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The Influence of Test Repetition on Bipodal Visually Controlled Static and Dynamic Balance

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A B S T R A C T

This study explores the influence of test repetition on bipodal visually controlled balance, both static and dynamic. Our goal was to get an insight into the pattern of changes in posture maintenance results during repeated balance tests. Fifteen young, healthy male recreational athletes were tested for static and for dynamic balance using KAT 2000 balance platform. The subjects first performed three trial tests of static and dynamic balance to get used to the platform followed by seven repetitions of static as well as dynamic test which were recorded. During the repeated tests we could not determine any significant improvements of static balance test resulting from number of test repetitions neither in static nor in dynamic balance (Friedman ANOVA: Static balance p=0.497, Dynamic balance p=0.393). Correlating static and dynamic balance results we found that only one third of the dynamic balance was related to static balance abilities (r^2=0.36). Possible patterns in front-back and left-right directions were analyzed as well, however, none of these balance scores were found to be related to the number of repetitions. In conclusion, this study found no significant influence of limited number of repetitions (seven) on test results in static and dynamic posture. However, as large number of repetitions might still influence test results we discourage the use of KAT 2000 as a training tool in patients in which it will be used as an instrument to validate postoperative rehabilitation or investigation results.

***Key words:** postural balance, learning influence, rehabilitation, investigational*

Introduction

Well functioning postural control system is essential in ability to control body balance. It is based on a complex interaction between the afferent impulses at visual, vestibular and somatosensory level and an adequate neuromuscular reaction[1]. Proprioceptive information is important in both static and dynamic balance ability and it is known that the proprioception could be both positively as well as negatively affected by some forms of training. For example, a practice or training could improve proprioception[2], while an injury sometimes decreases ability of the patient to maintain good body balance through impaired proprioception[3–5]. Bipodal balance or simply keeping balance while standing on two legs with eyes wide open is an essential part of the habitual daily activities[6]. Postural control is necessary in rehabilitation, sports[7,8], but also during simple tasks like taking a ride on a tram or mobile escalators or dancing[9]. Keeping in mind that there are many situations in which a sudden stimulus may lead to the loss of balance and eventually an injury, it is of importance to evaluate patients/athletes balance ability in the most precise manner possible[10]. Unfortunately, balance testing is still a matter of controversy and according to the available literature there is no consensus about the effect of motor learning on results.

As mentioned above, there is a huge impact of learning on balance test results in the first few trials but currently we are unaware of the effects of motor learning on two leg stability test (static) after the initial few trials. It would be of importance to establish the relationship between the number of repeated tests (after initial trials) and achieved results for balance testing platforms avail-

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able on the market in order to provide the surgeons and physiotherapist the information about the testing methods properties. Following that, the main goal of this study was getting an insight into the pattern of changes in posture maintenance results during repeated balance tests.

Material and Methods

Sample

The sample comprised of 15 healthy recreational male athletes aged 19–35 years, mean 24.5 years. Subjects with history of neuromuscular, vestibular or visual disturbances were excluded from the study as well as the subjects with previous or current problems involving lower extremities. All participants signed informed consent forms which were approved by the local Ethics Committee.

Methods

As one of the balance measuring methods used most often is a stabilometry on balance platforms we opted for one of the commercial models. The KAT 2000 is an instrument composed of a movable platform supported at its central point by a small pivot. KAT 2000 is a device found to be useful for predicting knee ligaments injury risk[11] or in validation of postoperative results after knee injuries[12]. In all these studies only two measurements, the initial and the final one were conducted.

The construction of the device encompasses one platform and the base of the unit designed as a circular pneumatic cushion. Through varying pressure of this cushion the stability of the platform is either increased or decreased. On the front of the platform is a tilt sensor which is connected to the computer which registers the deviation of the platform from a reference position 18.2 times *per* second. The distance from the center of the platform to the reference position is measured at every registration; summation of these distances is used to calculate a score-the Balance Index (BI). The BI is quantification of ones ability to keep balance; lower BI means a good ability to perform balance tasks. During the static test balance a task is to superimpose the cross, which on the computer screen represents the center of the platform, onto the cursor. In dynamic tests the cursor on the computer screen makes a circular movement with a speed of 360° every 10sec. Subjects had the task of superimposing the cross on the moving cursor.

Testing protocol

Prior to the beginning of the measurements each participant was allowed to practice on the KAT 2000. During this period both static and dynamic test were performed three times for 30 seconds. During all of the tests the subjects stood barefoot on the platform, held arms folded across the chest, with knees flexed at 20° and eyes were open. The tests were performed bipodally meaning standing on both feet. As proposed in the user manual, the pressure pillow was set on bar 6 while in dynamic tests the cursor moved at a medium speed set at 3. All subjects performed 7 sets of static test followed by dynamic tests and the break between each test set lasted for 3 minutes.

Results

The data of 15 subjects were analyzed. The mean Balance Index values for static and dynamic index were calculated. The descriptive statistics of the static and dynamic Balance Index scores are presented in Table 1.

As the overall Balance Index scores presented in Table 1 provided only a general insight into balance abilities of the subjects and could have been misleading we also analyzed the changes between the measurements meaning within subjects differences. To achieve that, the measured balance scores (BI) of each measurement was subtracted from subsequent measurements in order to obtain the delta values which was then used as the variable representing the change (improvement or worsening) in body static and dynamic balance during repeated tests. In that way we obtained six delta variables out of seven tests.

After the initial exploration of the obtained delta balance scores, we observed that subject responses to balance testing were very individual meaning the variance between the subjects were relatively large. Nevertheless, as we were interested in changes through time within subjects, meaning fitting the data for each subject separately then combining the fits and because of the high variance between subjects the Friedman ANOVA was used as an alternative to one-way repeated measures ANOVA, as it did not require the dependent variable to follow a normal distribution. The precondition for using

TABLE 1
MEANS AND STANDARD DEVIATIONS FOR BALANCE INDEX SCORES IN REPEATED STATIC AND DYNAMIC TESTS

Static Tests	BI Mean	BI Min	BI Max	SD
S1	94.2234	54.04420	174.7676	36.16385
S2	101.0615	53.99028	260.6183	55.16144
S3	95.9769	51.48099	289.8279	61.81286
S4	85.5144	44.45609	164.7402	36.06527
S5	85.7194	37.18576	164.1967	31.75305
S6	79.2462	34.08388	129.6197	25.95147
S7	83.6124	32.36710	164.2333	35.02913
Dynamic tests	BI Mean	BI Min	BI Max	SD
D1	238.4508	148.5517	362.7684	74.3189
D2	263.0452	132.6502	489.1767	112.7379
D3	250.0859	131.5757	527.6042	114.6343
D4	209.4091	119.0508	423.3234	76.0035
D5	207.3130	115.9588	412.3603	87.6458
D6	208.7307	100.4297	325.5088	71.4118
D7	190.0563	104.1035	253.5393	44.7325

BI – balance index scores, S – static test, D – dynamic test

TABLE 2
THE RESULTS OF FIEDMAN ANOVA FOR REPEATED MEASUREMENTS OF STATIC BALANCE

Friedman ANOVA and Kendall Coeff. of Concordance ANOVA χ^2 (N=15, df=5) = 4.367; p=0.497; Coeff. of Concordance= 0.0623; Aver. rank r=–0.0097

	Average	Sum of	Mean	SD
BI S2-S1	3.4286	48.0000	6.8380	25.8286
BI S3-S2	3.0000	42.0000	–5.0846	16.8149
BI S4-S3	3.1429	44.0000	–10.4625	35.7778
BI S5-S4	4.0000	56.0000	0.2051	21.6146
BI S6-S5	3.2857	46.0000	–6.4732	23.3553
BI S7-S6	4.1429	58.0000	4.3662	21.5277

BI – balance index scores, S – static test

TABLE 3
THE RESULTS OF FIEDMAN ANOVA FOR REPEATED MEASUREMENTS OF DYNAMIC BALANCE

Friedman ANOVA and Kendall Coeff. of Concordance ANOVA χ^2 (N=15, df = 5)=5.183; p=0.393; Coeff. of Concordance =0.0740; Aver. rank r=0.002

	Average	Sum of	Mean	SD
BI D2-D1	4.214286	59.00000	24.5944	67.76202
BI D3-D2	3.214286	45.00000	–12.9593	53.54884
BI D4-D3	2.928571	41.00000	–40.6768	80.59243
BI D5-D4	3.142857	44.00000	–2.0961	47.88616
BI D6-D5	4.000000	56.00000	1.4177	47.87597
BI D7-D6	3.500000	49.00000	–18.6743	36.98840

BI – balance index scores, D – dynamic test

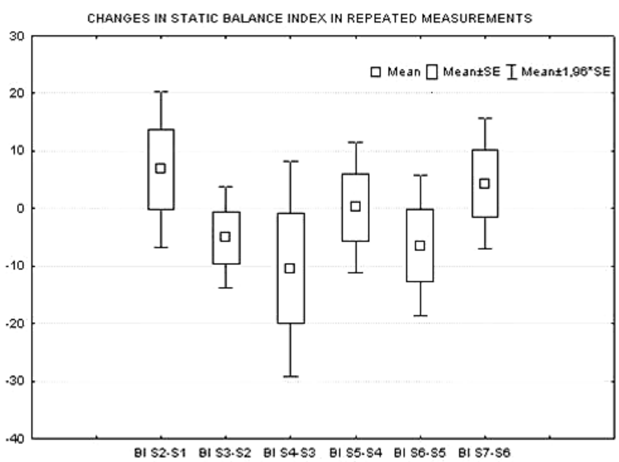

Fig. 1. Graphic presentation of changes in static balance during repeated measurements (BI – Balance Index; S (N) – static testing number).

this test was met as our sample (N=15) exceeded the minimal number of subjects needed for this type of analysis which is set to be 12. The model proved to be non-significant (p=0.497) and we could not determine any significant improvements of static balance test results resulting from test repetitions (Table 2).

It seemed that measurements of Balance Index after the first initial trials (not monitored and not included in below presented results) stabilized, and did not undergo further improvements which are clearly visible in Figure 1.

The same data analysis procedure was performed once more for dynamic balance test results. Even though, according to some previously published papers[13] the dynamic posture control should be influenced more by repetition of the test than the static balance our data did not reveal clear improvements with subsequent measurements. The model was also not significant (p=0.393) but the variances between subjects was still relatively large (Table 3).

Visually inspecting the dynamic balance data (Figure 2) we can see some improvements especially between the dynamic tests 1 and 4 but as the Balance Index values worsened again in last three measurements and the ANOVA was not significant, we could not attribute it to the learning process.

The correlation analysis between the static and dynamic balance provided a small significant correlation with determination coefficient of r^2=0.36 meaning that only 36% of the dynamic balance results could be attributed to the static balance abilities.

As we could not demonstrate any significant effects of repeated measurements on Balance Index we also searched for possible patterns in front-back as well as and left-right directions and analyzed the changes in the form of percentages but none of those balance scores proved to be related to the number of repetitions.

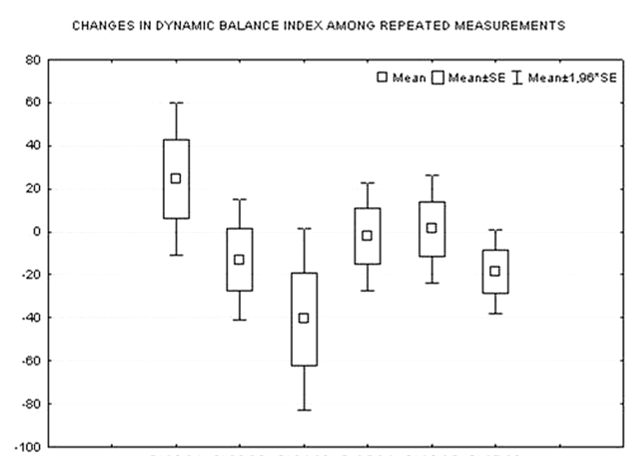

Fig. 2. Graphic presentation of changes in dynamic balance during repeated measurements (BI – Balance Index; D(N) – dynamic testing number).

Discussion and Conclusion

Little is known about the influence of repeated measurements on static and dynamic balance scores when KAT 2000 is used. Only a few authors have used this device to test balance[14,15]. We are the first to report on the influence of bipodal visually controlled static and dynamic balance.

Our study demonstrated that after the initial training period of three repetitions, the learning effect of the repeated balance motor tests is not significant, at least not within the seven repetitions which is usually enough to evaluate the rehabilitation process of the patient.

It is important to point to the fact that in many studies stabilometry on a force platform is used to quantify balance ability[16–18]. However, on a force platform dynamic balance ability as a coordination indicator cannot be evaluated while KAT 2000 is the instrument which gave us the possibility to measure both static and dynamic balance ability.

We intended to track changes for better or worse in ones static and dynamic balance during repeated tests. Very individual responses to testing were observed with large variances between the subjects. Previous investigations support these findings[13].

Our testing protocol consisted of bipodal visually controlled testing in a static and dynamic mode. We preferred to include this visual component as it significantly contributes to balance ability in both sports and activities of daily living and the intention was to simulate reality as closely as possible[19]. Compared to our study, Hansen et al.[13] reported on one-leg static balance testing without visual control and dynamic testing performed similarly to our protocol. They found the improvement in BI measurement in both tests, but pointed out that the process of learning was more pronounced in dynamic compared to static test. An explanation is given through characteristics of both tests. It is true that the static test mimics standing on one or both legs which is an activity of daily living while the dynamic test is something new to the subjects challenging its coordination ability and depends more on motor patterns that establish throughout time. However in their study, visual components were absent in static test, but it almost always present in practice.

As a weak but statistically significant positive correlation between the results in static and dynamic tests was found ($r^2=0.36$) we can say that the static balance contributes to the variance of dynamic balance by only 36% while the remaining 64% depends on some other neuromuscular factors. The findings in previous studies disagree about relations. For example Hansen et al.[13] suggest a strong positive correlation between those two, while Hrysomalis et al.[20] advise against inferring dynamic balance ability based on static balance ability. That means that if one scored low on static test it does not mean that the dynamic test result would always be poor.

The limitation of this study could be the preset number (seven) of each test repetition during measurement protocol. The protocol was set in that manner because we were mostly interested in the effects of limited number repetitions as in rehabilitation evaluation use up to three measurements (initial, transitory and final) are usually used[11,12]. Still, as a precaution, we would not recommend the same measuring device be used as balance training equipment because if a large number of trials are to be performed during a long period of time there still might be a chance of learning influence on results. Using this instrument as a training tool might compromise its diagnostic importance. In that case we could not surely attribute the improvement of balance ability only to the rehabilitation success. Our recommendation is to use other balance training hardware (like boards, ropes, polygons and similar) in order to preserve KAT 2000 for postoperative, rehabilitation or investigation purposes.

In conclusion, the learning effect of the repeated static and dynamic balance motor tests was not observed, at least not within the seven repetitions which is usually enough to evaluate rehabilitation process of the patient or the balance ability of an athlete.

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UTJECAJ PONAVLJANJA TESTA NA VIZUALNO KONTROLIRANU BIPODALNU STATIČKU I DINAMIČKU RAVNOTEŽU

S A Ž E T A K

Ova studija istražuje utjecaj ponavljanja testova na vizualno kontroliranu bipodalnu statičku i dinamičku ravnotežu. Cilj istraživanja bio je istražiti obrazac promjena rezultata održavanja ravnoteže tijekom ponavljanih testova balansa. Koristeći se balansnom platformom KAT 2000, petnaestorici mladih i zdravih rekreativaca testirana je statička i dinamička ravnoteža. Kako bi se upoznali s testnom platformom, ispitanici su najprije učinili tri pokusna testiranja statičke i dinamičke ravnoteže, nakon čega je uslijedilo sedam ponavljanih testiranja koja su bilježena. Tijekom ponavljanih testiranja, nismo utvrdili signifikantnih poboljšanja rezultata statičke niti dinamičke ravnoteže uslijed broja ponavljanja testa. (Friedman ANOVA: Static balance p=0,497, Dynamic balance p=0,393). Uspoređivanjem rezultata testiranja statičke i dinamičke ravnoteže, utvrdili smo da je tek trećina sposobnosti održavanja dinamičke ravnoteže posljedica mogućnosti održavanja statičke ravnoteže (r^2=0,36). Uspoređivani rezultati modela održavanja ravnoteže u smjeru naprijed-nazad te lijevo-desno, također nisu pokazali povezanost s brojem ponavljanja. Zaključno, ova studija utvrdila je da nema značajnog utjecaja ograničenog broja ponavljanja (sedam) na rezultate testiranja statičke i dinamičke ravnoteže. Kako veći broj ponavljanja ipak može utjecati na rezultate testiranja, ne preporučamo korištenje balansne platforme KAT 2000 u treningu pacijenata u kojih se planira njeno korištenje kao instrumenta vrednovanja rezultata postoperativne rehabilitacije ili rezultata istraživanja.