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Original Article

The reliability of postural control method in athletes with and without ACL reconstruction: a transitional task

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Abstract. [Purpose] To evaluate the intra- and inter-session reliability of dynamic postural control in ACL reconstruction and matched control athletes. [Subjects and Methods] By using force plate, the postural controls of both groups (20 ACLR and 20 healthy matched controls) were assessed during the transitional task from DLS to SLS. The outcome variables included COP displacement and area and the mean velocity of COP. [Results] The balance measures had moderate to high correlation for area (ICC=0.64–0.73) and rang of fore-aft (Rfa) (ICC=0.66–0.80) in the ACLR group and Rfa (ICC=0.70–0.86) in the healthy group. High to very high reliability was seen for rang of sideway (Rsw) (ICC=0.76–0.96) and mean velocity (Mv) (ICC=0.81–0.98) in ACLR and area (ICC=0.70–0.98) and Rsw (ICC=0.84–0.98) and Mv (ICC=0.89–0.97) in the healthy group. [Conclusion] Force plate measures of postural control demonstrated moderate to very high reliability in athletes with and without ACLR during the transitional task. The results of the recent study showed that the assessment of transitional task postural control in athletes with ACLR may reliably be incorporated in the evaluation of the physical function.

Key words: Anterior cruciate ligament reconstruction, Force plate, Transitional task

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INTRODUCTION

The anterior cruciate ligament (ACL) is one of the major ligaments of knee, riches mechanoreceptors[1)]. According to the sensory role of ACL, it plays a key role in the postural control of lower limbs[2)]. ACL injuries are the most common knee ligament injury in sports activities, among which 70% are due to non-contact processes such as jump-landing, pivoting, and cutting[3)]. ACL reconstruction (ACLR) is performed to restore the mechanical and functional stability of the knee[1)].

The ability to maintain postural control requires intact inputs from visual, vestibular, and somatosensory systems[4)]. Postural control impairments are related to a (re-)injury risk in healthy and lower extremity musculoskeletal pathological subjects[5)].

The recent literature supports a trend toward impaired postural control in ACLR subjects. So, postural control deficits exist in the operated and non-operated leg following ACLR surgery[6)].

Previous studies have shown that postural control differences in the static single-legged standing position (SLS) in ACLR individuals are controversial[6, 7)].

Moving toward the opposite leg before finishing the single leg stance phase is essential. The characteristics of this contra-lateral weight shift movement and the ability to overcome the internal perturbation created by the transitional movement from the double leg stance (DLS) to single limb largely influence postural control sequences when standing on one leg[5)]. Recently, the literature shows that the weight shift transitional task from DLS to SLS is different between healthy and pathological

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Table 1. Demographic characteristic of the subjects in the experimental group

Variables	Groups			
	ACLR (n=20)		Healthy (n=20)	
	Mean	SD	Mean	SD
Age (years)	27.2	3.75	26.2	3.18
Height (cm)	185.0	4.69	184.0	4.12
Weight (kg)	84.8	5.47	82.5	4.32

subjects[1, 8, 9], while its effectiveness on the characteristics of postural control in the SLS phase has not been much paid attention to in the previous studies.

In daily and sporting activities, the subject needs to switch from DLS to SLS and vice versa repeatedly[4]. Therefore, it seems necessary to use a transitional task from DLS to SLS with the aim of evaluating functional ability before, during, and after voluntary movements in healthy and ACLR subjects[6].

To the authors' knowledge, there is no study that has evaluated the reliability of this method in ACLR and healthy athletes. Since the reliability of this method may have important clinical implications for evaluating postural control and rehabilitation in ACLR subjects, this study aims to assess the intra- and inter-session test retest reliability of balance due to the transitional task from DLS to SLS in athletes with and without ACLR.

SUBJECTS AND METHODS

As many as 40 male soccer players (20 healthy and 20 ACLR athletes) voluntarily participated in the study. The athletes in the ACLR group had undergone reconstruction surgery by single orthopedic surgeons (who was referred samples from the University Hospital Orthopedic Center) in a similar fashion (hamstring tendon graft) and the control subjects were the patients' teammates. The ACLR group included athletes with a history of unilateral ACLR, at least six months before testing who had returned to their sports activities. Both groups were matched to their teammates according to the demographic characteristic (Table1). The ACLR and healthy groups were not different in terms of the physical activity level (all of them were scored 9 according to Tegner's questionnaire). The athletes in the two groups were excluded if they reported neurological and orthopedic problems in low back, either of the lower limbs (except meniscal injuries in the ACLR group), and vestibular and visual dysfunctions. After the athletes had been briefed on all testing procedures, they were asked to read and sign an informed consent form that was approved by Ethics Committee of Tehran University of Medical Science (Ethics approval number: 9323341999).

Each subject was asked to perform the weight shift task from DLD to SLS, by the same examiner. Each measurement was repeated three times in the test session, and all the measurements were repeated two to seven days later in the retest session. The average scores of each session were used for analysis. The participants were allowed to rest for one minute between each test to prevent fatigue. The test order was randomized to control for sequence effects. Only the reconstructed limbs of the patients and the matched limbs of the control group were tested.

In this study, the testing procedure was based on a method design by Dingenen et al[5]. The participants performed three standing trials for each testing procedure while keeping their eyes open at a fixed point localized on a facing wall. Each testing procedure started with a 25 second DLS where the athletes were asked to stand barefoot on the center of a single force platform and kept the arms along the body (90 × 90 cm, Bertec Columbus, OH, USA). Next, the athletes were instructed to do transition to SLS on their legs while they maintained 60° hip flexion for 30 seconds on their tested leg. Finally, the athletes' transition to DLS for 5 seconds on a line lying on the center of the force plate ensure that they were localized at the correct position. It is necessary to mention that the first 5 seconds of SLS phase was considered as the loading phase, while the last 5 seconds of the total testing procedure was regarded as the unloading phase. All the athletes were instructed to perform the transition task from DLS to SLS to DLS with preferred speed.

The 500 Hz frequency and low-pass filter with a cut off frequency of 10 Hz were measured by the following variables: COP displacement for range sideways (Rsw) and range fore-aft (Rfa), area, and the mean velocity (Mv) of COP[10].

The sample size was estimated based on the pilot study and 20 subjects were considered in each group: A significant level of 0.05 and a power of 0.95 was assumed. For statical analysis, the SPSS program (version 17) was used.

To explore the presence of any systematic bias, paired t-tests were used to compare the differences between COP variables in the test and retest sessions[11]. Three trials of each condition in the test-retest session were used to calculate the intra-session reliability of the COP variables. In the two sessions (test and retest session), an average of three trials for each condition were used to compute the test retest reliability. We calculated the relative intra- and inter-session reliabilities using a two-way random model of intraclass correlation coefficient (ICC2,3)[12]. Munro's classification for reliability coefficients was utilized to define the extent of reliability. In this classification, the criteria range for reliability is as the following: 0.26 and 0.49 (low correlation), 0.5 and 0.69 (moderate correlation), 0.7 and 0.89 (high correlation), and 0.9 and 1.00 (very high correlation)[13].

Table 2. Descriptive data for test-retest stability indexes made under different conditions of balance task in a sample of individuals with ACLR (n=20) and healthy (n=20) athletes

Group	Task	Variables	Test session			
		Stability index	Test		Retest	
			Mean	SD	Mean	SD
ACLR	DLS	Area	1.42	1.22	1.05	0.91
		Rfa	2.11	0.79	1.99	0.57
		RSW	1.12	0.41	1.11	0.43
		Mv	0.06	0.01	0.06	0.01
	Integration	Area	74.93	33.67	73.22	31.72
		Rfa	4.07	1.20	4.14	1.14
		RSW	20.05	3.13	20.31	3.47
		Mv	0.60	0.10	0.62	0.09
	SLS	Area	62.05	14.19	60.01	12.22
		Rfa	3.81	0.87	3.67	0.66
		RSW	3.07	0.49	3.03	0.49
		Mv	0.19	0.02	0.19	0.02
	Reintegration	Area	89.11	34.66	87.79	34.46
		Rfa	4.00	0.73	3.67	0.66
		RSW	19.94	4.15	20.10	4.28
		Mv	0.72	0.14	0.72	0.14
Healthy	DLS	Area	1.46	0.97	1.14	0.79
		Rfa	2.08	0.43	2.02	0.52
		RSW	1.27	0.52	1.16	0.49
		Mv	0.06	0.01	0.05	0.01
	Integration	Area	71.25	25.55	81.12	40.02
		Rfa	4.04	1.15	3.63	0.79
		RSW	19.69	3.28	19.64	2.15
		Mv	0.59	0.07	0.58	0.06
	SLS	Area	52.39	14.65	55.57	14.33
		Rfa	3.27	0.68	3.47	0.89
		RSW	2.90	0.39	2.85	0.38
		Mv	0.18	0.03	0.18	0.02
	Reintegration	Area	68.93	36.70	81.12	40.02
		Rfa	4.28	1.09	3.86	1.23
		RSW	19.41	3.94	19.86	3.61
		Mv	0.73	0.14	0.74	0.13

Values are mean ± Standard Deviation (SD). p refers to p values of paired t test on test–retest difference. n.s: non-significant. Unit of Area: cm^2, Rfa: cm, Rsw: cm and Mv: cm/sec.

To assess absolute reliability, the standard error of measurement (SEM) was computed to estimate the amount of error associated with the measurement. The minimal detectable change (MDC) was determined as 95% CI of SEM for balance variables (± 1.96 SEM) used to evaluate the change that could be considered significant between the two times of measurement[11, 14].

RESULTS

The mean and standard deviation (SD) of force plate measurements are represented in Table 2 for all testing conditions. There was no significant difference between the test and retest mean scores for all balance parameters (n.s) that demonstrate no systematic bias.

The intra-session reliability and inter-session reliability of the balance measures are shown in Table 3. In general, the intra-session reliability of the balance measure show moderate to very high correlation for the test and retest sessions in both groups. The intra-session ICCs of the test session ranged from 0.64 to 0.91 in the ACLR group and 0.67 to 0.94 in the healthy group. Moreover, the ICCs of the retest session ranged from 0.68 to 0.96 (ACLR) and 0.73 to 0.92 (Healthy).

Table 3. Intra- and intersession reliability of the stability indexes made under different conditions of balance test in a sample of individuals with ACLR and healthy athletes and healthy athletes

Group	Task	Variables	Intra session		Inter session		
		Stability index	Test ICC	Retest ICC	ICC	SEM	MMDC
ACLR	DLS	Area	0.82	0.91	0.73	0.57	40.94
		Rfa	0.90	0.69	0.80	0.28	14.98
		Rsw	0.69	0.77	0.76	0.85	19.36
		Mv	0.70	0.89	0.88	0.01	13.53
	Integration	Area	0.91	0.78	0.64	25.60	27.32
		Rfa	0.75	0.76	0.66	0.70	16.05
		Rsw	0.90	0.94	0.88	1.44	8.75
		Mv	0.73	0.89	0.81	0.04	7.47
	SLS	Area	0.70	0.68	0.68	9.23	15.03
		Rfa	0.64	0.73	0.67	0.56	14.67
		Rsw	0.65	0.69	0.96	0.09	8.40
		Mv	0.81	0.83	0.98	0.01	10.19
	Reintegration	Area	0.92	0.66	0.64	26.62	30.42
		Rfa	0.71	0.83	0.72	0.76	17.78
		Rsw	0.90	0.96	0.83	2.01	11.94
		Mv	0.90	0.94	0.86	0.07	11.77
Healthy	DLS	Area	0.75	0.91	0.70	0.70	51.53
		Rfa	0.67	0.73	0.70	0.47	20.89
		Rsw	0.89	0.90	0.84	0.22	23.60
		Mv	0.78	0.92	0.89	0.01	17.17
	Integration	Area	0.72	0.82	0.75	20.57	27.37
		Rfa	0.74	0.84	0.86	0.57	17.70
		Rsw	0.91	0.85	0.89	1.43	10.16
		Mv	0.80	0.90	0.89	0.04	10.08
	SLS	Area	0.88	0.80	0.70	8.90	13.45
		Rfa	0.76	0.91	0.70	0.58	12.86
		Rsw	0.76	0.83	0.88	0.22	9.96
		Mv	0.82	0.86	0.93	0.01	8.90
	Reintegration	Area	0.94	0.81	0.98	2.43	24.22
		Rfa	0.70	0.77	0.70	0.47	11.11
		Rsw	0.87	0.92	0.98	0.77	13.06
		Mv	0.89	0.90	0.97	0.01	12.29

ICC: intraclass correlation coefficient; SEM: standard error of measurement; MMDC: minimal metrically detectable change.

The inter-session reliability of the balance measure showed moderate to very high correlation in both ACLR (0.67 to 0.94) and healthy (0.73 to 0.92) groups. Besides, the SEM and MDC of the balance measures are displayed in Table 3.

DISCUSSION

The present study examined the inter-session and intra-session reliability of the force plate in subjects with and without ACLR during the weight shift transitional task from DLS to SLS. According to the author's findings, there has been no study until now on the reliability of force plate measurements in subjects with and without ACLR using the transitional task from DLS to SLS.

Significant findings of the present study were that dynamic balance measures are reliable outcomes in ACLR and healthy athletes.

The results of present study demonstrate moderate to very high reliability for balance measures in all test conditions. This indicates that the possibility of the Type 2 error would be limited because of small measurement errors in comparison with the variability between subjects[15].

The highest intra-session reliability for the test session was an area in the reintegration phase of the transitional task from DLS to SLS in ACLRs and healthy groups. And, the highest reliability for the retest session was Rsw in the reintegration phase of the test position in both groups.

The mean velocity parameters in SLS in ACLR groups as well as the area and Rsw parameters in the reintegration phase in the healthy group demonstrated the highest intra-session reliability.

Outcome stability is one of the fundamental factors related to variations in the test-retest reliability studies. Motor control system is mainly effective on the balance control measurements. Thus, learning is effective on the stability measurement, which reduces the outcome following multiple measurements[16]. The learning effect in the current study was minimal so that the balance measures showed an admissible reliability. Another possible reason may be related to the nature of this task. A static single legged phase has been used in the previous studies[7, 17], while an internal perturbation effect was applied in this study due to the transition from DLS to SLS. This transitional task was difficult to perform in comparisons with the static SLS. Moreover it was similar to what was experienced in daily living and might have thus caused differences in the postural control responses.

Although there are no studies assessing reliabilities of these parameters in the ACLR and healthy athletes and the mentioned transitional task from DLS to SLS, the results of the present study showed high levels of reliability (ICC>0.8) for mean velocity. In this case, it may be comparable to the study of Mohammadi et al[7].

Mohammadi et al.[7] examined the subjects eight months after surgery, but the test time in our study was 16 months after reconstructed surgery. On the other hand, the interval repetition between the test and retest sessions in the present study was two to seven days while the interval between the two test sessions was seven to eight days in Mohammadi's study. During the transitional task from DLS to SLS, the subject is in a state of internal perturbation, which influences the SLS phase. The present study shows a similar result by studying such perturbation[15, 16, 18].

The absolute reliability of mean velocity in both groups was the lowest score in all test conditions. The smaller SEM provides an estimate of the smaller error between the test and retest sessions[11].

The Rsw in both groups in the SLS position had the lowest MDC among all test conditions. Since the MDC of the stability index provides information about the amount of the measurement error, lesser scores imply a sensitive amount.

In the current study, the dynamic balance measures were found to produce satisfactory reliabilities in the ACLR and healthy athletes. Thus it may be clinically considerable to include these measures in the protocols examining the effects of surgical and rehabilitative interventions in athletes following an ACL reconstruction to restore their functional stabilities. Furthermore, the results may contribute to the description of the postural control deficits discovered in athletes especially during the transitional task from DLS to SLS. Also, transitional task trainer may benefit the training to improve their athletes' postural control performances.

One of the limitations of this study was the possibility of generalizing the results only to the mentioned tested populations, but not to any other populations or transitional tasks. Therefore, further research is suggested to be performed on the reliabilities of other force plate parameters among populations with varied histories of activity levels and injuries.

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Conflict of interest

None.

REFERENCES

1) Furlanetto TS, Peyré-Tartaruga LA, do Pinho AS, et al.: Proprioception, body balance and functionality in individuals with ACL reconstruction. Acta Ortop Bras, 2016, 24: 67–72. [Medline] [CrossRef]
2) Jacobs JV, Horak FB: Cortical control of postural responses. J Neural Transm (Vienna), 2007, 114: 1339–1348. [Medline] [CrossRef]
3) Seidel JC, Grooms DR, McNally MP, et al.: The relationship between knee proprioception and balance in anterior cruciate ligament reconstructed individualS. The Ohio State University, Columbus. http://medicine.osu.edu/hrs/at/research.
4) Van Deun S, Stappaerts K, Levin O, et al.: Stability of measurement outcomes for voluntary task performance in participants with chronic ankle instability and healthy participants. J Athl Train, 2011, 46: 366–375. [Medline] [CrossRef]
5) Dingenen B, Staes FF, Janssens L: A new method to analyze postural stability during a transition task from double-leg stance to single-leg stance. J Biomech, 2013, 46: 2213–2219. [Medline] [CrossRef]
6) Dingenen B, Janssens L, Claes S, et al.: Postural stability deficits during the transition from double-leg stance to single-leg stance in anterior cruciate ligament reconstructed subjects. Hum Mov Sci, 2015, 41: 46–58. [Medline] [CrossRef]
7) Mohammadi F, Salavati M, Akhbari B, et al.: Static and dynamic postural control in competitive athletes after anterior cruciate ligament reconstruction and controls. Knee Surg Sports Traumatol Arthrosc, 2012, 20: 1603–1610. [Medline] [CrossRef]
8) Levin O, Van Nevel A, Malone C, et al.: Sway activity and muscle recruitment order during transition from double to single-leg stance in subjects with chronic ankle instability. Gait Posture, 2012, 36: 546–551. [Medline] [CrossRef]

9) Sole G, Milosavljevic S, Nicholson H, et al.: Altered muscle activation following hamstring injuries. Br J Sports Med, 2012, 46: 118–123. [Medline] [CrossRef]
10) Raymakers JA, Samson MM, Verhaar HJ: The assessment of body sway and the choice of the stability parameter(s). Gait Posture, 2005, 21: 48–58. [Medline] [CrossRef]
11) Atkinson G, Nevill AM: Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med, 1998, 26: 217–238. [Medline] [CrossRef]
12) Weir JP: Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res, 2005, 19: 231–240. [Medline]
13) Domholdt E: Rehabilitation research: principles and applications, 4th ed. Elsevier, 2011, pp 86–101.
14) Corriveau H, Hébert R, Prince F, et al.: Intrasession reliability of the "center of pressure minus center of mass" variable of postural control in the healthy elderly. Arch Phys Med Rehabil, 2000, 81: 45–48. [Medline]
15) Akhbari B, Salavati M, Ahadi J, et al.: Reliability of dynamic balance simultaneously with cognitive performance in patients with ACL deficiency and after ACL reconstructions and in healthy controls. Knee Surg Sports Traumatol Arthrosc, 2015, 23: 3178–3185. [Medline] [CrossRef]
16) Leitner C, Mair P, Paul B, et al.: Reliability of posturographic measurements in the assessment of impaired sensorimotor function in chronic low back pain. J Electromyogr Kinesiol, 2009, 19: 380–390. [Medline] [CrossRef]
17) Mazaheri M, Negahban H, Salavati M, et al.: Reliability of recurrence quantification analysis measures of the center of pressure during standing in individuals with musculoskeletal disorders. 2010, 32: 808–812.
18) Ikai T, Kamikubo T, Takehara I, et al.: Dynamic postural control in middle-aged and elderly peaple. Jpn J Rehabil Med, 2002, 39: 311–316. [CrossRef]