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Reliability of the Center of Pressure Parameters after ACL Reconstruction Surgery

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Abstract

***Background*:** The elicited parameters from the center of pressure (COP) of patients after surgery of the anterior cruciate ligament are proper indications for estimating balance after surgery and rehabilitation. Thus, making sure about repeatability of COP parameters which can determine the knee joint after the knee reconstruction surgery is very important. This study measures repeatability rate of some COP parameters after reconstructing anterior cruciate ligament in various positions.

***Materials and Methods*:** In this study, 15 athlete men (mean age: 27±5) after 4-6 months since repair of their anterior cruciate ligament were included; they have been selected through simple non-probability sampling method. The study was conducted in biomechanics lab of Tarbiat Modares University in 2010. Assessment of balance was done with open/closed eyes, with/without foam using force platform in two sessions with 48 hours interval.

Results The external-internal amplitude (0.86), external-internal standard deviation (0.86), phase plane (0.82) and area oscillation (0.81) were among parameters which showed the most repeatability. The average oscillation of anterior - posterior frequency (0.6) showed the lowest repeatability.

***Conclusion*:** A number of parameters caused by oscillation of COP show high rate of repeatability after reconstructing anterior cruciate ligament which can be used as an assessment of patients condition after reconstruction of the anterior cruciate ligament.

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Introduction

Analysis and studying of balance and posture and assessment of effect of the medical measures entails reliable measuring tools. As one of the most common tools used to assess balance, force platform can be used to extract oscillation parameters of Center of pressure [1].

The COP parameters are used as indicators of balance control and posture in many musculoskeletal disorders [2, 3]. Among musculoskeletal disorders, anterior cruciate ligament injury [1] is treated as a complication which remains even after repairing of the ligament. Since, the anterior cruciate ligament is active in proprioception and hence keeping balance, a considerable part of the functional analyses of the joint after anterior cruciate ligament injuries deal with the ability to keep balance and proprioception of such patients [4]. Some assessments conducted for analyzing the improving rate of patients after undergoing surgical reconstruction of anterior cruciate ligament are related to function of knee. For such patients, assessment of COP parameter is a proper tool for assessment which is used in other knee related studies, as well [4- 6]. COP is used in other musculoskeletal diseases including functional ankle instability and low-back pain as an assessment indicator of balance [7- 9]. However, the important point is that the repeatability of various parameters adopted from the COP is not identical in different condition and diseases [9, 10]. In order to make sure about the results gained from the examination, we should make sure about the repeatability of the system output and the recorded parameters in certain lab condition [11]; as a result this discussion is one of the most important parts of the study.

Repeatability can be due to test condition, test place, test tools, tester and variable nature of the biological events. Errors due to test tools can be controlled very easily and the available instrumentations and the techniques used by manufacturers to calibrate machines make errors due to tools controllable. Test condition and testers' mistakes can be controlled using a proper research method. However, the innate changes of the measured parameters which are related to the internal changes of body and posture and balance control systems are out of researcher's control. Therefore, such studies mainly focus on selection of parameters equipped with repeatability, and their changes reflect the effects of treatment. For instance, in injuries such as functional ankle instability, low-back pain and anterior cruciate ligament injury, some more repeatability has been confirmed in some parameters such as mean total velocity and phase plane portrait [2, 8, 12]. Hence, as mentioned already, the

extracted parameters from the COP of patients underwent anterior cruciate ligament surgery are proper indicators for assessing patients' balance after surgery and rehabilitation. Therefore, making sure of repeatability of COP parameters which are able to specify the knee joint status after knee repair surgery is very valuable.

Although several clinical studies on patients with anterior cruciate ligament take advantage of COP values to assess postural stability, no methodological study has been done so far for setting COP values in these patients [1, 16- 18]. Moreover, incorrect use of the healthy people to approve repeatability of the clinical values can increase the repeatability, because healthy people undertake tests simpler than patients.

This study tries to assess the repeatability rate of some COP parameters after surgery of the anterior cruciate ligament in various postures.

Materials and Methods

In this study, a number of 15 athlete men (with the mean age: 25±5 years) with repaired anterior cruciate ligament after 4-6 months from their operation were included in this study, they all have referred to the orthopedics department of Akhtar Hospital. They were selected after filling questionnaires regarding the inclusion and exclusion criteria of the study. It is necessary to mention that based on the radiological examination and evidence all patients before surgery showed the full rupture of the anterior cruciate ligament. All subjects filled the conscious consent form approved by the medical ethical committee of the university. The inclusion criteria were: anterior cruciate ligament rupture with rupture of the peripheral parts including meniscus, posterior cruciate ligament, internal lateral ligament, external lateral ligament and healthy opposite foot, the ability to practice light activities 4 months after injury, being athlete (sports involve with foot), full skeletal range of joint, 20-40 years old men, BMI:20-25%, height: 160-180 cm, lack of history of surgery in the involved knee which had normal function in other joints of leg.

The exclusion criteria were knee fractures, instability of the injured knee before surgery, pain and abnormal swelling, vascular and nervous problems, vestibular and visual problems, meniscus or nerves injury, severe cardiopulmonary problems, diabetes, and consuming drugs which affect the balance. COP data were recorded using the force platform made by the Swiss Kistler company (model 9286 B) equipped with data recorder and processor software (bioware). Data were captured through frequency 100 Hz for 4 seconds and then was measured using Matlab software. Before beginning the test, the force platform was calibrated according to the machine manual with a 20-kg weight. In the squatting test, a mechanical goniameter was used to set the angle of the patient's knee was used. Two tests, standing on one foot and standing on two feet were conducted in this stage.

Standing on two feet: In this stage, the patient conducted eight tests including standing on two feet with open/closed eyes, with/without foams. Each test's duration was 2 seconds and each test repeated three times and the patient was resting in interval between two tests for 20 seconds. The patient stood barefoot at the center of the force platform. He/she was asked to stare a point in the opposite wall while his/her head was straight, hands hanging beside the body. When the patient reached a stable status, the test was beginning. In the next stage, the patient repeated the test without foam while her/his eyes were closed. Then he/she repeated the test with a foam, as after standing on the foam the therapist let the patient to find his/her stability and then tests were started.

Standing on one foot: In this stage each foot of the patient is participated in four tests, with open and closed eyes. Each tests lasted 20 seconds and each one repeated three times and the patient rested in the intermissions between tests for 20 seconds. After standing on the force platform, patient lifted his/her non-test foot, while the thigh angle was about 0 and the knee angle was about 90°, and put the hands on pelvis. The patient was asked to stare a point marked on the opposite wall and to keep his/her condition during test. The test would be finished when the patient's would reach the ground. The oscillation rate of body's center of gravity for each foot was recorded in terms of degree/sec.

The average value of measuring COP three times in each posture was used to set the repeatability coefficient. All information were stored and then sent to Matlab program. Posterior-anterior movement and interior-exterior movement of the COP towards x and y axes were measured. Analyzing the COP data showed that removing the 8 Hz frequency is the best solution to avoid noise power; however removing 10 Hz frequency was selected for better results. Then signals of COP were filtered using frequency removing of zero-second order, butterworth low pass filter and phase and 10 Hz frequency removing.

Results

Patients demographic information: In this study the following information were measured: mean age: 27.1±5.2 years, mean height: 177.9±7.4 cm, BMI: 77.67±13.77 kg, mean duration since repair: 5.5±3.2 months. The derived measurements of COP which were used in this study were: 1-Velocity (cm/sec.); 2- time (second); 3- frequency (Hz); 4) distance (cm).

Table 1 shows the equations used to measure the mentioned parameters.

The paired t-test was used to determine the lack of any systemic error. The alpha level of 0.05 was used for the statistical analysis. Interclass correlation coefficient (ICC) is the most common indicator used to report the relative repeatability [13]. In this study, ICC was used to state the relative repeatability of values [14].

In order to report the repeatability degree, the coefficient range of repeatability reported by Munro was used: 0.00 to 0.25: low if any correlation; 0.26-0.49 low correlation; 0.50-0.69: medium correlation; 0.70 -0.89: high correlation and 0.90-1.00 very high correlation [15]. Both ICC levels and p-values have been reported in table 2. Most parameters in most difficult postures had medium

Table 1. ICC values diagram and meaningful level in various postures

Standing on one leg				Standing on two legs							
Blindfold		With open eyes		Foam surface Blindfold		Foam surface With open eyes		Hard surface Blindfold		Hard surface With open eyes	
p	ICC	*p*	ICC	*p*	ICC	*p*	ICC	*p*	ICC	*p*	ICC	
Anterior - posterior												
0.04	0.48	0.04	0.6	0.04	0.6	0.05	0.54	0.01	0.85	0.001	0.88	Average oscillation frequency
0.001	0.8	0.01	0.7	0.007	0.72	0.01	0.7	0.03	0.59	0.001	0.91	Amplitude
0.001	0.87	0.002	0.78	0.004	0.75	0.01	0.87	0.17	0.45	0.006	0.73	SD of Amplitude
Internal – external												
0.005	0.72	0.009	0.7	0.02	0.62	0.006	0.72	0.002	0.77	0.001	0.83	Average oscillation frequency
0.001	0.96	0.001	0.8	0.01	0.7	0.001	0.8	0.001	0.97	0.001	0.98	Amplitude
0.001	0.94	0.001	0.81	0.004	0.76	0.001	0.84	0.001	0.94	0.001	0.91	SD of Amplitude
Speed												
0.009	0.73	0.18	0.39	0.002	0.75	0.001	0.81	0.001	0.78	0.002	0.75	The average speed
0.001	0.92	0.001	0.79	0.003	0.75	0.001	0.87	0.002	0.77	0.002	0.76	Deviation page *
0.001	0.8	0.001	0.89	0.001	0.81	0.001	0.92	0.01	0.65	0.001	0.86	Page Phase
Surface												
0.002	0.77	0.003	0.76	0.06	0.53	0.001	0.82	0.001	0.99	0.001	0.99	Circular fluctuating levels

*Planar Deviation

Table 2. Mean values of oscillatory parameters of COP

	Standing on one injured leg			
	With open eyes		Blindfold	
Puschral parameters	Test	Retest	Test	Retest
Anterior - posterior				
Average frequency (Htz)	0.81±0.22	0.51±0.03	0.77±0.14	
SD of Amplitude (cm)	0.78±0.32	0.46±0.09	1.9±0.76	1.1±0.26
Amplitude (cm)	1.9±1.9	3.14±4.53	4.5±4.45	1.96±2.91
Fluctuation level				
Circular fluctuating levels (cm^2)	3.5±3.5	5.61±1.2	1.49±1.49	6.02±4.4
Internal – external				
Average frequency (Htz)	1.04±0.3	1.01±0.29	1.03±0.22	1.16±0.28
SD of Amplitude (cm)	2.41±5.59	2.77±2.76	1.77±1.76	0.96±0.27
Amplitude (cm)	2.84±2.84	2.01±2.56	1.7±1.7	6.34±2.69
Speed				
The average speed (cm/s)	2.35±3.66	2.32±3.81	6.06±1.18	6.75±1.72
Page Phase	1.11±1.1	2.89±5.11	6±5.99	1.45±8.36
Deviation page*(cm)	3.25±3.25	0.65±8.23	1.75±1.74	1.45±2.98

Table 3. The diagram for mean value and SD of oscillatory parameters of COP

	Standing on two legs							
	Hard surface With open eyes		Hard surface Blindfold		Foam surface With open eyes		Foam surface Blindfold	
	Test	Retest	Test	Retest	Test	Retest	Test	Retest
Anterior - posterior								
Average frequency (Htz)	0.54±0.11	0.5±0.12	0.54±0.13	0.42±0.06	0.58±0.16	0.36±0.02	0.65±0.18	0.39±0.04
SD of Amplitude (cm)	5.53±2.41	2.84±2.83	6.56±2.85	1.29±6.2	6.53±6.51	1.38±6.55	7.01±6.9	2.03±0.38
Amplitude (cm)	0.33±0.06	0.35±0.07	0.31±0.05	0.26±0.04	0.54±0.07	0.48±0.08	0.92±0.1	0.78±0.1
Surface								
Circular fluctuating levels (cm^2)	1.76±1.76	1.9±1..9	1.35±1.35	1.05±1.05	2.12±2.12	5.49±1.49	1.76±1.76	1.16±1.73
Internal – external								
Average frequency (Htz)	0.99±0.31	1.22±0.32	0.96±0.32	1.26±0.39	0.92±0.26	0.83±0.22	0.93±0.24	0.9±0.21
Amplitude (cm)	8.09±8.08	2.83±4.45	3.21±3.2	4.46±4.45	9.05±9.03	1.62±1.92	9.65±9.62	2.91±3.64
SD of Amplitude (cm)	5.15±5.12	6.38±6.36	4.61±4.59	6.62±3.6	6.64±6.6	0.37±4.42	6.79±6.71	0.69±0.09
Speed								
The average speed (cm/s)	6.92±1.12	7.5±1.29	7.61±3.23	7.28±1.1	1.76±3.23	1.75±2.96	3.55±4.54	3.1±3.37
Page Phase	2.17±2.17	2.12±2.12	2.2±2.2	1.12±1.12	2.97±2.97	2.19±4.5	2.65±2.64	3.65±4.41
Deviation page*(cm)	7.06±7.02	6.69±2.99	3.8±1.7	7.47±3.25	9.44±9.37	0.62±8.69	8.12±8	0.98±1.12

Planar Deviation*

to very high correlation. Table 2 shows the descriptive statistics of the postural rates of parameters (mean value and SD) for each posture and class.

Most parameters of postural difficulty had medium to very high correlation. According to Munro classification, the mean ICC for all parameters, except for the mean value of anterior-posterior oscillation frequency, had >0.8 correlation. The ICC mean value for area, interior-exterior oscillation range, interior-exterior oscillation SD, planar deviation and phase plane were 86.81, 0.0, 0.86, 0.81, and 0.82, respectively. The average rate of the interior-exterior frequency (0.6) had the lowest average ICC.

Discussion

The results of the study were based on the mean correlation coefficient, the highest repeatability coefficients belonged to phase plane, interior-exterior SD and interior-exterior oscillation range and the lowest repeatability coefficient belonged to mean posterior-anterior oscillation frequency.

The participants tested under difficult postural condition, usually, such postural condition was being used by researchers to assess the balance under instability condition and/or decreased accessibility to the afferent inputs [19]. The several values of the COP are selected based on their usage in researches. The current results show that most parameters in most difficult postures had medium to high postural correlations. The mean anterior-posterior oscillation frequency in standing on two feet with open and closed eyes had high correlation coefficients. The correlation coefficient of anterior-posterior oscillation range in standing on two feet with open eyes was very high. The coefficient for other mentioned difficult postures (except for standing on two feet with closed eyes) was high. For the area parameter with the circular oscillation, standing on feet with either open or closed eyes had high correlation coefficient as well, likewise, other states of the condition had medium to high correlation coefficients. The mean frequency power in interior-exterior direction, except for standing on two feet with foam and closed eyes (ICC=0.62) had high correlation coefficient. The exterior- interior oscillation range in three postures: standing on two feet with foam with closed and open eyes and standing on the injured foot with the closed eye had high repeatability, so we observed high correlation coefficients in three remaining postures. All average velocity values had high correlation coefficients. The statistical analyzes on the phase plane indicate very high correlation coefficients for the posture of standing on two feet with foam with open eyes and high correlation coefficient for other postures except for standing on two feet with foam with closed eyes. For the planar deviation, we observe very high correlation coefficient in standing on the injured foot with the open eyes and high correlation for other postures. The statistical analyzes on the anterior-posterior SD, except for standing on two feet with the injured eyes, had low correlation coefficient, but it was high for other postures. The results obtained from the ICC test showed very high correlation coefficient for standing on two feet with foam and standing on one foot with the closed eyes, while three remaining postures we saw very high correlation coefficient. In this study, based on the average correlation coefficient value, the most repeatability coefficients belonged to the phase plane, interior-exterior SD and exterior-interior oscillation range, while the lowest one belonged to the average anterior-posterior oscillation frequency. Riley et al. concluded that phase plane and velocity are two parameters of COP which can distinguish between the healthy people and a group whose bilateral vestibular function had been declined [20]. Lafond et al. concluded that the mean oscillation velocity of COP is the most distinguishable parameter which can be used to assess the changes related to age in the postural control [11]. Salavati et al. selected oscillation velocity and phase plane as the sensitive values of the COP which are useful for setting the balance distinguish between patients with anterior cruciate ligament injury and assessment of the effect of rehabilitation plan on such patients [9]. It is possible that the obtained difference in this study with other studies would be due to the difference of the studied population.

Based on the average correlation coefficient, the highest repeatability coefficients belong to the phase plane parameters, interior-exterior SD and interior-exterior oscillation range and the lowest one belongs to anterior-posterior oscillation frequency.

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Authors' Contributions

All authors had equal role in design, work, statistical analysis and manuscript writing.

Conflict of Interest

The authors declare no conflict of interest.

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