Pedobarography of the Coper and Non-Coper ACL-Deficient Knee Subjects during Single and Double Leg Stance

Abbas Rahimi [a*], Narjes Soltani [b], Sedigheh Sadat Naimi [a], Khosro Kalantari Khademi [a], Hassan Saeedi [c]

a Physiotherapy Research Centre, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, *b* Physiotherapist, Private office, Mashad City, Iran; *c* The University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

Corresponding Author:** Abbas Rahimi. Physiotherapy Research Centre, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran. ***E-mail: a_rahimi@sbmu.ac.ir

Submitted: 2015-12-08; **Accepted**: 2016-03-10

Introduction: Biomechanical studies have frequently shown a close relationship between the knee and ankle joint movements. ACL-deficiency may change the foot pressure pattern of the ACL-deficient knee subjects. The current study aimed to investigate the pattern of the foot pressure in coper and non-coper ACL-deficient knee subjects during standing on one and both feet. **Methods and Materials:** This case-control study was conducted on 12 coper and 12 non-coper ACL-deficient knee subjects and 25 age-sex matched healthy subjects. The subjects were tested barefoot during single and bilateral standing on the platform of a Zebris pedobarograph tool. The outcome measures included the measurements of the pressures of each part of the foot during the tests. **Results:** The results showed a significantly decreased total pressure only between the non-coper and control groups during double leg stance test. In terms of the forefoot pressure, a significant increased pressure was shown only in the non-coper ACL-deficient knee subjects during both single and double leg stance tests ($P<0.05$). In both test conditions, the coper ACL-deficient knee subjects showed forefoot and hind foot pressures very close to the control group ($P>0.05$). **Conclusion:** This study revealed marked changes following ACL-deficiency mainlyin non-coper ACL-deficient knee subjects. The increased forefoot pressure in non-coper ACL-deficient knee subjects was probably due to the forwarded line of gravity in these patients aligned with their base of support to keep their knees more stable. Further studies are needed to verify the differences between the male and female ACL-deficient knee subjects.

Keywords: Coper/Non-Coper ACL-Deficient Knee Subjects; Stability; Pedobarograph; Foot Pressure System; Postural Control

Please cite this paper as: Rahimi A. Soltani N, Naimi S.S, Khademi K.K, Saeedi H. Pedobarography of ohe Coper ond Non-Coper ACL-Deficient Knee Subjects during Single and Double Leg Stance. JCPR. 2017; 1(1): 17-22.

Introduction

The anterior cruciate ligament (ACL), as the primary knee stabilizer in both static and dynamic status in sagittal plane, works mainly to prevent anterior tibial translation relative to the femur in an open kinetic chain (OKC) and vice versa in the closed kinetic chain (CKC) (1, 2). In addition, this ligament plays an important role in tibio-femoral rotational axis, particularly tibial internal rotation, during knee flexion (3). The incidence of the ACL injury is much higher in athletes than in normal people (4). When this ligament is torn, the subjects turn to be either copers or non-coper (5). The minority coper subjects (14-20%) use some complex neuro-musculo-skeletal strategies to dynamically stabilize their ACL-minus knees and are able to return to their professional sport at their pre-injury level (6, 7). However, the rest of the ACL-deficient (ACL-D) knee subjects exhibit knee instability and use different strategies to keep their daily activities almost normal (8-10). To return to pivoting sport activities, the non-coper ACL-D knee subjects need ACL-reconstruction surgery, which may not guarantee their return to the vigorous maneuvers (7, 10). A review of the literature reveals that the compensatory strategies used by each group are still controversial (11). In addition to the kinematic and kinetic parameters in gait analysis, during the last decade, investigation of the foot pressure patterns of patients have widely been accepted as a functional assessment to provide useful information to scientists (12, 13, 14). Due to the existence of the closed kinetic chain in the lower limb during stance phase of walking, researchers have studied the relationship between foot pathologies and the risk of ACL-injuries in different activities (15, 16). Some studies, such as Stergiou *et al.* (1997), have reported a close link between foot pronation and knee function through tibial rotations, which may predispose the subjects to knee injuries (17). This was also confirmed by Timble *et al.* (18) in 2002 who demonstrated a direct association between the foot

Table 1. Demographic characteristics of the subjects

Groups	No.	Age (years)	Height (Cm)	Weights (Kg.)	Times past Injury (months)	KOOS Score (out of 100)
Copers	12	26±3	176±4	69±4	10.2±5	85±3
Non-copers	12	24±2	180±6	71±10	9±6.4	66±7
Controls	25	23.7±2.4	179±5.5	70.9±11	-	-

Table 2. The foot pressure data of the coper, non-coper, and control groups in double leg stance (*=significant difference)

Variables (N)	Copers	Non-Copers	Controls	P-value (ANOVA)	Within Groups Analysis	*P*-value
Total Foot Pressure	47.8	45	50.8	0.043*	Coper vs. Control	0.717
					Non-coper vs. Control	0.008*
					Coper vs. Non-coper	0.512
Forefoot Pressure	39.6	55.9	36.1	0.027*	Coper vs. Control	0.402
					Non-coper vs. Control	0.001*
					Coper vs. Non-coper	0.002*
Hindfoot Pressure	60.4	44.1	63.9	0.038*	Coper vs. Control	0.402
					Non-coper vs. Control	0.001*
					Coper vs. Non-coper	0.002*

and knee movements during daily and sporting activities. Since then, many studies have been conducted to investigate knee injuries via foot pressure assessments. Chemielewski *et al.* (19) compared the weight bearing changes of the foot of the ACL-D and ACL-reconstructed knee subjects and reported a non-significant reduction of weight bearing time in both groups when compared to those in the normal subjects. Hoftberger *et al.* (20) found a more foot pressure on the forefoot of ACL-D knee subjects related to the hindfoot during walking on level ground. Kaplan reported a marked reduction of the weight bearing time in both the forefoot and hindfoot of the ACL-reconstructed knee subjects three weeks after the surgery (21). In addition, there are many studies on the foot pressure of the subjects with different foot and knee problems (22, 23, 24). However, to the best of our knowledge, there is very little evidence regarding the foot pressure of the coper and non-coper ACL-D knee subjects during standing on one or both feet. Therefore, the current study aimed at investigating the changes on the foot pressure patterns of the coper and non-coper ACL-D knee individuals during static single and double leg stance conditions.

Methods and Materials

Subjects

Based on the relevant sample size formula, 24 ACL-D knee subjects, including 12 non-coper and 12 coper ACL-D knee subjects, were recruited in the present cross-sectional case-control study and were compared with 25 normal subjects as the control group. All the subjects were males and signed a consent form confirming their voluntarily participation in the study. The ACL-D subjects were recreational athletes and were selected based on the inclusion and exclusion criteria among the patients who had referred to the Tehran's Sports Clinic in 2012. The ACL-minus knees were confirmed by MRI and should have had a completely torn ACL between the last 6-12 months. All patients had to have an isolated full tear of the ACL with no meniscal or other associated injuries. Another inclusion criterion for the patients was no noticeable pain or inflammation and the ability to stand on their injured limb with open eyes for at least one minute. The subjects were excluded if they had any meniscal or other ligamentous injuries, any visual, vestibular or neurological problems disturbing their balance, limitation of motion of the knees, inflammation, pain higher than 3 (out of 10) in VAS in the injured or apparently healthy knees. The control group included 25 healthy males with no history of knee injuries or operation matched to the ACL-D knee subjects in terms of age, sex, BMI, and the level of activities (Table 1).

Study design

The present case-control study was carried out in the Biomechanic laboratory of the School of Rehabilitation at Shahid Beheshti University of Medical Sciences, Tehran, Iran, in 2012. All the ACL-D subjects were examined, confirmed, and referred by one orthopedic surgeon expert in knee joint. Firstly, a professional physiotherapist working with athletes examined all the subjects and recorded their knee range of movement, pain, inflammation, and their ability to stand on their injured or healthy limbs individually and checked all the inclusion/exclusion criteria. The subjects were then allocated into the coper group if they had a KOOS score higher than 80 (out of 100), experienced no knee instability (giving way) during the last six months in any sporting activities, and had returned to their pre-injury level activities (25, 26). The non-coper ACL-D subjects were those who had experienced giving way at least once during the past six months, were not able to return to their pre-injury level

Table 3. The foot pressure data of the coper, non-coper, and control groups in single leg stance (*=significant difference)

Variables (N)	Copers	Non-Copers	Controls	*P*-value (ANOVA)	Within Groups Analysis	*P*-value
Forefoot Pressure	40.7	59.4	38.2	0.027	Coper vs. Control	0.600
					Non-coper vs. Control	0.001*
					Coper vs. Non-coper	0.017*
Hindfoot Pressure	59.3	40.6	61.8	0.025	Coper vs. Control	0.600
					Non-coper vs. Control	0.001*
					Coper vs. Non-coper	0.017*

Table 4. A comparison of all data during single and double leg stance at a glance

Groups	Single Leg Stance		Double Leg Stance		
	Forefoot	Hind foot	Forefoot	Hind foot	Total foot
Coper	40.7	59.3	39.6	60.4	47.8
Non-Coper	59.4	40.6	55.9	44.1	45
Control	38.2	61.8	36.1	63.9	50.8

activities, and had KOOS score less than 80 (out of 100) (25, 26). A Pedobarograph platform (Zebris, Company, Germany) with the size of 55*40*2.5 cm with 1920 capacitive sensors and a frequency rate of 100 Hz was used to record the pressure patterns of the subjects (Figure 1). Nakhaee *et al.* (2008) reported a good reliability index (ICC >0.90) for this system (27). The outcome measurements of the present study included the forefoot, hindfoot and total foot pressure during double leg stance, and the forefoot and hindfoot pressures during a single leg stance condition. To eliminate any bias of the order of the tests, the single and double leg standing tests were carried out randomly. All tests were carried out with barefoot by the following procedure:

Single leg stance test:

In this test, the subjects stood on the platform on one leg while their hands were next to their bodies and stared at the front wall. The data was captured for 10 seconds with a 30-second rest interval. Five successful trials were recorded. Only the injured legs of the ACL-D subjects were tested, while in healthy subjects, the test was carried out on the knees matched to the ACL-D knees (Figure 2).

Double leg stance test:

In this test, the subjects stood on the platform on both feet while their hands were next to their bodies and stared at the front wall. The data was captured for ten seconds and five successful trials were recorded with thirty-second rest interval (Figure 3).

Statistical analysis:

The values of the forefoot, hindfoot, and total foot pressure during single and double leg stance of the coper, non-coper, and control groups were collected in the Excel spread sheath and were statistically analyzed using SPSS (v. 20). The Kolmonogrov-Smirnov test was run to check if the data was normally distributed. One-way ANOVA was used when the data was normally distributed in the three groups. The Bonferonni post Hoc test was used for within group analysis when the ANOVA showed a significant difference. The p-value was set at $\alpha=0.05$.

Results

Prior to carrying out the main study, to ensure if the pedobarograph data of the study was reliable, a repeatability pilot study was conducted on five healthy subjects. The subjects stood on the platform both single and double leg stance three times. The test was conducted twice on the same day and once one week later. The Intra Class Correlation Coefficient (ICC) was 0.90%, which shows a good repeatability data that convinced the researchers to continue for data analysis with more subjects. The Kolmonogrov-Smirnov test showed that only the total foot pressure data was normally distributed.

Table 2 shows that during the double leg stance test, the non-coper ACL-D knee subjects showed a significantly lower total pressure compared with that of the control group (*P*=0.008). However, the coper subjects showed a total foot pressure was very close to the control group (*P*>0.05). The analysis of the forefoot pressure demonstrated that the non-coper ACL-D subjects applied significantly more pressure compared with that of either the coper or the control groups (*P*=0.002, *P*=0.001, respectively). Also, no significant difference was found between the coper and healthy groups (*P*=0.0402). Inversely, the data on hindfoot pressure revealed that the non-coper ACL-D subjects showed significantly lower hindfoot pressure compared with that of either the coper or the healthy groups (*P*=0.002, *P*=0.001, respectively).

Figure 1. A Zebris Pedobarograph Platform

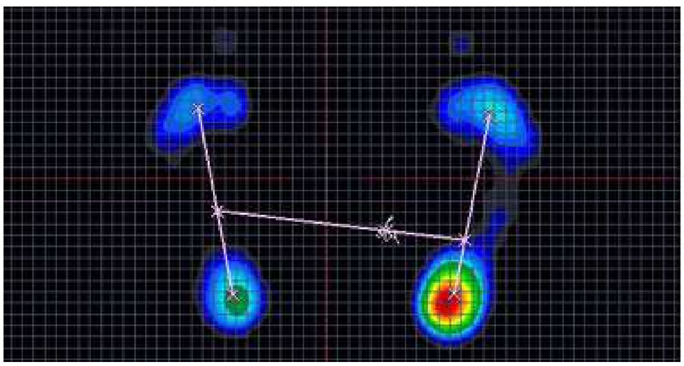

Figure 3. A sample of the foot pressure pattern during double stance test

As Table 2 clearly shows, the non-coper ACL-D subjects showed lower total and hindfoot pressure and significantly more forefoot pressure than those of either the coper or control groups. In other words, the non-coper ACLD subjects kept their stability during double leg stance via applying more pressures on their forefoot on the ground. The coper ACLD subjects, however, could keep their stability during double stance standing very similar to the healthy subjects. They used less forefoot and more hindfoot pressure on the ground like normal subjects.

The foot pressure pattern of the coper, non-coper, and control groups during single leg stance are provide in Table 3.

During a single leg stance, only the forefoot and hindfoot pressures were recorded and compared among groups.

According to Table 3, during the single leg stance, similar to the double leg stance, the forefoot pressure was significantly higher in non-coper ACLD subjects compared with that in either the coper or the control groups ($P<0.05$). The coper and control groups were observed to have forefoot pressures very close to each other ($P>0.05$). Again, the hindfoot pressure of the subjects showed a significant lower pressure in the non-coper ACL-D knee subjects as compared with that in the coper and control groups during single leg stance ($P=0.017$, $P=0.001$, respectively).

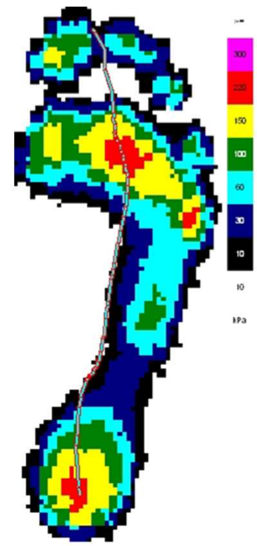

Figure 2. A sample of the foot pressure pattern during a single stance test

Comparison of Tables 2 and 3 is helpful in understanding the point that the non-coper ACL-D knee subjects used their forefoot more than their hindfoot to keep their stability during both single and double leg stance conditions.

Table 4 was drawn to have a better comparison for foot pressure among different groups during single and double leg stance.

Discussion

The current study was carried out to understand how the coper and non-coper ACL-D knee subjects apply foot pressures on the ground during single or double leg stance to keep their balance. The results showed that the coper and non-coper ACL-D knee subjects used an opposite strategy to keep balance during either single or double leg stance conditions. In other words, while the coper ACL-D subjects showed foot pressures very close to the healthy subjects by applying more hindfoot pressure than forefoot pressure, the non-coper ACL-D knee subjects always used more forefoot pressure and less hindfoot pressure in standing conditions.

The results of the present study are in some parts in agreement with many studies in the literature. The healthy subjects showed nearly 38% forefoot versus 62% hindfoot pressure during single stance, and 36% forefoot and 64% hindfoot pressure during double leg stance, which is in agreement with Cavanagh *et al.*, Imamura *et al.*, and Tuna *et al.* (28-30). Unfortunately, most investigations available in this area have studied healthy subjects and there are only a few reports on studying foot pressure pattern in ACL-D knee subjects. The current study confirmed the results in Hoftberger *et al.* who reported more forefoot pressure in ACL-D knee subjects (20). In normal subjects, in sagittal view, the line of gravity passes slightly anterior to the knee joint and lands on the front of the ankle joint, thus needs little calf muscle activities to counter balance this small forward bending moment. However, in non-coper ACL-D knee subjects, who make up more than 80% of the ACL-deficient knee subjects, the line of gravity probably passes more through the front of the knee (31) and hyper-extends the joint to keep its balance to avoid giving way, thus lands more front of the ankle joint. This needs more calf muscle activities in these subjects who normally complain of many trigger points in this area. Therefore, these participants involuntarily use the front of their feet more in order to keep their balance during standing on level ground. This is in agreement with the quadriceps avoidance gait pattern which has frequently been reported in these subjects (32-34). In contrast, Harty *et al.* (2005) reported that a knee with flexion angle around 20 degrees is often used in subjects with lower limb instability to increase their forefoot pressure via closing their center of gravity to their base of support (35). This theory might be sensible in such subjects with ACL-deficient knee as this position places their hamstring muscle in a better position for pulling back their tibia by hamstring contraction (35). However, it should be noticed that this might be true only during the heel strike phase and not in standing single or double leg stance positions. In either of those above-mentioned theories, a co-contraction occurs around the knee joint to provide a physiologic stable knee by increasing knee prorioception and awareness to help the patients' stability (36). In 2008, Kaplan *et al.* reported a marked reduction of the weight bearing time in both the forefoot and hindfoot of the ACL-reconstructed knee subjects three weeks after the surgery, which is expectable after the surgery (21). Some researchers have reported a less weight bearing force on the injured leg when compared to the healthy leg during a double stance position. This was reported by Ashvin *et al.* who reported this as a natural defense of the deficient knee to reduce total loads (37). In contrast, Chmielewski *et al.* reported an equal weight bearing on both knees of the ACL-deficient knee subjects during double leg stance. However, a detailed look at their study reveals that this did not occur routinely in these patients. In fact, this happened intentionally by the researchers to teach the ACL-deficient knee subjects to distribute their weights equally on their legs (9). In the current study, only the injured leg was studied and no comparison was made between the injured feet and the apparently healthy leg.

Conclusion

Following an ACL-deficiency, many foot pressure changes occur on the plantar pressure pattern of the ACL-D knee subjects, which were prominent only on the non-coper ACL-D knee subjects. A minority of these subjects, called copers, showed foot pressure patterns very close to those of the healthy subjects. Contrary to the coper ACL-D knee subjects who applied pressure more on the hindfoot rather than on the forefoot, the non-coper ACL-D knee subjects applied more pressure on their fore foot to keep their stability. Further studies are recommended to monitor the whole lower limb vectors in these subjects during either single or double leg stance positions.

Acknowledgments:
None

Conflict of interest:
None

Funding support:
The authors would like to thank the "Physiotherapy Research Center", Shahid Beheshti University of Medical Sciences, Tehran, for its financial supports and providing the Pedobarograph. Also, we would like to acknowledge all participants for their participation in the present study.

Authors' contributions:
All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

1. Solomonov.M. Sensory-motor control of ligaments and associated neuromuscular disorders. Journal of Electromyography and Kinesiology. 2006;16.549-567.
2. Micheo.W ,Hernandez.L , Seda.C . Evaluation, Management, Rehabilitation, and Prevention of Anterior Cruciate Ligament Injury: Current Concepts. Physical Medicine and Rehabilitation Journal. 2010;Volume 2, Issue 10, Pages 935-944.
3. Levangie P, Norkin C. Joint structure and function: a comprehensive analysis. 4ed. 2005. philadelphia . F. A. Davis Company. Georgoulis AD, Ristanis S, Moraiti CO, Paschos N, Zampeli F, Xergia S. ACL injury and reconstruction: Clinical related in vivo biomechanics . 2010. Orthopaedics & Traumatology: Surgery & Research Volume 96, Issue 8, Supplement 1, S119-S128.
4. Boerboom A L; Hof A L; Halbertsma J P; van Raaij J J; Schenk W; Diercks R L, Atypical hamstrings electromyographic activity as a

compensatory mechanism in anterior cruciate ligament deficient. Knee surgery, sports traumatology, arthroscopy 2001;9 :211–216.

5. Chmielewski TL, Rudolph K, Snyder-Mackler L. Development of dynamic knee stability after acute ACL injury. Journal of Electromyography and Kinesiology. 2002;12 (4): 267–274.
6. Eastlack ME, Axe MJ, Snyder-Mackler L. Laxity, instability, and functional outcome after ACL injury: copers versus non-copers. Medicine & Science in Sports & Exercise 2001;31:210–215.
7. Rudolph K, Axe M J ,Buchanan T S, Scholz J P, Snyder- Mackler L . Dynamic stability in the anterior cruciate ligament deficient knee. Knee surgery, sports traumatology, arthroscopy. 2001;9 (2) 62–71.
8. Chmielewski T L,Rudolph K , Fitzgerald G K, Axe M J, Snyder-Mackler L. Biomechanical evidence supporting a differential response to acute ACL injury. Clinical Biomechanics. (Bristol, Avon) 2001;16 (7) 586–591.
9. Chmielewski TL , Hurd W J, Synder-Mackler L. Elucidation of a potentially destabilizing control strategy in ACL deficient non-copers. Journal of Electromyography and Kinesiology. 2005;15 :83–92.
10. Reed-Jones R J, Vallis L A. Kinematics and muscular responses to a ramp descent in the ACL deficient knee. The Knee 2008;15 :117–124. 12).
11. Gerbino P, Griffin E, Zurakowski D. Comparison of standing balance between female collegiate dancers and soccer players. Gait & Posture. 2007;26 . 501–507.
12. Rai DV, Aggarwal LM. The study of plantar pressure distribution in normal and pathological foot. Polish Journal of Medical Physics and Engineering. 2006;12(1) :25-34.
13. Orlin MN, McPoil TG. . Plantar pressure assessment. Physical Therapy. 2000;80: 399–409.
14. Beckett M, Massie D, Bower D, Stoll D, Incidence of Hyper-pronation in the ACL Injured Knee: A Clinical Perspective. Journal of Athletic Training. 1992;7(1): 58-62.
15. Loudon JK, Jenkins W, Loudon KL. The relationship between static posture and ACL injury in female athletes. The Journal of Orthopaedic and Sports Physical Therapy. 1996;24(2):91-97.
16. Stergiou N, Bates B . The relationship between subtalar and knee joint function as a possible mechanism for running injuries. Gait and Posture;1997;6(3):177–185.
17. Trimble M, Bishop M, Buckley B, Fields L, Roza G. The relationship between clinical measurements of lower extremity posture and tibial translation. Clinical Biomechanics 2002;17: 286–290.
18. Chmielewski L, Wilk K, Snyder-Mackler L. Changes in weight-bearing following injury or surgical reconstruction of the ACL: relationship to quadriceps strength and function. Gait and Posture.2002;16:87–95.
19. Hoftberger D, Kozek A, Langari J, Obergruber J. Gait analysis of subjects with anterior cruciate ligament rapture using medilogic sole pressure distribution measurement system. 2003. Access date:31Oct2014: [http://scholar.googleusercontent.com/scholar?q=cache:jcRCBPRWU5QJ:scholar.google.com/&hl=en&as_sdt=0,5].
20. Kaplan Yonatan. Weight bearing deficits following anterior cruciate ligament reconstruction. Gait and Posture.2008;28: 64–70.
21. Kadhim M. & Miller F. Crouch gait changes after planovalgus foot deformity correlation in ambulatory children with cerebral palsy. Gait & Posture.2014: Feb;39(2):793-8.
22. Hadi M., Assef A., Fahad A., Akinwande A. Foot pressure comparison between hallux regidus patients and normal asymptomatic matched individuals using pedobarograph. Journal of Orthopaeidcs, Trauma and Rehabilitation. 2012; 16:13-15.
23. Hadson D. The effects of walking with poles on the distribution of planatr pressures in normal subjects. PM&R. 2014, 6(2):146-151.
24. Salavati M, Mazaheri M, Negahban H, Sohani S, Ebrahimian M, Ebrahimi I, Kazem nejad A.Validation of a persian-version of knee injury and osteoarthritis outcome scores(KOOS) in iranians with knee injuries.Osteoarthritis and Cartillage. 2008;16(10):1178-1182.
25. Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Kaufman KR . Fate of the anterior cruciate ligament-injured patient. A prospective outcome study. The American Journal of Sport medicine.1994;22: 632–644.
26. Nakhaee Z., Rahimi A., Abaee A., Rezasoltani A., Khademi Kalanatri K. The Relationship Between The Height Of The Medial Longitudinal Arch (MLA) And The Ankle And Knee Injuries In Professional Runners. The Foot. 2008;18:84-90.
27. Cavanagh P, Morag E, Boulton A, Young M. The relationship of static foot structure to dynamic foot function. Journal of Biomechanics. 1997;30(3):243-250.
28. Imamura M, Salomao O, Pereira C, Carvalho D. Pedobarometric evaluation of normal adults male foot. Foot and Ankle.2002;23(9):804-810.
29. Tuna H. Static and dynamic plantar pressure measurement in adolescents. Acta Orthop Traumatol Turc. 2004;38(3):200-5.
30. Papadonikolakis A, Cooper L, Sterqiou N, Georqulis O, Soucacos P. Compensatory mechanism in anterior cruciate ligament deficiency. Knee Surgery, Sports Troumatology, Arthroscopy; 2003; 11(4):235-243.
31. Roberts C, Rash J, Honaker J, Shaw J. A deficient anterior cruciate ligament does not lead to quadericeps avoidance gait. Gait and Posture. 1999;10(3).189-199.
32. Torry M.R., Decker M.J., Millett P.J., Steadman J.R.,, Sterett M.I. The effects of knee joint effusion on quadriceps electromyography during jogging. Journal of Sports Science and Medicine. 2005;4: 1-8.
33. Rice, D. A., & McNair, P. J. Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. Semin Arthritis Rheum, 20010;40(3), 250-266. doi:S0049-0172(09)00121-8.
34. Harty J, Soffe K, O'toole G. The role of hamstring tightness in plantar fasciitis.. Foot and Ankle. 2005;vol. 26,: 1089-1092.
35. Lephart S, Fu F. Proprioception and neuromuscular control in joint stability. 2000. Human Kinetics Publishers.
36. Ashvin T, Palaniappan T, James G, Knee joint moments during stair climbing of patients with ACL deficiency. Clinical Biomechanics. 2004;19: 489-496