price & MacLeod, 1987).

Artistic gymnastics (AG) is a sport that requires a great sense of balance. It plays important role in postural control and force production while performing difficult gymnastic elements and landings. Many factors influence gymnastics postural control and force production performance, which include sensory information, motor responses and attention demands (Horak, 1987, Vuillerme & Nougier, 2004). The gymnasts are mostly exposed to above-mentioned factors when performing difficult gymnastics skills and/or at competitions. Difficult gymnastics skills demand high level of sensory utilization for good postural orientation, high level of coordination, strength and joint range of motion in order to produce appropriate force direction and magnitude. Gymnasts have to focus their attention on the skill execution and not let other environmental factors distract them.

The aesthetic note of the AG demands from the athletes balanced and controlled execution. Landings are present in every gymnastics discipline and are being assessed by judges not only in artistic gymnastics, but also in acrobatic gymnastics, trampoline, rhythmic gymnastics, aerobic gymnastics and gymnastics for all. Landings in artistic gymnastics are parts of gymnastics routines where most of mistakes happen because of lack of balance (Marinšek, 2009, 2010). Somersault twists are mostly the reason, which causes landing asymmetries and thus lack of balance (Marinšek & Čuk, 2013). In most of gymnastics disciplines, static as well as dynamic balance is demanded. Motionless balance skills, holds on reduced base of support, such as various static holds in pyramids (Figure 1) and other leaping and tumbling skills are part of every gymnastics disciplines.

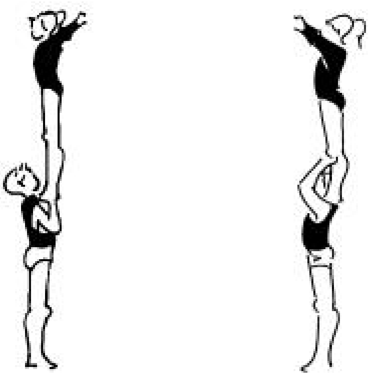

Figure 1: Stand in hand or on shoulder (Acrobatic Gymnastics Code of Points 2013-2016, FIG, 2013)

Balance training can improve postural control (Heitkamp, Horstmann, Mayer, Weller & Dickhuth, 2001, Granacher, Gollhofer & Strass 2006, Myer, Ford, Brent & Hewett, 2006, Yaggie & Campbell 2006, Beck et al., 2007, Gruber et al. 2007a, Taube et al., 2007a), has also a great impact on strength and jumping abilities (Bruhn, Kullmann & Gollhofer, 2004, Gruber & Gollhofer 2004, Kean, Behm & Young, 2006, Gruber et al., 2007b, Taube et al., 2007b, Tsopani et al., 2014) and can be used as injury prevention in elite sport.

Balance can be developed with different training devices such as tilt boards, half discs, soft mats (Heitkamp et al., 2001, Gruber & Gollhofer 2004, Taube, Gruber & Gollhofer, 2008), and sport specific movements on all gymnastics apparatus (Bressel, Yonker, Kras & Heath, 2007).

Numerous assessment protocols have been developed to provide important information on balance progress. Various protocols on tilt boards and force plates have been used as well as other tests such as Star Excursion Balance Test (Filipa, Byrnes, Paterno, Myer & Hewett, 2010) and Y Balance Test (Plisky et al., 2009).

Previous research indicates attempts to use other popular technologies for postural control and force production assessment such as Wii Balance Board (Clark et al., 2010), EquiTest t computerized dynamic posturography system (Tsopani et al., 2014), accelerometer-embedded springboard (Čuk, Penič & Križaj, 2011). These technologies can come into wide use because of their portability, inexpensiveness and availability. One of the most popular and widespread electronic devices nowadays which is equipped with a large set of embedded sensors is a smart phone.

Increasing number of smart phones enhances the number of applications used in smart phones. Recently, the application for the balance test has been developed. The application measures angle displacements on a T shaped tilt board in frontal and sagittal plane. The data can be exported to the excel worksheet and used for further analysis.

The aim of this study was to compare measurement reliability between a G-weight goniometer and the balance test application on two different smartphones for various positions on a T shaped tilt board. Our hypothesis was that a smart phone measurement would provide reliable output in comparison to the G-weight goniometer measurements regardless of the smart phone model used.

METHODS

Apparatus

Two smart phones Huawei Ascend P6 (OS: Android OS, v4.2.2 CPU: Quad-core 1.5 GHz) and Samsung I9100 Galaxy S II (OS: Android OS, v2.3.4 CPU: Dual-core 1.2 GHz Cortex-A9) with balance test application and G-weight goniometer (Winkelmesser BMI) were used.

For determining the orientation of the device, one can use the rotational vector sensor, which is either of software or hardware type. Usually the rotation vector sensor fuses data from three different sensors: accelerometer, gyro and magnetic field sensor. Additional rotation vector sensors can be available on the Android device. By default, our program chooses the software sensor, whose vendor is Google Inc. and its version is 3. This sensor is part of The Android Open Source Project. If this sensor is not present then the default rotation vector sensor is chosen. Based on the data provided by the sensor we calculate the rotation matrix from which we derive the orientation of the device. When the device is lying on the horizontal plane with screen up the angle in the x- and y-axes is 0°. The application can be downloaded from https://play.google.com/store/apps/details?id=org.slani.balancetest.

Procedures

Thirty different positions (15 in positive and 15 in negative side) in x-axis and thirty different positions (15 in positive and 15 in negative side) in y-axis were used as a criteria. We acquired position (in degrees) in x- and y-axis randomly for G-weight goniometer and both smart phones. The acquired data was used to examine the eventual measurement errors of smart phones.

After initial position acquirement, we acquired one real time measurement for 10 seconds on the T shaped tilt board. The tilt board was moved randomly simulating balance assessment protocol and recorded with both smart phones. The acquired data was used for comparison of displacement-time curve in x- and y- axis between both smart phones.

Statistical analysis and data processing

Kolmogorov Smirnov test was used to test the data distribution. The measurement error was evaluated by the relative absolute error (RAE). The data gathered by smart phones was compared to the G-weight goniometer representing the gold standard for measuring range of motion. The t-test for paired data was calculated in order to find out the differences between G-weight goniometer and both smart phones. Additionally Pearson’s correlation coefficient (PCC) was used to find out correlations between G-weight goniometer, Huawei, and Samsung smart phones. With respect to internal consistency, Cronbach's alpha was calculated in order to evaluate the reliability of the survey measures. The alpha value of 0.70 to 0.80 are regarded satisfactory for group comparison and 0.90 to 0.95 for individual comparison (Bland and Altman, 1997). As proposed by Bland and Altman (1986) an analysis of 95% limits of agreement (LoA) was performed to compare absolute reliability between the G-weight goniometer and smart phone measurements.

RESULTS

Kolmogorov-Smirnov test showed that distributions of the variables significantly do not deviate from normal distribution (p>0.01, Table 1). The differences in the mean values of the measurements were statistically significant in x- (p<0.001) and y- axis (p<0.001). Samsung smart phone showed smaller difference to the G-weight goniometer (diff=0.753°) in comparison to Huawei smart phone (diff=1.18°) in x-axis. In y-axis the difference to the G-weight goniometer was smaller for the Huawei smart phone (diff=1.043°) than for the Samsung (diff=1.477°) (Table 1).

SEM for goniometer and smart phones ranged from 2.050° to 2.243° in x-axis and from 2.023° to 2.210° in y-axis (Table 1), suggesting consistency of the measurements. Relative absolute error compared to goniometer, which can be considered as gold standard is 0.85° and 1.48° for Samsung in x- and y-axis, and 1.19° and 1.07° for Huawei, respectively (Table 1)

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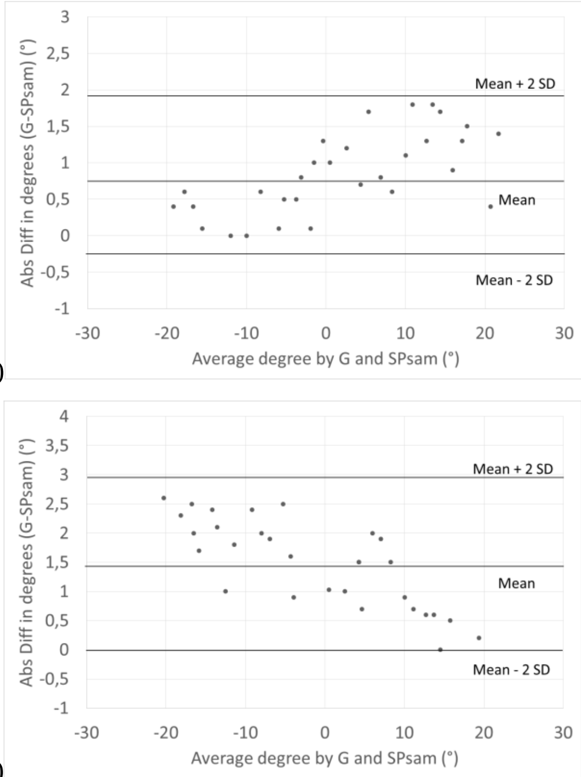
Table 1. *Descriptive statistics, distribution and difference between G-weight goniometer and smart phone measurements.*

		N	Mean±SD (°)	RAE	SEM	P (K-S)	t	P(t)
Pair 1	xG	30	1.667±11.742	/	2.144	0.200	-5.974	0.000
	xSPsam	30	2.420±12.286	0.85	2.243	0.200		
Pair 2	xSPsam	30	2.420±12.286	0.85	2.243	0.200	7.485	0.000
	xSPhua	30	0.487±11.229	1.19	2.050	0.200		
Pair 3	xG	30	1.667±11.742	/	2.144	0.200	6.165	0.000
	xSPhua	30	0.487±11.229	1.19	2.050	0.200		
Pair 4	yG	30	-0.667±11.513	/	2.102	0.200	10.794	0.000
	ySPsam	30	-2.144±12.107	1.48	2.210	0.200		
Pair 5	ySPsam	30	-2.144±12.107	1.48	2.210	0.200	-2.269	0.031
	ySPhua	30	-1.710±11.078	1.07	2.023	0.200		
Pair 6	yG	30	-0.667±11.513	/	2.102	0.200	8.916	0.000
	ySPhua	30	-1.710±11.078	1.07	2.023	0.200		

Legend: N – numerous, Mean – mean value, SD – standard deviation, RAE - relative absolute error, SEM - standard error mean, P(K-S) – Sig. Kolomogorov Smirnov test, t – t value, P(t) – Sig. paired t test

Table 2. *Corelations between G-weight goniometer and smart phone measurements in x- and y- axis.*

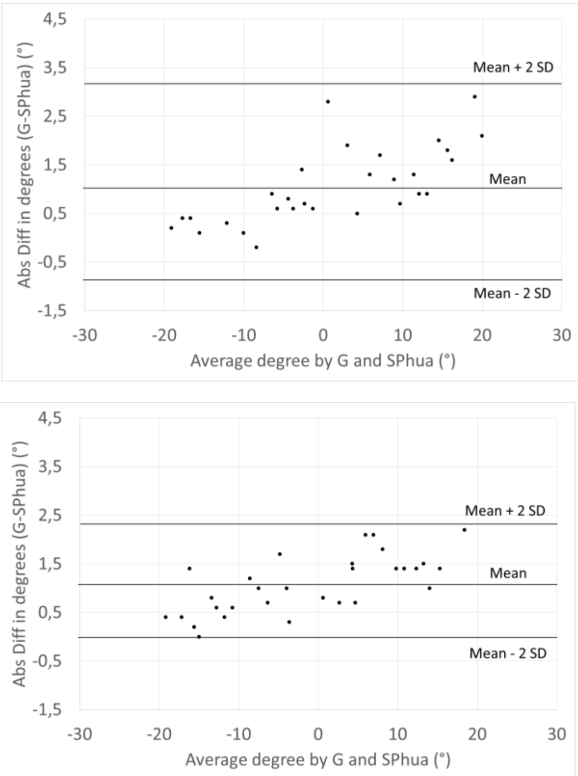
	xSPsam	xSPhua	ySPsam	ySPhua
xG	.999	.997		
yG			.999	.999



(A)

(B)

Figure 2. *Bland – Altman plots for the comparison between G-weight goniometer and Samsung smart phone in (A) x-axis and (B) y-axis.*



(A)

(B)

Figure 3. *Bland – Altman plots for the comparison between G-weight goniometer and Huawei smart phone in (A) x-axis and (B) y-axis.*

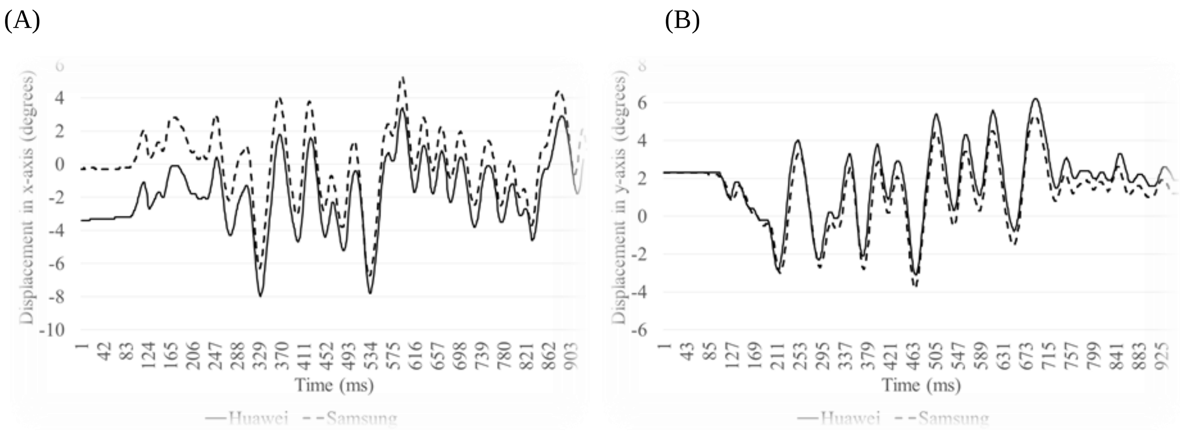


Figure 4. *Comparison of displacement (degrees) in (A) x-axis and in (B) y-axis for Huawei and Samsung smart phones.*

All Person's correlations are very high in x-axis ($r_{xG-xSPsam}$=.999; $r_{xG-xSPhua}$=.997; $r_{xSPhua-xSPsam}$=.997) and in y-axis ($r_{yG-ySPsam}$=.999; $r_{yG-ySPhua}$=.999; $r_{ySPhua-ySPsam}$=1.000) which is showing a strong positive correlation (Table 2). Despite the fact that results in nominal mean value are different they have the same function when angle of the tilt board is getting higher or lower.

Cronbach's alpha (.999 for x- and y-axis) showed very high reliability of the survey measures. Reliability index for the devices is very high. In order to compare absolute reliability between the G-weight goniometer and smart phone measurements the Bland and Altman plots for the degrees are presented in Figure 2 and 3.

The limits of agreement show that the measurement with the Samsung smart phone can be 0.15° below or 1.95° above the goniometer in x-axis and 0.00° below or 2.96° above in y-axis (Figure 2).

The limits of agreement show that the measurement with the Huawei smart phone can be 0.85° below or 3.23° above the goniometer in x-axis and 0.09° below or 2.23° above in y-axis (Figure 3).

Smart phones have different frequencies of recording. Despite selecting the same frequencies of recording (Hz), we the sampling rate was different. For the Huawei it was sampling rate 933 samples per 10 seconds, while for Samsung 950 samples per 10 seconds.

For Huawei we had to eliminate every 22nd measure to equalize time in y- and x-axis with Samsung smart phone. Figure 4 A and B show very similar displacement-time curve in x- and y- axis.

Correlation between both smart phones in x-axis was 0.94 and 0.97 in y-axis respectively. Thus, smart phones share 88% and 94% of variance in x- and y-axis respectively. This means very good to excellent reliability and validity of measurement.

DISCUSSION

The aim of this study was to find out if the smart phone could be reliable as a balance assessment device. There has been many devices used to assess balance, one of them being T shaped tilt board. The protocol to assess balance on the T shaped tilt board can be measured in time elapsed from the start of the protocol until the touchdown of the tilt board or in range of motion during protocol.

In the present study, we used two different models of smart phones to assess angle displacement on the T shaped tilt board and compare them to the G weight goniometer. After the comparison, we conducted two 10-seconds standing protocols with both smart phones.

In our research, we proved that two smart phone devices had a very strong positive correlation with G-weight goniometer, which is considered a gold standard in range of motion measurements. SEM for goniometer and smart phones showed consistent measurements. Relative absolute error of two smart phones used compared to goniometer was between 0.85° and 1.19° in x-axis and between 1.07° and 1.48° in y-axis, showing slightly higher error in y-axis.

Internal consistency was confirmed by Cronbach's alpha values of 0.999 for x-axis and 0.999 for y-axis.

In measurement comparison between new and established measurement technique limits of agreement should be calculated (Bland & Altman, 1986). Bland – Altman's limits of agreement revealed that the measurement with smart phone could be as much as 0.85° below or 3.23° above in x-axis and 0.09° below or 2.96° above in y-axis the goniometer measurement, depending on the smart phone model. Figure 2 and 3 displayed lack of agreement between goniometer and smart phone that would be unacceptable for clinical purpose, but would be acceptable for practical use in monitoring balance progress of an individual.

Both smart phones share a very similar displacement-time curve. Despite selecting the same frequencies of recording (Hz), we found that the smart phone's operating system dynamically manages its sampling rate. As mentioned in a research by Mellone, Tacconi & Chiari (2012) occasionally the sampling rate intervals undergo large changes because of the concurrent processes with higher priority.

It seems that smart phones with its measurement characteristics are reliable and valid enough for monitoring balance on T shaped tilt board for practical use but are not good enough for research or clinical use.

However, we do not have to overlook advantages of smart phones in assessment procedures. As mentioned in other studies (Nishiguchi et al., 2012; Mellone, Tacconi & Chiari, 2012; Shin, Ro, Lee, Oh & Kim, 2012) smart phone's applications are relatively easily to improve. The data acquired through assessment can be presented in intelligible graphical way in smart phone's application, transmitted fast, and convenient to another device for statistical use. Because of their cost-efficiency, smart phones are available to broader public and therefore useful for monitoring balance progress during individual physical therapy or training.

CONCLUSION

Smart phone can be a valid and reliable balance assessment device for practical use in monitoring balance progress. Popular technologies such as smart phones can come into wide use as assessment devices because of their portability, inexpensiveness and availability. They come with a large set of embedded sensors, which can be used in many assessment circumstances.

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