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Effect of Muscular Strength on landing Error Scoring System Score amongst Track and Field Athletes

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Abstract

Introduction: Landing error scoring system (LESS) is a clinical screening test used to evaluate the success of a certain athletic program designed to prevent ACL rupture, often used to identify subjects with an increased risk of ACL injury. It is consisted of 17 items depicting control over lower extremities' positioning during jumping and subsequent landing.

Aim: The purpose of this study is to determine if the strength of certain muscle groups has an effect on LESS score.

Patients and methods: For the purposes of this study, two study groups had been formed. The examined group consisted of 41 subjects (29 male and 12 female) who had a confirmed ACL rupture. The control group, consisted of subjects with a knee injury not related to ACL, was paired according to 4 factors: gender, age, type of sport activity and side of the injury. All subjects practiced a sport at least two times per a week. Apart from LESS score during jumping and subsequent landing, measurements were made to determine the strength of knee joint flexors and extensors, as well as thigh abductors and

adductors. The correlation was examined using Pearson's correlation coefficient. Significance level was set at 0.05.

Results: A significant indirect statistical correlation ($p<0.05$) has been confirmed between knee joint extensor strength and the LESS score within the mixed population, kept amongst the study group ($p<0.05$), but this statisticaly significant correlation was not present within the control group ($p>0.05$). A similar trend is present with abductor and adductor strenght, showing high statistically significant indirect correlation with LESS within the entire population ($p<0.01$, both movements) and examined group ($p<0.01$, both movements), but is not present within the control group ($p>0.05$, both movements).

Conclusion: A low LESS score present with subjects with ACL rupture can be caused by low muscule strenght of the extonsors of the knee, as well as the abducors and adductors of the thigh. Muscle strenght amongst patitents with intact ACL does not appear to have an effect on LESS score.

Key words: anterior cruciate ligament, landing error scoring system, jumping,

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Introduction

Anterior cruciate ligament injury (ACL) is a highly prevalent injury, with an estimated range between 80 000 and 250 000 ACL ruptures annually, and a particular affect on young athletes from 15 to 25 years of age (50% of the affected).[1,2,3,4,5] ACL rupture is a common, yet serious and costly injury.[6] Surgical ACL reconstruction procedures are routinely done, being the sixth most common surgery performed by sports medicine fellows.[7] However, the quality of certain procedures, in terms of full recovery, is questioned by multiple authors.[8,9] The implications are that prevention strategies must be further developed to lower ACL rupture incidence.

Risk factors surrounding ACL ruptures include anatomical, environmental, hormonal and biomechanical-neuromuscular circumstances. Biomechanical-neuromuscular factors contain knee kinematics and muscle strength/rigidity, both being measurable and, importantly, modifiable traits.

A possible prevention strategy related to knee kinematics is the use of the Landing Error Score System (LESS). LESS is a test utilized to assess the effectiveness of training programs designed to prevent ACL injury, also used to indentify subjects with an increased ACL injury risk. Muscle strength might have an effect on LESS score, therefore indirectly correlating with ACL injury risk.

Possible theoretical explanations include the hamstring and quadriceps-dominant theories.[10,11,12] The quadriceps-dominant hypothesis denotes that increased m. quadriceps femoris strength might cause: increased anterior sheer stress, tibial rotation and knee valgus. All of these factors add additional mechanical strain on the ACL, therefore increasing injury risk. The hamstring hypothesis indicates that strong hamstring muscles stabilize the knee joint by counteracting anterior sheer stress, decreasing tibial rotation and preventing knee valgus. Both previously mentioned muscle groups may have an effect on knee kinematics, thereby might be associated with LESS score.

Patients and Methods

Subjects of this study are individuals that practice a sport that involves running, sudden changes of direction, jumping and rotary movement (football, basketball, handball, volleyball, athletics), either professionally or recreationally, with a frequency of two or more times per a week. All test subjects have a non-contact knee joint injury in their anamnesis, with or without an anterior cruciate ligament injury. All patients have voluntarily agreed to take part in this study, by signing an informed consent form. Patients that were unable to conduct a full flexion-extension knee movement (0°-125°), felt pain or have shown a high level of instability have been excluded from the study.

For the purpose of this study, two study groups have been formed. The study group consisted of 41 subjects (29 male and 12 female) who had a

confirmed ACL rupture. The control group was composed of 41 subjects with a knee injury not related to the ACL, and were matched according to 4 factors: gender, age, type of sport activity and side of the injury. Due to injury lateralization, the right knee was monitored amongst 18 clinical pairs (13 male and 5 female), and the left knee was monitored amongst 23 pairs (16 male and 7 female).

Amongst the tested population, 28 pairs (18 male and 9 female) are professionally engaged with sports, while 13 pairs (10 male and 3 female) conduct sport activities regularly at an amateur level. Control group subjects trained on an average of 4.6 times per a week, while the study group subjects trained 4.3 times per a week. Sport activity distribution is as follows: 19 subject pairs acquired the injury while playing football, 7 while training basketball or other athletic disciplines, 5 pairs while practicing volleyball and 3 pairs during handball training. Average age amongst patients with ACL rupture was 24.3 years and 24.1 years amongst patients without ACL injury.

Muscle strength of knee flexors and extensors, as well as hip abductors and adductors was measured by using a dynamometer and a band.

For the purpose of measuring flexor and extensor strength, subjects laid horizontally, face down, with their lower limb flexed in a 90 degree angle. The dynamometer was tied to the ankle using the band. The subject then conducted knee flexion and extension. The valid result was the value the subject managed to maintain for 3 seconds. For hip abductor and adductor strength measurements, patients were seated, and instructed to fixate their upper body by gripping the chair with their arms to prevent leaning and abdominal muscle interference. The angle between the upper and the lower limb was held at 90°, with feet making full contact with the ground. After connecting the dynamometer with the medial or lateral distal part of the upper leg, the subject conducted abduction or adduction. The valid result was the value the subject managed to maintain for 3 seconds. Therefore, 4 parameters were measured: flexor, extensor, abductor and adductor strength.

The Landing Error Score System (LESS) was utilized for lower extremities' positioning assessment. Jumping and subsequent landing was recorded via Sony DCR-SR220 camera, and analyzed with "Adobe Premiere" software to assert a LESS score.

Jumping and subsequent landing on a flexed knee was conducted in a following manner: Seven markers (points 10 mm in diameter) were placed on the subject's leg. Four of the markers were placed in the frontal plain: anterior superior iliac spine, basis of the patella, apex of the patella and at the middle of the intermalleolar line. Three of the markers were placed in the sagittal plain: above the major trochanter, on the lateral epicondyle of the femur and the lateral malleolus. First two markers in both the frontal and the sagittal plain represent femur direction, while the second and the third in the sagittal, and the third and the fourth in the frontal plain represent tibial direction. The subject jumps forward from a box (30 cm in height), to a distance equal to the half of his or hers height. The patient then immediately jumps as high as possible. Both jumps are recorded with the camera, from a distance of 5 meters, at the

level of the knee joint, both in the sagittal (Figure 1.) and the frontal plain (Figure 2.).

Figure 1. *Frontal knee angulation during forward and upward jump*

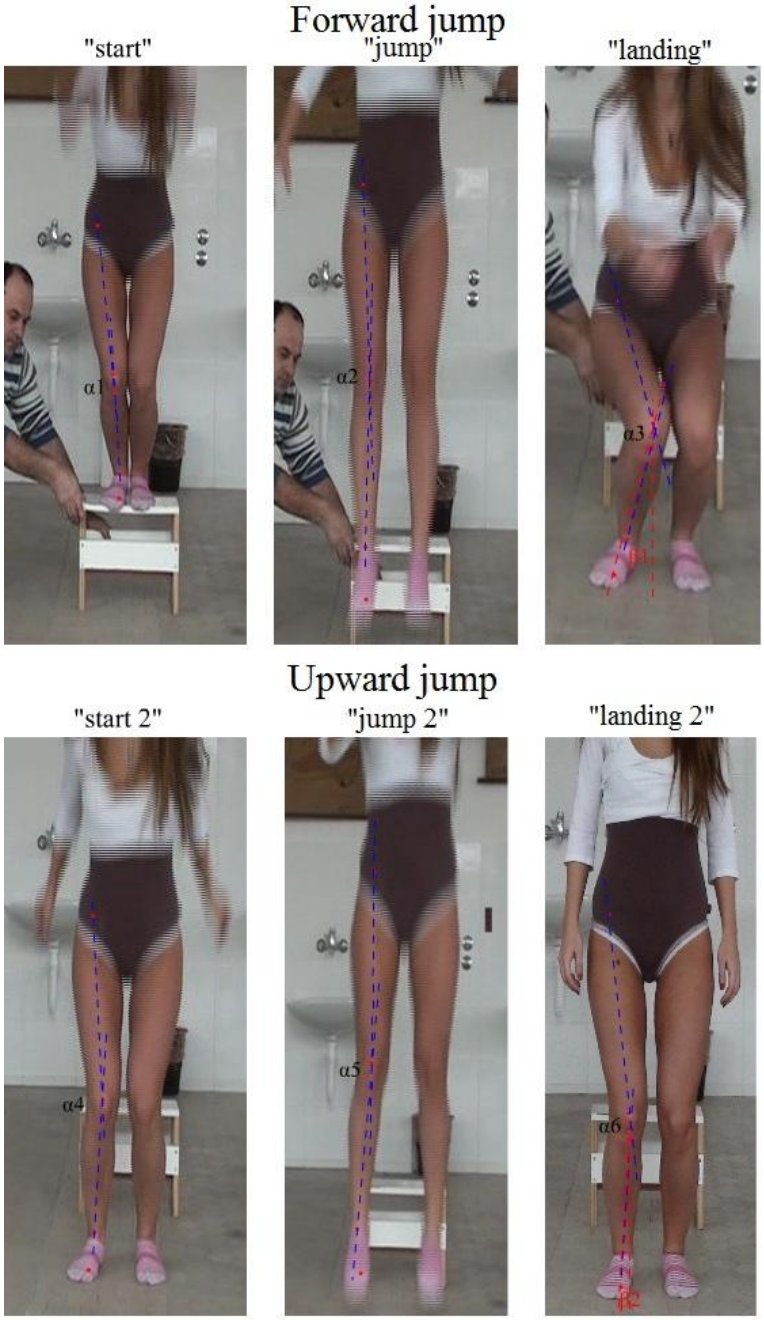
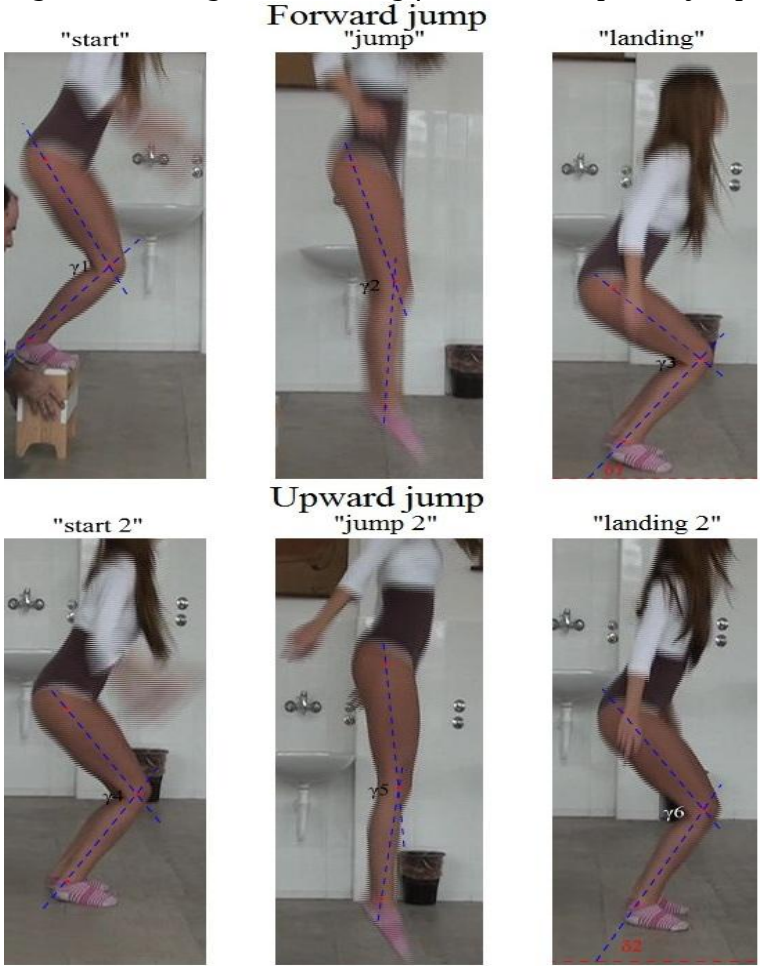


Figure 2. *Sagittal knee angulation during forward and upward jump*



Video footage analysis involves the use of LESS score evaluation, described in detail by Padua and al. This score system is consisted of 17 parameters related to the forward and upward jump, each valued as 1 point. Four or less points depict an excellent jump, four to five as a good jump, five to six as an average jump, and six or more indicate a bad performance.

All data was processed with SPSS 11.0 software. Correlation was examined with the Pearson's coefficient within the SPSS 11.0 pack. The level of statistical significance was set at 0.05.

Results

Patients with ACL rupture have shown statistically significant higher flexor muscle strength, when compared with patients with an intact ACL ($p=0.08$ $p<0.01$). Flexor strength amongst the study group varies from 4.5 kg to 19 kg, while in the control group the same perimeter varies 4-19.5 kg. A statistically significant difference between extensor, abductor and adductor muscle strength was not established in a control group and study group

comparison. ($p>0.05$ in all three cases). Subjects with an ACL rupture have an increase in LESS scores of high statistical relevance when compared to patients with an intact ACL ($p=0.002$; $p<0.01$). LESS values amongst the study group range from 4 to 12, while a variation spanning between 1 and 11 is present amongst the control group.

A significant indirect statistical correlation ($p<0.05$) has been confirmed between knee joint extensor strength and the LESS score within the mixed population, kept amongst the study group ($p<0.05$), but this statistically significant correlation was not present within the control group ($p>0.05$). A similar trend is present with abductor and adductor strength, showing high statistically significant indirect correlation with LESS within the entire population ($p<0.01$, both movements) and study group ($p<0.01$, both movements), but is not present within the control group ($p>0.05$, both movements).

Figures 3. and 4. represent the correlation between LESS values and the strength of certain muscle groups. On Figure 3. a decrease in strength related to higher LESS values is noticeable. This excludes the flexor strength category, where higher LESS values relate with increased muscle strength. A correlation between these two parameters has not been made. Figure 4. displays large oscillations of muscle strength, when compared to LESS values, which is confirmed by statistical tests. There is a certain decrease in muscle strength connected with rising LESS values, but a correlation between these two parameters has not been established.

Figure 3. *Correlation between muscle strength and LESS values in the study group*

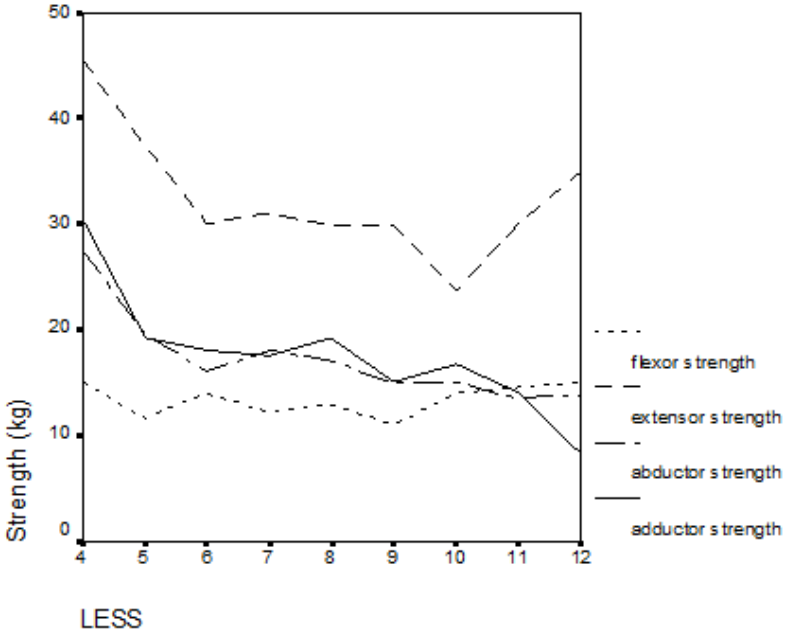
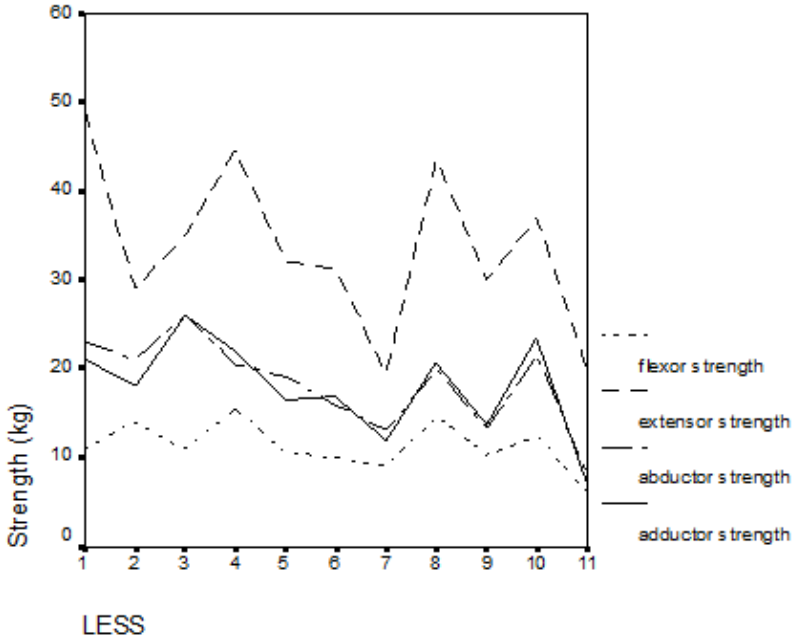


Figure 4. *Correlation between muscle strength and LESS values in control group*



By dividing the study group to subjects with a good LESS score (LESS≤7; 21 subjects) and a poor LESS score (LESS≥8; 20 subjects), a statistically significant difference in extensor, adductor and abductor has been detected. Both groups had an approximately same male to female ratio (70:30 %).

Discussion

The results of our study do not support the "quadriceps dominant theory", which claims that excessive m. quadriceps femoris strength causes additional extension, strain and eventually ACL rupture. The strength of knee extensors amongst patients with ACL rupture did not significantly differ from the strength of the knee extensors amongst patients with an intact ACL ($p>0.05$).

The theory that indicates that the loss of balance and body lateralization causes knee valgus, accompanied by hamstring activation[13], is not supported by the results of our study. The strength of both adductor and abductor muscles does not vary significantly, when making a comparison between subjects with and without an ACL injury.

LESS is a clinical test developed in order to indentify subjects with increased risk of ACL rupture. This test relies on examining biomechanics during jumping and subsequent landing. It is consisted of 17 items related to the body and lower extremity positioning at the moment of initial contact with the surface, during maximal flexion, as well as the movement of the entire body in the sagittal and frontal plain during the subsequent upward jump. A

high LESS score indicates a bad jump and, hypothetically, an increased risk of ACL injury. A low LESS score denotes a good jump, and therefore a decreased risk of ACL rupture.

Padua et al.[14] (2009) used LESS as tool for measuring the effectiveness of a training program, designed to prevent ACL injury amongst football players. The prevention program was consisted of 10-15 minutes of exercise before every training session (3-4 times a week) during 3 months (short term group) and 9 months (long term group).

A similar study performed by Di Stefano[15] et al. (2009) has verified the ACL rupture prevention program. Smith et al.[16], in their three year long matched cohort study conducted on 5047 high-school children and students, have not found a statistically significant increase in LESS score amongst the study group (with ACL ruptures), when compared to the control group (without ACL rupture). Padua et al[17]. (2011) state that women have significantly worse LESS values. By testing 2691 subjects they have determined that 30% of males have a good LESS score, while 23% have a bad LESS value. However, only 14% of female subjects have a good LESS score, and 36% have a bad score.

Our study records higher LESS values amongst the study group, compared to the control group. We can observe that our study shoes higher LESS scores than the ones previously mentioned. Two of the possible reasons will be noted. The first being that, contrary to the previous studies where the test subjects were professional athletes, our measurements were conducted on amateurs. The second could be contributed to the test itself. During the evaluation of items 16 and 17 of the LESS test, we were not always certain if we should grade the subject with “0”, “1” or “2”. We could have been too critical when it comes to the landing technique evaluation in the sagittal plain and knee positioning in the frontal plain.

On the graph denoting the connection between LESS score and the strength of certain muscle groups within the control group (Figure 4.), it is seen that a decrease in strength leads to a slightly worse LESS score, but no statistical importance has been inferred. This leads us to the conclusion that muscle strength does not play an important role in stabilizing the knee during jumping and subsequent landing, hence it does not affect the LESS value amongst individuals with an intact ACL. An intact ACL itself prevents knee oscillation during jumping and landing, regardless of muscle strength.

Amongst the study group a correlation between LESS score and the strength of extensor, adductor and abductor muscles has been established. A knee with a deficient ACL does not possess stability and rigidity, therefore the forces present during jumping and landing are being absorbed by the muscles, whose strength determines the LESS score. An increase in muscle strength could be seen as a compensatory response, aimed at preserving the stability of the knee. We have confirmed this hypothesis by comparing patients with good and poor LESS values within the study group. Patients with a good LESS score had a statistically significant higher strength of extensor, abductor and adductor muscles, when compared with the subjects with a poor LESS score.

Conclusion

The previous analysis leads us to the conclusion that an intact knee may have differing LESS scores and those values are not related to muscle strength, but probably depend from the style and technique of jumping. Patients with an ACL ruptures may have good or bad LESS scores. Individuals with a good LESS score have strong muscles that are managing to compensate the deficiency of the ACL, and are absorbing the sheer stress forces during jumping and landing (extensors, abductors, adductors). Poor LESS scores amongst patients with ACL injury might be caused by weaker muscles that fail to stabilize the knee during jumping and landing.

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Table 1. *Knee Joint Muscle Strength (kg) and LESS Values*

	Study group	Control group	Mixed population
Lower leg flexor strength	12.7±3.7	10.7±3.8	11.7±3.9
Lower leg extensor strength	31.3±9.2	31.6±12.6	31.5±11.0
Thigh Adductor strength	18.1±5.9	17.0±6.5	17.6±6.1
Thigh Abductor strength	17.1±5.3	17.5±7.1	17.4±6.3
LESS	7.5±1.8	6.1±2.1	6.8±2.1

Table 2. *Correlation between LESS Values and Study/control Group Muscle Strength*

	Study group	Control group	Mixed population
Lower leg flexor strength	0.019	- 0.099	0.052
Lower leg extensor strength	- 0.331*	- 0.189	- 0.236*
Thigh Adductor strength	- 0.440**	- 0.242	- 0.327**
Thigh Abductor strength	- 0.405**	- 0.307	- 0.238*

Table 3. *Knee Joint Muscle Strength (Kg) amongst Patients with ACL Rupture*

	LESS≥8	LESS≤7	t-test
Lower leg extensor strength	29.2±7.7	34.9±9.7	0.044
Thigh Adductor strength	16.1±4.7	19.6±6.0	0.040
Thigh Abductor strength	15.9±2.9	19.5±6.3	0.023