RELIABILITY OF POSTURAL BALANCE EVALUATION USING THE BIODEX BALANCE SYSTEM IN SUBJECTS WITH AND WITHOUT LOW BACK PAIN

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ABSTRACT

Objective: *The purpose of this study was to evaluate the reliability of dynamic standing balance in individuals with and without low back pain (LBP) using Biodex Balance System (BBS).*

Material and Methods: *Twenty three patients with LBP and 20 age-matched healthy subjects participated in this study. Bilateral and unilateral stance both with eyes open and eyes closed with the BBS over a period of 20s was assessed. The subjects were assigned to two groups (with and without LBP) by an independent observer. The tester was unaware of the group assignment and completed balance test using BBS. Two days after the first measurement session, the tester retested the subjects in the second measurement session in a random order, different from the first measurement session.*

Results: *The results of this study showed that the intra-class correlation coefficient in normal subjects and those with LBP was between (0.91-0.95) and (0.88-0.96) respectively. The results showed that BBS is reliable for evaluating dynamic postural balance in subjects with and without LBP. A significant difference was found in Medial–Lateral Stability Index (MLSI) and Overall Stability Index (OSI) between subjects with and without LBP.*

Conclusion: *The findings of this study showed high reliability for BBS to evaluate dynamic postural balance in subjects with and without LBP.*

Key Words: *Biodex Balance System, Low Back Pain, Balance, Reliability.*

INTRODUCTION

Low back pain (LBP) is one of the most common and costly musculoskeletal complaints in today's societies, affecting up to 70-80% of the population at least one episode during their lifetime[1]. Several factors such as lumbar spine stiffness, muscle shortness and weakness, decreased muscle endurance have been associated with the LBP[2,3]. Several recent studies have also indicated that patients with LBP show reduced postural control commonly manifested in balance problem[4-7]. The maintenance and control of balance, whether under static or dynamic conditions, is considered as an essential requirement for physical and daily activities[8]. Thus postural control variables have often been used to evaluate patients with various musculoskeletal or neuromuscular disorders[9,10]. Balance is a complex function involving numerous neuromuscular processes[11,12]. Balance is controlled by sensory input, central processing, and neuromuscular responses. The sensory components include the vestibular, visual, and proprioceptive systems[13-16]. An appropriate motor response requires an intact neuromuscular system and sufficient muscle strength to return the center of mass within the base of support when balance is disturbed[17]. Proprioceptive impairment has also been suspected as one of the possible causes for balance impairments in LBP. LBP has been associated with decreased muscle strength and proprioception[2,3]. This may affect the quality of sensory information and disrupt the relation between postural responses and sensory information. The Biodex Balance System (BBS; Biodex Inc.) has been used to evaluate postural balance in recent years[18,19]. The BBS

INTRACLASS CORRELATION COEFFICIENT VALUES FOR RELIABILITY FOR THE BALANCE TEST MEASUREMENTS IN SUBJECTS WITH AND WITHOUT LBP

Condition	Stability Indices	Without LBP N=20 ICC(3,1)	With LBP N=23 ICC(3,1)
DLEO	OSI	0.97	0.95
	APSI	0.93	0.90
	MLSI	0.91	0.88
DLEC	OSI	0.95	0.96
	APSI	0.97	0.94
	MLSI	0.96	0.89
SLEO	OSI	0.97	0.91
	APSI	0.96	0.89
	MLSI	0.97	0.91
SLEC	OSI	0.97	0.96
	APSI	0.96	0.95
	MLSI	0.93	0.95

Table 1

ICC = Intraclass Correlation Coefficient, LBP = Low Back Pain,

OSI: Overall Stability Index , APSI: Anterior–Posterior Stability Index,

MLSI: medial–lateral stability index

DLEO: Double Leg Eyes Open, DLEC: Double Leg Eyes Closed

SLEO: Single Leg Eyes Open, SLEC: Single Leg Eyes Closed

is a multi-axial device that objectively measures and records an individual's ability to stabilize the involved joint under dynamic stress. It uses a circular platform that is free to move in the anterior–posterior and medial–lateral axes simultaneously [19]. The BBS allows up to 20° of foot platform tilt, which permits the ankle joint mechanoreceptors to be stimulated maximally. The BBS measures, in degrees, the tilt about each axis during dynamic conditions and calculates a medial–lateral stability index (MLSI), anterior–posterior stability index (APSI), and an overall stability index (OSI). These indexes represent fluctuations around a zero point established prior to testing when the platform is stable [19]. For example, an OSI of 5° would be interpreted to mean that on average, the displacement from center is 5°.

The Bland-Altman plot of agreement in OSI in Double Leg Eyes Open condition between the test and retest

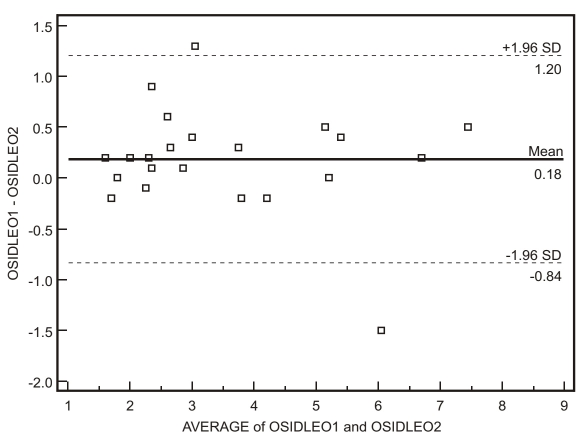

Figure 1

Previous studies have shown that BBS is reliable for evaluating dynamic postural balance in healthy subjects[19,20]. It has been assumed that in normal subjects, balance and postural adjustments during standing are generally achieved using “ankle strategy”, while patients with LBP use different strategies to maintain balance [8,21,22]. Furthermore some attributed changes in postural control in LBP patients to pain and disability. This interference is likely to contribute to different adaptive changes in postural control and balance in individuals with LBP.

The purpose of this study was to evaluate the reliability of dynamic standing balance in individuals with and without LBP using BBS and to determine the association within the LBP subjects between dynamic balance scores and pain or disability characteristics.

The Bland-Altman plot of agreement in OSI in Double Leg Eyes Closed condition between the test and retest

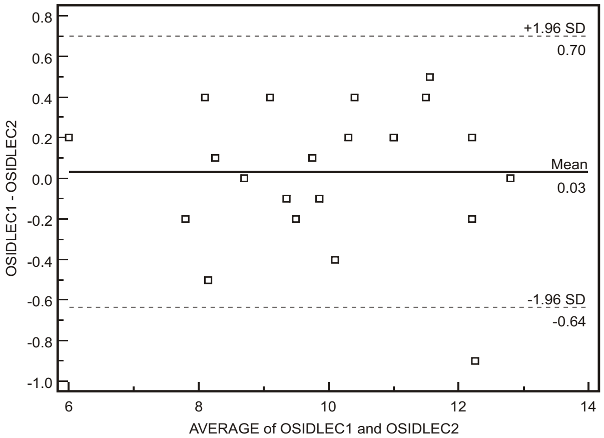

Figure 2

The Bland-Altman plot of agreement in OSI in Single Leg Eyes Open condition between the test and retest

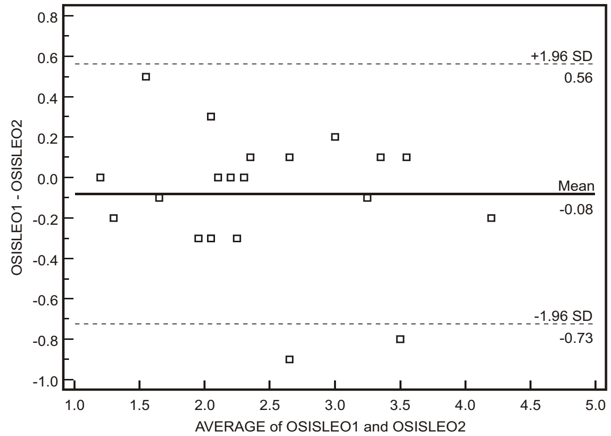

Figure 3

MATERIAL AND METHODS

Subjects:

Twenty three LBP patients and 20 age-matched healthy subjects participated in this study. All the individuals who participated in the study filled out a simple health questionnaire. Those who met the selection criteria were included in the study. All the subjects signed an informed consent form approved by the human subjects committee at the Tarbiat Modarres University before participating in the study. LBP patients were included if they had a history of LBP for more than six weeks before the study or had on and off back pain and had experienced at least three episodes of LBP, each lasting more than one week, during the year before the study. Asymptomatic subjects were evaluated and found to have no complaint of any pain or dysfunction in their low back, thoracic and neck area and lower extremities. Subjects with history of spinal surgery, fracture of the spine, pelvis and lower extremities, hospitalization for severe trauma or car accident, leg length difference, hip/knee dysfunctions, any systemic disease such as arthritis or tuberculosis and liver and/or kidney failure were also excluded.

Instruments and procedure:

The Biodex Balance System (BBS) was used to measure balance and postural stability under dynamic stress (BBS; Biodex Inc., Shirley, NY). As noted, the BBS uses a circular platform that is free to move in the anterior–posterior and medial lateral axes simultaneously. The BBS allows up to 20° of foot platform tilt and calculates three separate measures: Medial-Lateral stability Index (MLSI), Anterior–Posterior Stability Index (APSI) and Overall Stability Index (OSI). A high score in the for example, OSI, indicates poor balance. The OSI score is believed to be the best indicator of the overall ability of the patient to balance the platform. The stability of the platform can be varied by adjusting the level of resistance given by the springs under the platform. The platform stability ranges from 1–8, with 1 representing the greatest instability. The lower the resistance level the less stable the platform [22-24]. In this study, we assessed bilateral and unilateral stance both with eyes open and eyes closed with the BBS over a period of 20s. Stability levels were changed from level 6 to level 3 and from level 8 to level 4 for bilateral and unilateral stance assessment respectively, and subjects were instructed to maintain their center of pressure in the smallest concentric rings (balance zones) of the BBS monitor, named A zone. All subjects in two groups were right leg dominant and right leg was used for stability scores in unilateral stance. To begin, participants stood on the BBS's locked platform. To assess the foot position coordinates and establish the subjects' ideal foot positioning for testing, the stability platform was unlocked to allow motion. Participants were instructed to adjust the position of the foot until they found a position at which they could maintain platform stability. The platform was then locked. Foot position coordinates were constant throughout the test session. Next, testing began as the platform was released for a 20s trial and participants were asked to maintain an upright standing position on their limb/limbs. For the trial to be complete, balance needed to be maintained for 20 sec[23-25]. All participants were trained 1 min for adaptation to the machine, following which three practice trials, to reduce any learning effects, and three test evaluations were performed in each measurement session. A mean score was calculated from the three trials. As noted, balance was measured in

The Bland-Altman plot of agreement in OSI in Single Leg Eyes Closed condition between the test and retest

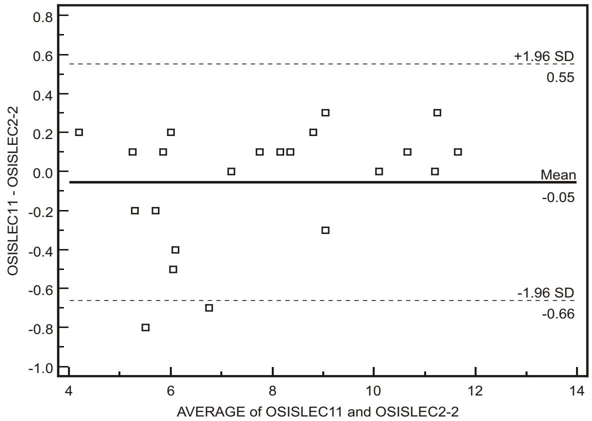

Figure 4

four conditions: bilateral and unilateral stance with eyes open and eyes closed. The tester undertook the balance test in each condition in random order and not in specified in subjects.

The subjects were assigned to two groups (with and without LBP) by an independent observer. The tester was unaware of the group assignment and completed balance test using BBS. Two days after the first measurement session, the tester retested the subjects in the second measurement session in a random order, different from the first measurement session.

Self-reported disability was assessed with the Oswestry Low Back Pain Disability Questionnaire (OSW) and Quebec Back Pain Disability Scale (QUE)[26]. Self-reported measurements of disability have been used as an outcome measure for people with LBP. OSW and QUE are two of the most commonly used disability scales for patients with LBP. The measurement properties of these scales have been studied extensively, and a recent report of the International Forum for Primary Care Research in Low Back Pain contended that scales are valid and acceptable for measuring disability related to LBP. Pain intensity was evaluated with the Visual Analog Scale (VAS).

Data Analysis:

The intra-class correlation coefficient (ICC), two way mixed effect model, was used to assess intra-tester reliability of the measurement for dynamic standing balance in patients with LBP and control group. We calculated the ICC (3,1), because only one judge evaluated the same population of subjects.

The 95% limits of agreements method of reliability assessment providing upper and lower limits for variation with a confidence level of 95% was measured by plotting a Bland-Altman plot to assess absolute reliability. Pearson correlation

CORRELATION ANALYSIS BETWEEN STABILITY INDICES AND VARIABLES OF DISABILITY AND PAIN

Condition	Stability Indices	OSW		QUE		VAS	
		r	P	r	P	r	P
DLEO	OSI	0.26	0.31	0.34	0.17	-0.11	0.60
	APSI	0.14	0.58	0.16	0.52	-0.18	0.41
	MLSI	0.30	0.23	0.42	0.08	-0.01	0.93
DLEC	OSI	-0.25	0.33	-0.24	0.34	-0.17	0.43
	APSI	-0.41	0.09	0.27	0.28	-0.37	0.07
	MLSI	-0.08	0.74	-0.17	0.49	0.14	0.52
SLEO	OSI	0.08	0.74	-0.11	0.66	-0.11	0.59
	APSI	0.13	0.61	-0.08	0.75	-0.22	0.30
	MLSI	0.01	0.96	-0.06	0.79	0.38	0.07
SLEC	OSI	0.27	0.29	0.17	0.50	-0.37	0.08
	APSI	0.15	0.54	0.19	0.44	-0.39	0.06
	MLSI	0.38	0.12	0.25	0.32	-0.12	0.52

Table 2

LBP = Low Back Pain, OSI: Overall Stability Index
APSI: Anterior–Posterior Stability Index, MLSI: Medial–Lateral Stability Index
DLEO: Double Leg Eyes Open, DLEC: Double Leg Eyes Closed
SLEO: Single Leg Eyes Open, SLEC: Single Leg Eyes Closed
OSW: Oswestry Low Back Pain Disability Questionnaire
QUE: Quebec Back Pain Disability Scale
VAS: Visual Analog Scale

BALANCE TEST MEASUREMENTS IN FOUR CONDITIONS BETWEEN SUBJECTS WITH AND WITHOUT LBP

Condition	Stability Indices	Without LBP N=20		With LBP N=23		P-value
		Mean	SD	Mean	SD	
DLEO	OSI	1.76	0.99	3.64	1.69	**<0.001**
	APSI	2.22	1.14	2.56	1.23	0.35
	MLSI	1.5	0.56	2.75	1.31	**<0.001**
DLEC	OSI	6.65	2.04	10	1.74	**<0.001**
	APSI	6.86	1.27	7.09	1.45	0.58
	MLSI	5	1.87	7.19	1.68	**<0.001**
SLEO	OSI	1.41	0.47	2.37	0.75	**<0.001**
	APSI	1.88	0.77	1.92	0.81	0.86
	MLSI	1.14	0.23	1.64	0.43	**<0.001**
SLEC	OSI	5.79	2.21	7.69	2.3	**<0.001**
	APSI	6.22	2.05	6.44	2.24	0.73
	MLSI	3.47	2.19	4.85	2.41	**0.04**

Table 3

LBP = Low Back Pain, OSI: Overall Stability Index
APSI: Anterior–Posterior Stability Index, MLSI: Medial–Lateral Stability Index
DLEO: Double Leg Eyes Open, DLEC: Double Leg Eyes Closed
SLEO: Single Leg Eyes Open, SLEC: Single Leg Eyes Closed
- Bold cells indicate significant difference between LBP patients and healthy group.

coefficients were calculated to evaluate the LBP group regarding the relationship between dynamic postural balance indices and disability score of OSW and QUE and VAS score for pain intensity. Independent t–test was also used to determine any difference in balance scores between LBP patients and control group.

RESULTS

Twenty three LBP patients (age: 30.46.5 years, height: 174.57.3 cm, weight: 76.610.8 kg) and 20 age-matched healthy subjects (age: 29.86.4 years, height: 174.96.4 cm, weight: 76.110.1 kg) participated in this study. Statistical analysis (independent t-test) revealed no significant difference in age (P = 0.87), weight (P = 0.83) and height (P = 0.83) between two groups.

Table 1 presents the ICC for each index in different test position. All ICC values were greater than 0.90 and 0.85 in healthy subjects and those with LBP, respectively. (Table1). The Bland-Altman plot of agreement in balance scores between tests and retests demonstrated good agreement between test and retest. The Bland-Altman plots for OSI in four conditions (double and single leg with eyes open and closed) are shown in Figure 1-4 as examples.

Descriptive statistics for the OSW, QUE and VAS in LBP group are 10.585.09, 19.6415.66 and 4.111.32, respectively.

Correlation analyses were performed between stability indices (OSI, APSI, MLSI) and variables of disability and pain characteristics (OSW, QUE and VAS) in four test conditions (double and single leg with eyes open and closed) in LBP group. No significant correlation was detected between stability indices and OSW, QUE and VAS. The results are presented in Table 2.

Independent t-test showed significant difference in the OSI (P < 0.001) and MLSI (P< 0.001 = 0.25) in four test conditions between subjects with and without LPB. Our data, however, showed no significant difference in APSI between two groups (Table3).

The figures 1-4 show the Bland-Altman plot of agreement in OSI in Double Leg Eyes Open condition /Double Leg Eyes Closed condition/ in Single Leg Eyes Open condition and Single Leg Eyes Closed condition between the test and retest.

DISCUSSION

Our data indicate a high reliability in balance test indices measured by using BBS (OSI, APSI, MLSI) both in subjects with and without LBP (Table1, Figure 1-4). This finding is in accordance with other studies showing good reliability for using BBS to assess postural balance in healthy subjects[19-20]. The BBS was shown to be reliable in several previous studies. Pincivero et al.

found the BBS to be a reliable assessment device across multiple test trials (20 sec) in healthy college students (N = 20). At Level 2 resistance (out of 8 possible), the ICC for the OSI measures was 0.60 for testing on the dominant and the non-dominant limb [27]. At Level 8, the ICC was 0.95 for the dominant limb, and 0.87 for the nondominant limb. Pincivero et al. recommended two practice trials [27]. With respect to the other two indexes available when using the BBS (MLSI and APSI), Schmitz and Arnold found with a decreasing stability protocol (from Level 8 to Level 1 over 30 sec; N = 19), intra-tester reliability of 0.80 for the APSI and 0.43 for the MLSI[21]. The intra-tester reliability was reported as 0.82 for the OSI. Schmitz and Arnold concluded that the overall stability index measures were the most reliable. Reliability estimates obtained in this study for the OSI measures were higher than those reported by Pincivero et al[27]. The high reliability estimates of the OSI measures found in this study, supports the conclusion drawn by Schmitz and Arnold [21] that the overall stability index measures may be more reliable than the other two indexes. The more important observation, however, was that for the protocol of two test trials, all of the measures provided by the BBS had similar, and good, reliability estimates. However, the significance of this study was assessing the reliability of BBS to assess postural control both in subjects with and without LBP. We found that BBS is reliable for postural balance assessment is LBP patients and could be used in studies assess balance in these patients. The results of this study showed a significant difference in the OSI and MLSI between subjects with and without LPB. Our data, however, showed no significant difference in APSI between two groups (Table 3).

Similar findings have been reported by others[4-7]. An appropriate motor response for postural balance control requires an intact neuromuscular system and sufficient muscle strength to return the center of mass within the base of support when balance is disturbed. Decreased muscle strength and proprioception in LBP patients compared to those without LBB have been shown in several studies. Muscle weakness and proprioceptive impairment has been suspected as one of the possible causes for balance impairments in patients LBP [2,3,28,29]. This may affect the quality of sensory information and disrupt the relation between postural responses and sensory information[30-33]. Nadler et al found that muscle imbalance in hip abductors is highly associated with LBP occurrence in female athletes[34]. The fact that in this study there was significant difference in MLSI and no significant difference in APSI between healthy group and LBP patients may be because of hip abductor weakness and imbalance in patients with LBP.

REFERENCES

1. Svensson H, Anderson GBJ, Johansson S, Wilhemsson C, Vedin A. A retrospective study of low back pain in 38-to-64 year old women: frequency of occurrence and impact on medical services. Spine 1988; 13: 548-52.
2. Kisner C. Therapeutic exercise: Foundations and Techniques. 2nd ed. Philadelphia: F.A. Davis; 1990.
3. Kendall FP, McCreary EK, Provance PG. Muscle testing and function. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 1993.
4. Sullivan PE, Markos PC. Activities: Postures and Movement Patterns. In: Sullivan PE, Markos PC. Eds. Clinical Decision making in Therapeutic Exercise. 2nd ed. Norwalk: Appleton & Lange, 1995; 1-20.
5. Brownstein B, Bronner S. Functional Movement in Orthopedic and sports Physical Therapy: Evaluation, Treatment and Outcomes. Churchill Livingstone Inc 1997, PP 1-5.
6. Volpe RD, Popa T, Ginanneschi F, Spidalieri R; Mazzocchio R; Rossi A. Changes in coordination of postural control during dynamic stance in chronic low back pain patients. Gait & Posture 2006; 24: 349–55.
7. Henry SM, Hitt JR, Jones SL, Bunn JY. Decreased limits of stability in response to postural perturbations in subjects with low back pain. Clinical Biomechanics 2006; 21: 881–892.
8. Shummway-Cook A, Woolacott MH. Motor Control Theory and Practical Applications. 2nded, Philadelphia, Lippincott Williams & Wilkins, 2001; 25-60.
9. Horak FB. Clinical measurement of postural control in adults. Phys Ther 1987; 67(20): 1881-5.
10. Blackburn T, Guskiewicz KM, Petschauer MA, Prentice WE. Balance and joint stability: The relative contributions of proprioception and muscular strength. J Sport Rehabil, Human kinetics 2000; 9:315-28.
11. Horak FB, Henry SM, Shummway-Cook A. Postural perturbations: New insights for treatment of balance disorders. Phys Ther 1997; 77(5): 517-33.
12. Allum JHJ, Bloem BR, Carpenter MG, Hulliger M, Hadders-Algra M. Proprioceptive control of posture: a review of new concepts. Gait Posture 1998; 8 : 214–42.

13. Tropp H, Ekstrand J, Gillquist J. Factors affecting stabilometry recordings of single limb stance. Am J Sports Med 1984; 12: 185-8.
14. Lephart SM, Pincivero DM, Rozzi SL. Proprioception of the ankle and knee. Sport Med 1998; 25(3): 149-55.
15. Hemami H, Barin K, Jalics L, Heiss DG. Dynamics, Stability and Control of Stepping. Ann Biomed Eng 2004; 32(8): 1153-60.
16. Shields RK, Madhavan S, Cole KR, Brostad JD, Demeulenaere JL, Eggers CD, et al. Proprioceptive coordination of movement sequences in humans. Clin Neurophysiol 2005; 116: 87–92.
17. Alexandrov AV, Frolov AA, Horak FB, Carlson-Kuhta P, Park S. Feedback equilibrium control during human standing. Biol Cybern 2005; 93(5):309-22.
18. Aydog E, Bal A, Aydog ST, Cakei A. Evaluation of dynamic postural balance using the Biodex Stability System in rheumatoid arthritis patients. Clin Rheumatol 2005; 10: 1-6.
19. Arnold BL, Schmitz RJ. Examination of balance measures produced by the Biodex Stability System. J Athl Train 1998; 33(4):323-7.
20. Cachupe WJ, Shifflett B, Kahanov L, Wughalter EH. Reliability of biodex balance system measures. Measurement in physical education and exercise science, Lawrence Erlbaum associates, Inc, 2001; 5(2), 97-108.
21. Schmitz R, Arnold B. Intertester and intratester reliability of a dynamic balance protocol using the biodex stability system. Journal of sport rehabilitation, Human kinetics publishers 1998; 7: 95-101.
22. Hinman MR. Factors affecting reliability of the Biodex Balance System: A summary of four studies. J Sport Rehabil 2000; 9: 240-52.
23. Perron M, Hébert LJ, McFadyen BJ, Belzile S, Regniére M. The ability of the Biodex Stability System to distinguish level of function in subjects with a second-degree ankle sprain. Clinical Rehabilitation 2007;21:73-81
24. Aydog E, Depedibi R, Bal A, Ekşioğlu E, Ünlü E, Çakci A. Dynamic postural balance in ankylosing spondylitis patients. Rheumatology 2006; 45(4):445-8.
25. Rowe A, Wright S, Nyland J, Caborn DN, Kling R. Effects of a 2-hour cheerleading practice on dynamic postural stability, knee laxity, and hamstring extensibility. J Orthop Sports Phys Ther 1999; 29(8): 455-462.
26. Mousavi SJ, Parnianpour M, Mehdian H, Montazeri A, Mobini B. The Oswestry Disability Index, the Roland-Morris Disability Questionnaire, and the Quebec Back Pain Disability Scale: translation and validation studies of the Iranian versions. Spine 2006;31(14):E454-9.
27. Pincivero D, Lephart SM, Henry TJ. Learning effects and reliability of the Biodex Stability System. J Athl Train 1995;30:S35.
28. Henry SM, Hitt JR, Jones SL, Bunn JY. Decreased limits of stability in response to postural perturbations in subjects with low back pain. Clin Biomech (Bristol, Avon). 2006;21(9):881.
29. dellaVolpe R, Popa T, Ginanneschi F, Spidalieri R, Mazzocchio R, Rossi A. Changes in coordination of postural control during dynamic stance in chronic low back pain patients. Gait Posture. 2006;24(3):349-55.
30. Pollock AS, Durward BR, Rowe PJ. What is balance? Clinical Rehabilitation 2000; 14: 402–6.
31. Riemann BL, Lephart SM. The sensorimotor system, part I: The physiologic basis of functional joint stability. J Athl Train 2002; 37(1):71-9.
32. Tsao H, Hodges PW. Persistence of improvements in postural strategies following motor control training in people with recurrent low back pain. J Electromyogr Kinesiol 2007 Mar 1. [Epub ahead of print]
33. Radebold A, Cholewicki J, Polzhofer GK, Greene HS. Impaired postural control of the lumbar spine is associated with delayed muscle response times in patients with chronic idiopathic low back pain. Spine 2001; 26 (7): 724–30.
34. Nadler SF, Malanga GA, Feinberg JH, Prybicien M, Stitik TP, DePrince M. Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes. a prospective study. Am J Phys Med Rehabil 2001; 80: 572-7.

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