Original Research

Correlation between Quadriceps, Hamstring, Tibialis Anterior, and Gastrocnemius Muscle Activation, with Knee Flexion Angle in Basketball Athlete while Performing Double-Leg Landing Task

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ABSTRACT

Background: Anterior cruciate ligament (ACL) injury cause great disability for athlete. Recent focus of ACL injury management is on prevention by identifying the risk factors. Most of basketball injury mechanism is non-contact, related to landing process with small knee flexion angle. Muscle activation and its ratio, which control movement pattern in sagittal plane, are said to play a role in dynamic movement such as landing.

Aims: The purpose of this study is to analyze the correlation between muscles activation and their activation ratio of quadriceps, hamstring, tibialis anterior and gastrocnemius with knee flexion angle of basketball athlete while performing double-leg landing task.

Material and methods: This study was an observational analytic, cross sectional study. Study subjects was basketball athletes age 16 – 25 years in Surabaya. Measurements of knee flexion angle done with digital measurements of reflective marker, and muscle activation was measured with sEMG while performing double-leg landing task.

Result: There was no significant correlation between maximum knee flexion angle and muscle activation of quadriceps (p=0,562), hamstring (p=0,918), tibialis anterior (p=0,394) and gastrocnemius (p=0,419). There was also no significant correlation between maximum knee flexion angle and the muscle activation ratio of quadriceps-hamstring (p=0,347), quadriceps-tibialis (p=0,139), quadriceps-gastrocnemius (p=0,626), hamstring-tibialis anterior (p=0,365), hamstring-gastrocnemius (p=0,867), and tibialis anterior-gastrocnemius (p=0,109).

Conclusions: There was no correlation between muscle activation and muscle activation ratio of quadriceps, hamstring, tibialis anterior and gastrocnemius with maximum knee flexion angle in basketball athlete while performing double-leg landing task.

Keywords: *ACL, quadriceps, hamstring, tibialis anterior, gastrocnemius, knee flexion angle, landing task*

Introduction

Injury of anterior cruciate ligament (ACL) can cause great disability, especially for athletes. ACL injury require time and cost for recovery, but restoration to the pre injury activity level is not always achievable. ACL injury can happen with other injury of knee ligament or meniscus.[1-3] ACL injury can lead to knee osteoarthritis, joint effusion, disturbance in pattern of movement, muscle weakness, decrease in functional performance and loss of time in sport participation.[1]

The highest incidence of non-contact injury in basketball athlete is knee injury [4] ACL injury rate among recreational basketball athlete is 0.08 in male and 0.29 in female, with the ratio of 3.63 between male and female. In professional basketball athlete the incidence is lower, 0.20 for male and 0.21 for female.[5] ACL injury accounts for 40% of all sports injury.[6] Incidence of ACL injury is highest in the age of 15 – 24 years.[7] There is 55 cases of athlete with ACL injury having treated at Sport Clinic Dr. Soetomo General Hospital from January 2012 – May 2014.

Recently, the management of ACL injury focused on injury prevention, by identifying risk factors and mechanism of injury.[2] According to the mechanism, 72% of ACL injury happened through non-contact mechanism, when athlete perform landing movement with 2 feet.[2,8] Movement pattern that can cause non-contact injury in basketball athlete mostly happened during deceleration movement such as landing with knee in small knee flexion angle.[2,8] Krosshaug movement analysis study of 39 ACL injury video showed most of the athlete have injury when they landed with 2 feet.[8] Movement analysis showed decrease in sagittal plane movement when landing, so the body position is relatively upright (small knee, hip and trunk flexion angle), this pattern thought to be the risk factors for ACL injury.[9]

Muscle activation controlling sagittal plane movement play a role in the amount of knee and hip flexion angle during dynamic movement such as landing task. Eccentric quadriceps muscle contraction will increase internal knee-extension moment when landing, this will facilitate more erect posture and smaller knee flexion angle. While concentric contraction of hamstring and gastrocnemius will increase internal knee-flexion moment and cause greater knee flexion angle when landing.[9] Gastrocnemius muscle is an antagonist of the ACL which will cause increase of anterior shear force of the tibia, but this statement is still debatable.[3] Sousa showed correlation between gastrocnemius and tibialis anterior muscle in ballet dancer while doing sauté.[10] Walsh et al, reporting knee flexion angle was influenced by co-activation ratio of quadriceps and hamstring muscle.[9]

The purpose of this study is to analyze correlation between muscle activation around knee joint, namely quadriceps (Q), hamstring (H), tibialis anterior (TA) and gastrocnemius (G) at basketball athlete when performing double-leg landing task. This study also analyze the correlation between ratio of quadriceps-hamstring (Ratio Q-H), quadriceps-tibialis anterior (Ratio Q-TA), quadriceps-gastrocnemius (Ratio Q-G), hamstring-tibialis anterior (Ratio H-TA), hamstring-gastrocnemius (Ratio H-G), and tibialis anterior-gastrocnemius (Ratio TA-G) with knee flexion angle at basketball athlete when performing double-leg landing task.

Material and Methods

Study Subjects

Study population was male basketball athletes, trained on basketball club in Surabaya meeting the inclusion criteria. Inclusion criterias: (1) basketball athlete from basketball club in Surabaya age 16 – 26 years, (2) agree to participate in the study, follow the examination and sign the informed consent. Exclusion criterias: (1) has lower extremity injury or surgery at lower extremity in the past 6 months, (2) subject with other musculoskeletal disorder which can endanger or limit subject to perform double-leg landing task.

Sample Size

This study used each jump as a sample unit. Each subject performed 2 test procedure, taken as 2 sample unit. Minimal sample unit needed is 15.

Study Design

This is an observational analytic study, with a cross sectional design. Study conducted from January until March 2015. The study conducted at Gait Analysis Laboratorium, Physical Medicine and Rehabilitation Department, Dr. Soetomo General Hospital, Surabaya.

Test Procedure

Study subject who signed the informed consent underwent physical examination for body weight, body height and joint laxity. Subject conducted test session for double leg landing task wearing spandex shorts and shirt and also athletic shoes they frequently used. The test was done at gait analysis laboratorium and recorded with digital video camera placed 3 meter from platform to measure knee flexion angle and muscle activation.

Subject performed double-leg landing task from top of wooden box 30 cm high, 50 cm behind the platform. Both feet was opened as wide as the shoulder, upper extremity raised paralel to the floor in front of the body, eyes staring forward. Subject jumped as natural as possible to the force plate in the platform with two feet. The dominant leg land on force plate and the non-dominant legs land outside force plate. Each subject did 2 jumps and the data from 2 jumps included in data measurement.

Reflective markers placed at dominant legs (greater trochanter, lateral epicondyle of femur, lateral malleolus) to measure knee flexion angle. Knee flexion angle measured at maximum knee flexion after subject landed. Measurements done using software (Protractor, Korea).

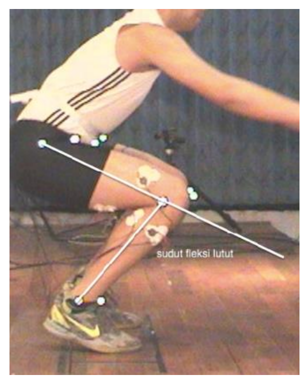

Figure 1. Measurement of knee flexion angle

Muscle activation measured by surface electromyography (sEMG) recorded through surface electrodes on muscle belly of the dominant leg. Measurement of quadriceps muscle done at vastus medial oblique muscle belly, 4cm superior and 3 cm medial from superomedial border of patella. Hamstring muscle electrode placed at the middle between ischial tuberosity and head of fibula. The gastrocnemius electrode placed on the lateral head of gastrocnemius. The tibialis anterior muscle electrode placed on 4 finger below tibial tuberosity and 1 finger lateral to tibial crest. Maximum muscle activation was taken.

Ratio of quadriceps-hamstring, quadriceps-tibialis anterior, quadriceps-gastrocnemius, hamstring-tibialis anterior, hamstring-gastrocnemius, and tibialis anterior-gastrocnemius was measured from maximum muscle activation.

Data Collection

The parameter of this study is muscle activation and muscle activation ratio of quadriceps, hamstring, tibialis anterior and gastrocnemius muscle, and also knee flexion angle while performing double leg landing task. Knee flexion angle was measured as maximal knee flexion performed by subject in degree (Picture 1). Muscle activation was the maximal amplitude produced by the muscle while performing double-leg landing task in millivolt. The muscle activation ratio was measured between quadriceps and hamstring, quadriceps and tibialis anterior, quadriceps and gastrocnemius, hamstring and tibialis anterior, hamstring and gastrocnemius, and also tibialis anterior and gastrocnemius.

Statistical analysis

The statistical analysis performed with SPSS 17 with level of signification $p < 0{,}05$ using double regression analysis or *pearson* correlation analysis.

Ethical Clearance

This study is approved by Ethical Comitee for Basic and Clinical Science Dr. Soetomo General Hospital Surabaya.

Result

Characteristic of Subject Study

There were 20 athletes who met the inclusion criteria and all of them included in this research (Table 1). Subject underwent physical examination and measurement of knee flexion angle and muscle activation while performing double-leg landing task. Subject study was all male 18 – 25 years old. All subject was right leg dominant and have no joint laxity. This study sample unit was jump, there was 20 sample, and 40 sample units were obtained. There is no subject excluded from study, all subject followed the study program.

Table 1. Characteristics of Subject Study

Variabel	Mean (SD)	Minimum	Maximum	Median
Age	21.35 (2.17)	18	25	20.5
Body Weight (BW)	78.40 (8.25)	68	98	76.5
Body Height (BH)	1.83 (0.07)	1.74	1.98	1.82
Body Mass Index (BMI)	23.2 (1.59)	20.01	25.48	23.19

Table 2. Knee Flexion Angle

Variable	Mean (SD)	Minimum	Maximum	Median
Maximal knee flexion angle	90.43 (11.15)	65.5	114.3	89.5

Table 3. Characteristics of Muscle Activation and correlation with knee flexion angle

Variable	Mean (SD)	Minimum	Maximum	Median	*p*
EMG Q (mV)	1.39 (0.53)	0.54	3.05	1.39	0.56*
EMG H (mV)	0.62 (0.48)	0.14	2.14	0.47	0.92*
EMG TA (mV)	1.28 (0.58)	0.56	2.63	1.04	0.39*
EMG G (mV)	1.14 (0.42)	0.43	2.21	1.15	0.42*

**Significant correlation if $p<0.05$ with Pearson Correlation analysis*

Table 4. Characteristics of Muscle Activation Ratios and its correlation with knee flexion angle

Variabel	Mean (SD)	Minimun	Maximum	Median	*p*
Ratio Q-H	3.21 (2.5)	0.76	15.4	3.21	0.35
Ratio Q-TA	1.26 (0.74)	0.46	3.7	0.98	0.14
Ratio Q-G	1.35 (0.66)	0.52	3.59	1.17	0.63
Ratio H-TA	0.49 (0.32)	0.12	1.83	0.44	0.37
Ratio H-G	0.63 (0.6)	0.13	3.13	0.41	0.87
Ratio TA-G	1.27 (0.67)	0.4	2.92	1.24	0.11

**Significant correlation if $p<0.05$ with Pearson Correlation analysis*

Knee Flexion Angle

Maximum knee flexion angle obtained were 90.43°±15° as described in Table 2.

Muscle Activation

Quadriceps muscle activation (EMG Q) ranged from 0.55–3.06 mV. Hamstring muscle activation (EMG H) ranged from 0.14–2.14 mV. Tibialis anterior muscle activation (EMG TA) ranged from 0.57-2.63 mV. Gastrocnemius muscle activation (EMG G) varied between 0.43-2.21 mV. The range of muscle activation is described in Table 3, and the muscle activation ratio is described at Table 4.

Correlation Between Knee Flexion Angle and Muscle Activation

There is no significant correlation between maximal knee flexion angle and muscle activation of quadriceps, hamstring, tibialis anterior and gastrocnemius (Table 3).

Correlation Between Knee Flexion Angle and Muscle Activation Ratios

There is no significant correlation between maximal knee flexion angle and muscle activation ratios of quadriceps, hamstring, tibialis anterior and gastrocnemius (Table 4).

Discussion

Characteristics of Study Subjects

Subjects age were 18 – 25 years old, at this age, sexual maturation already occurred and it brings better neuromuscular control assumption. Sexual maturation process at pubertal and pre-pubertal age can affect tendon adaptation and muscle force capacity.[7] All subjects were male to eliminate gender differences in knee flexion angle, since female reported to land with smaller knee flexion angle.[11] All subjects had no joint laxity. Joint laxity is associated with greater risk for not proper position in landing that increase injury risk, which happened more in female athlete [12] All athletes had right foot domination. Even when landing with 2 feet, there is some different biomechanics associated with feet domination, that can increase the risk of injury.[13]

Knee Flexion Angle Measurement

In this study, knee flexion angle were 90.43°±15°. Ismail et al., in their study about biomechanical analysis on knee flexion angle during jump-landing between volleyball, basketball and badminton athletes showed that knee flexion angle of male athletes are above 110° with the highest value in basketball athletes (135.89°), and smaller value in female athletes (83.5°).[14] Louw and Grimer said that subject landing with knee flexion angle less than 45° will increase the risk injury. The value of knee flexion angle showed individual ability to control eccentric knee movement and absorbtion of forces in the knee which will influence knee stability.[4] Increase in Ground Reaction Force (GRF) will be followed by internal moment in the form of muscle contraction to compensate the GRF. Higher GRF showed increase of injury risk.[15]

Walsh in the study about lower extremity muscle activation in male and female athlete measured the initial contact knee flexion angle and difference between maximal and initial contact knee flexion angle (Δ knee flexion angle).[9] In this study, we also measured the knee flexion angle in initial contact and the Δ knee flexion angle, shown in figure 2. It showed that the greater the knee flexion angle during initial contact, the greater is the maximal knee flexion angle. It showed that there is a preparation phase during double-leg landing task which influence the maximal knee flexion angle.

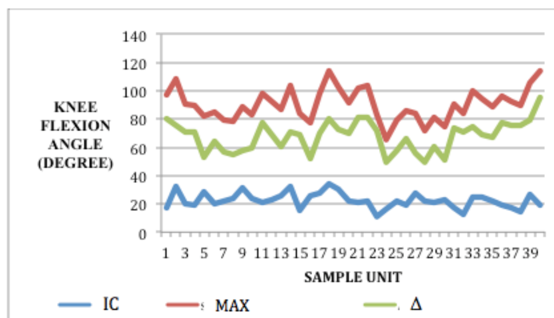

Figure 2. Knee flexion angle during Initial Contact (IC), maximal (MAX) and the difference (Δ)

During landing, GRF will increase 3 -14 times the body weight, which shows the amount of pressure absorbed by the body in this activity.[16] In this study, we measured the GRF at maximal knee flexion angle and the peak GRF (Figure 3). GRF when maximal knee flexion angle reached were lower than peak GRF. Peak GRF happened between initial contact and maximal knee flexion angle at deceleration phase during double-leg landing task. Decrease in GRF during maximal knee flexion angle happened because the internal moment of the muscle can compete with external flexion moment.

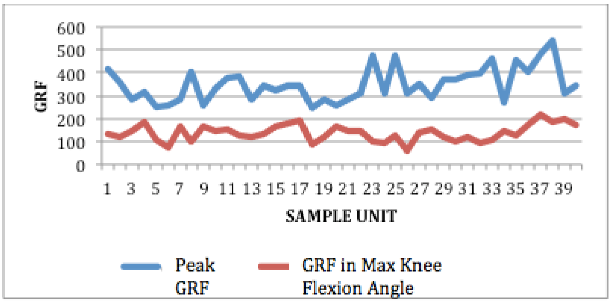

Figure 3. Ground reaction force

Muscle Activation

In this study, muscle activation data (Table 3) showed variation of muscle activation value. The peak muscle activation value is very wide, which shows variation of muscle recruitment each time subject performed double-leg landing task and also variation between subject. The biggest muscle activation value is in quadriceps muscle, followed by tibialis anterior, gastrocnemius, and hamstring muscle. This can show domination of the quadriceps muscle in subject study. During landing, there will be a deceleration phase which there will be muscle contraction of the lower extremity to counteract the external moment, and the greatest contraction provided by quadriceps muscle.[15] This study also found that hamstring muscle showed smallest amplitude, means hamstring muscle role during landing is less than other muscles. The value of muscle activation in this study cannot be compared to other study because the data was not normalized.

In this study there were muscle activation pattern trend found during double-leg landing task, from the initial contact until maximum knee flexion angle reached. The pattern was gastrocnemius muscle was the earliest, followed by quadriceps, then tibialis anterior and hamstring muscle was the last. But this trend of pattern needs more study to be conduct.

Muscle co-contraction is a simultaneous activation of agonist and antagonist muscle. Muscle co-contraction is a motor control strategy to increase joint stabilization.[17] Quadriceps-Hamstring muscle activation ratio (Ratio Q-H) in this study was 3.21 which showed quadriceps muscle activation is 3.21 times higher than hamstring. This shows the domination of quadriceps muscle compared to hamstring during double-leg landing task. It also showed hamstring muscle was weaker than quadriceps. This study confirmed Walsh study which shows domination of quadriceps, where the ratio Q-H was expected to be near to 1.[9] Ratio of the Q-TA, Q-G, and TA-G showed values near to 1, that shows balance among this muscle. There is no study stating the normal value of Q-TA ratio, Q-G ratio and TA-G ratio. Ratio of H-TA and ratio H-G shows less than 1, that can happen because the muscle activation of hamstring muscle is small. More study is needed about muscles activation ratio for muscle in the lower extremity.

Correlation between Knee Flexion Angle and Muscle Activation

Walsh study about correlation between knee flexion angle and lower extremity muscle activation shows negative correlation between maximal knee flexion angle and quadriceps muscle activation, but no significant correlation on hamstring and gastrocnemius. Walsh concluded that there is domination of quadriceps muscle compared to knee flexors at deceleration phase, where quadriceps muscle activation will decrease knee flexion angle at deceleration phase during double-leg landing task.[9] This study found no significant correlations between knee flexion angle and quadriceps muscle activation. This can happen because of different placement of electrode compared from the study performed by Walsh. Insignificant correlation of hamstring and gastrocnemius showed domination of quadriceps. There is no significant correlation also for tibialis anterior muscle, this may happen because tibialis anterior muscle do not influence the knee joint greatly, tibialis anterior major influence can be found in the ankle joint.

In this study muscles activation were measured with sEMG but without normalization through software neither with maximal voluntary isometric contraction that cannot be performed because of methods limitation, this may influence the result of the study.

Correlation between Knee Flexion Angle and Muscle Activation Ratio

There was no significant correlation between knee flexion angle and Q-H ratio, the same as Walsh study. This showed domination of quadriceps muscle during landing [9] Other muscle activation ratio also showed no significant correlation. But in this study, muscles activation used in measuring muscle activation ratio were not normalized, that may influence the correlation analysis.

Utilization of Study Findings

This study has the benefit on giving the study subjects the information about the muscle activation characteristics. There is domination of quadriceps muscle compared to other muscle, especially hamstring. The differences can also be seen in the Q-H ratio. Knee flexion angle value in this study was above 45°, but there was one subject landed with knee flexion angle 65.50° that can increase the risk of injury.

Injury prevention program can be done with exercises to increase knee flexion angle during landing and increase balance between muscle activation. For prevention program, posterior chain exercises, proper landing techniques, core stability exercises and perturbation exercise can be done. Even though in this study we found no significant correlation between muscle activation and knee flexion angle during double-leg landing task, the test can still be done since the small knee flexion angle while landing is the risk factor of ACL injury.

Study Limitation

The limitation of this study is there is no normalization for muscle activation.

Conclusion

There is no correlation between knee flexion angle and muscle activation. There is no correlation between knee flexion angle and muscle activation ratio. Further study needed to be conducted with normalization of muscle activation, study sample should include female athlete as comparation, to knew more about muscle activation sequence and to evaluate all muscles in the lower extremity to kinematic changes in frontal and sagittal plane during landing. Neuromuscular training needs to be performed to correct ratio between quadriceps and hamstring.

Acknowledgement

The author declares that there was no conflict of interest.

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