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ORIGINAL RESEARCH

The effect of open kinetic chain exercise and close kinetic chain exercise on strength quadriceps femoris muscle post anterior cruciate ligament surgery in terms of age

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Abstract

This study aims to determine (1) the effect of giving Open Kinetic Chain Training to adolescent athletes on Quadriceps Femoris muscle strength after ACL surgery, (2) knowing the effect of giving Open Kinetic Chain Training to adult athletes on Quadriceps Femoris muscle strength after ACL surgery, (3) determine the effect of giving Close Kinetic Chain Exercises to adolescent athletes on Quadriceps Femoris muscle strength after ACL surgery, (4) determine the effect of giving Close Kinetic Chain Exercises to adult athletes on Quadriceps Femoris muscle strength after ACL surgery. This research is descriptive quantitative research. The sample was 16 post-ACL surgery patients at the Ibest Sport Physiotherapy Clinic Solo, covering the OKC and CKC exercise categories and based on the age categories of teenagers and adults. Samples were taken using purposive sampling technique. Variables in this study include: 1) Quadriceps Femoris (Y) Muscle Strength; 2) OKC Practice (X1); 3) CKC Training (X2); and 4) Age (Z). Research data was obtained from measurements using an Electromyograph (EMG). The data were analyzed using descriptive analysis and two-way Anova analysis at a confidence level of 95% or alpha = 0.05. The swimmer test includes homogeneity and normality tests. Hypothesis testing uses the two ways Anova test and t test. The results showed that from the two-way Anova analysis, the training factor Sig. equal to 0.000 < 0.05 while for the age factor the value of Sig. equal to 0.000 < 0.05. The average value of EMG results for the OKC Training group was 109.63, while for the CKC Training group it was 124.50. The tcount value is -4.515. The highest average increase in muscle strength after CKC training in the adult age category was 12.55%.

Introduction

One of the activities body that is activity physique own complex dimensions, where to reach superior performance and exercise well, necessary integrated and sustainable preparation between elements physical, technical, strategy and psychology that can be done calculated with carefully through coaching beginning, mastery Skills technical, required planning mature tactical and effective strategy, as well diverse approaches. However, to achieve success in sports with excellent physical condition is one of the important requirements needed by athletes, because excellent physical condition will help athletes make it easier to master basic techniques in sports (Prima & Kartiko, 2021).

Excessive physical activity during training in the world of sports often causes injuries for athletes (Wiratna, 2015). Injury itself is defined as damage to the structure or function of the body that arises as a result of physical or chemical pressure that occurs due to one's own actions (Wiratna, 2015). Injury can occur caused by several factor trigger like lack of adequate warming up, too much load weight, impact physique from external, and factors others. As for one type injury in the world of most common sports occurs in athletes is anterior cruciate ligament (ACL) injury.

Anterior Cruciate Ligament (ACL) injury is the most common knee injury in athletes. Usually, this injury occurs during sports that require zig-zag movements, changes in direction of movement, and instantaneous changes in acceleration (acceleration-deceleration) that occur in physical activities such as basketball, volleyball, soccer and futsal (Fukuda, 2013). Most of the injuries that occur do not involve direct contact and are caused by knee valgus and twisting mechanisms. This situation often occurs in athletes when controlling the ball or having an incorrect

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knee position when falling. ACL ligament rupture can occur especially when there is a direct injury to the knee with a sideways force (Herman & Komalasari, 2022). In 2019, the World Health Organization (WHO) released data that estimated as many as 200,000 incidents cruciate ligament injury happen every year, of which 70% happen through non- contact mechanism when play sports that require agility, like football, basketball and skiing, meanwhile about 30% of the results depends on contact in a way direct and from all case cruciate ligament injury, almost half from entirely form the ACL tear that became factor main instability knees and can change function , so influence activity daily and abilities walking (WHO, 2019).

ACL injury recovery consists of two methods, namely operative (reconstruction) and non-operative (therapy). Non-operative therapy is carried out using therapeutic modalities such as knee braces, diathermy and ultrasound, as well as muscle strengthening programs. Meanwhile, operative treatment is carried out through reconstruction. Reconstruction (operation) is the main choice in treating ACL injuries because surgery to stitch back damaged or torn ACL ligaments is often unsuccessful. This is caused by the absence of fibrin in the ACL ligament so it cannot heal by itself. Reconstruction involves replacing the ACL ligament with another material (graft) and usually, patients use their own hamstring tendon or patellar tendon (autograft) (Fukuda, 2013).

Saputro & Rachman (2019) explains that after undergoing ACL reconstruction surgery, several problems can arise such as pain, edema, atrophy and decreased muscle mass, limited ROM, problems with walking patterns, and obstacles in knee function after ACL reconstruction surgery. Therefore, it is necessary to apply physical therapy to treat pain in the knees of patients who have undergone ACL reconstruction, with the aim of reducing discomfort and swelling, improving and increasing muscle strength, preventing loss of muscle mass (athropy), increasing knee stability (Yabroudi, 2013), as well as helping to restore self-confidence in patients who have suffered ACL injuries. This is because when an athlete experiences a torn injury to the ACL ligament, the muscles associated with the knee joint will decrease as a result of the operative action, such as the Quadriceps Femoris muscle which has a vital role in controlling body movements during dynamic activities (Syafa'at & Rosyida, 2020). One form of exercise that can be used to optimize balance after ACL surgery is Open Kinetic Chain Exercise-Close Kinetic Chain Exercise which can improve dynamic balance (Fukuda, 2013).

Open Kinetic Chain Exercise is a type of exercise that only involves movement at one joint (single joint exercise) with movement occurring in the distal part without involving proximal movement. This type of training is effective for increasing strength in certain muscle groups because most of the load force will be received by that muscle group (Nugroho, 2015). Meanwhile, the Close Kinetic Chain Exercise movement is a type of movement that utilizes several joints and moves by supporting the body's weight to place a load on several muscle groups simultaneously, including agonists and antagonists. This exercise can increase proprioception activation in the lower limbs (Hewison, 2015). Susilawati (2015) found that Closed Kinetic Chain exercise could improve functional abilities more effectively than the group given Open Kinetic Chain Exercise. Meanwhile, Nugroho (2015) found that there was no significant difference between Open Kinetic Chain Exercise and Closed Kinetic Chain Exercise in increasing functional activity.

Apart from inconsistencies in administering Open Kinetic Chain Exercise or Close Kinetic Chain Exercise, it was also found that there was no research that specifically evaluated the difference in the effect of Open Kinetic Chain Exercise and Close Kinetic Chain Exercise exercise on Quadriceps Femoris muscle strength after ACL surgery in terms of age. However, few studies have been conducted to evaluate the effect of exercise on ACL rehabilitation in general. In this study, there was no emphasis on differences in the effect of exercise based on their age. Therefore, further research is still needed to clarify the differences in the influence of Open Kinetic Chain Exercise and Close Kinetic Chain Exercise exercise on Quadriceps Femoris muscle strength after ACL surgery in terms of age. Anterior cruciate ligament injuries are one of the most common types of injuries in sports every year. Thus, researchers are interested in learning more about the differences in the influence of Open Kinetic Chain Exercise & Close Kinetic Chain Exercise on Quadriceps Femoris muscle strength after Anterior Cruciate Ligament (ACL) surgery.

Thus, the novelty of this research is that it uses a tool to measure Quadriceps Femoris muscle contraction using an Electromyograph (EMG) power meter as a data collection instrument, does not use manual muscle testing (MMT). However, using an EMG Power Meter, the output results are directly taken via the Quadriceps Femoris muscle contraction sensor. In addition, this research was reviewed from age to see the results of research on differences in physical development between adolescents and adults. Effectiveness in each age group may provide a more accurate guide to ACL injury recovery at each stage of development.

Methods

This study is type study descriptive quantitative with experimental factorial method which is modification from true experimental with notice possibility exist influencing moderator variables treatment to results with all group given a pre-test. Research design used namely factorial design 2x2 because researcher. No only want to see effect from variable free to variable bound just but also effects interaction of two variables free to variable bound, where group first accept Open Kinetic Chain Exercise based exercises difference age teenagers and adults, meanwhile group second accept Close Kinetic Chain Exercise based exercises difference age teenagers and adults.

The population in this study was all post-ACL surgery patients at the Ibest Sport Physiotherapy Clinic Solo. Meanwhile, the sample for this study used a purposive sampling technique of 16 teenagers and adult with the following criteria.

a. Criteria Inclusion: 1) Patient previous ACL injury does operation after 4 weeks. 2) Own degrees ACL injuries among 2-4. 3) Don't have comorbidity disease chronic. 4) Willing become sample study.

b. Criteria Exclusion: 1) Patient ACL injury with degrees injury light. 2) Own comorbidity disease chronic.

Instrument data collection in research this use guide to the management of Open Kinetic Chain Exercise and Close Kinetic Chain Exercise with the Training program below this.

Meanwhile on tools Measuring EMG Wireless Transmitter is originating signal from contraction of the muscles human.

Detection, amplification and recording changes that occur in the tension produced by contraction base network muscle called electromyography, and results the recording called electromyogram (EMG). The data analysis technique uses prerequisite tests namely the homogeneity test with mark significant ≥ 0.05, normality test with mark probability > 0.05, and test the hypothesis use two-way anova test with mark significance set of 0.05.

Results

Respondent study is post ACL surgery patients at the Ibest Sport Physiotherapy Clinic Solo as many as 16 people with Division of 4 people per each group variable. Entire respondents' study this has fulfilled criteria inclusion and exclusion that have been set. Based on the results obtained, characteristics are obtained age respondents indicated distribution age respondents at the time study can seen in the following table. Table 2 shows that respondents research with ages 16-18 years amounted to 8 respondents or 50%. Meanwhile, there were 8 respondents aged 18-25 years or 50 % of all respondents studied.

Table 1
Open kinetic chain exercise and close kinetic chain exercise training programs.

Exercise	Repititions / Sets
1. Squats (Bousquet et al., 2018)	30-120 sec / 2-4 sets
2. Lunges (Bousquet et al., 2018)	6-8 reps / 3-5 sets
3. Step Ups (Risberg et al., 2007)	15-20 reps / 3 sets
4. Wall Sit (Bousquet et al., 2018)	30-120 sec / 2-4 sets
5. Single Leg Balance (Bousquet et al., 2018)	15-20 reps / 3 sets
6. Straight Leg Raises (Risberg et al., 2007)	20-30 reps / 4 sets
7. Hamstring Curl(Risberg et al., 2007)	12-15 reps / 3 sets
8. Knee Extension (Risberg et al., 2007)	15-20 reps / 3 sets
9. Leg Press (Risberg et al., 2007)	12-15 reps / 3 sets
10. Terminal Knee Extension (Bousquet et al., 2018)	5 sets / 1 minute hold

Table 2
Characteristics respondent according to age.

No	Category	Age	n	%
1	Teenager	16-18 Years	8	50
2	Mature	18-25 Years	8	50
			16	100

Table 3
Analysis results descriptive strength muscle.

Exercise	Age	n	Mean	Std. Deviation
Open	Teenager	4	114.50	2.380
	Mature	4	104.75	2.062
	Total	8	109.63	5.605
Close	Teenager	4	130.75	4.349
	Mature	4	118.25	2.500
	Total	8	124.50	7.445
Total	Teenager	8	122.62	9.273
	Mature	8	111.50	7.521
	Total	16	117.06	9.976
Minimum		104.75		
Maximum		130.75		

Table 4
Anova test results for EMF Results.

Source	Type III Sum of Squares	df	Mean Square	F	*p*
Corrected Model	1387.688 [a]	3	462.563	52.739	.000
Intercept	219258.063	1	219258.063	24998.544	.000
EXERCISE	885.063	1	885.063	100910	.000
AGE	495.063	1	495.063	56.444	.000
EXERCISES * AGE	7.563	1	7.563	.862	.371
Error	105.250	12	8.771		
Total	220751.000	16			
Corrected Total	1492.938	15			

a. R Squared = .930 (Adjusted R Squared = .912)

Table 5
Comparison of the EMG results.

Variables	t	df	*p*	Mean Difference	Std. Error Difference	95% CI	
						Lower	Upper
EMG Results	-4.515	13.005	.001	-14.875	3.295	-21.992	-7.758

Based on Table 3, it can be seen that the amount of data from this research is 16 data. The test results above show the minimum, maximum, average and standard deviation values for the variables strength muscle . Strength variable muscle (Y) has the lowest value of 104 and the highest value of 130 with an average value of 117.06 and a standard deviation (level of data distribution) of 9.976.

Based on Table 4, it was obtained mark the significance of each factor training (OKC and CKC) and age (teenagers and adults), so can withdraw conclusion as following. In the "Corrected Model" section, the model is valid if all independent variables (exercise, age, and interaction of age and exercise) together have an effect ($p< 0.05$) on the dependent variable (strength EMG results muscle). In the “Intercept” section, value change variable dependent without need influenced variable independent that is without there is influence variable independent, variable dependent can changed value. Significance value (Sig.) $0.000 < 0.05$ means the intercept is significant. On factors exercise obtained Sig value. equal to $0.000 < 0.05$, so stated hypothesis that there is influence giving exercise both OKC and CKC against strength Post Quadriceps Femoris muscle anterior cruciate ligament (ACL) based surgery age can accepted. Meanwhile on factors age obtained Sig value, equal to $0.000 < 0.05$, so stated hypothesis that there is influence giving exercise to strength post quadriceps femoris muscle anterior cruciate ligament (ACL) surgery is neither good age teenager nor mature can accepted.

In Table 5, you can see the Sig value amounting to $0.000 < 0.05$ in the "Equal variances assumed" section, as the basis for decision making in the independent sample t-test. It can be concluded that the hypothesis is accepted. Thus, it

can be concluded that there is a significant difference between the average EMG results in the OKC and CKC training groups. Furthermore, from the table above it is known that the "Mean Difference" value is -14.875. This value shows the difference between the average EMG results in the OKC Exercise group and the average EMG results in the CKC group or 109.63-124.50 = -14.875 and the difference is -21.941 to -7.809 (95% Confidence Interval of the Difference). Meanwhile, the negative t value of -4.515 is caused by the average EMG results in the OKC group being lower than the average EMG results in the CKC group.

Discussion

Atrophy or weakness quadriceps muscle occurs after immobilization joints knees and can cause weakness in the quadriceps muscles after ACL injury and reconstruction. Muscle thigh front (quadriceps muscle) has role important in effort reduce problems for patients because function quadriceps muscle as a shock absorber so can reduce weight on the knees. Decline strength muscle thigh front can cause excessive pressure on the knees so that lower function motion knee (Nishino et al., 2020). In patients with anterior cruciate ligament (ACL) injury, deficit of strength quadriceps muscle is 10-27% (Kim et al., 2022).

In open exercises the kinetic chain increases strength muscle focused on one muscle so that can hinder happen atrophy muscle increase circulation blood, and it happened enhancement strength muscles that can increase ability functional (Eggerding et al., 2015). Exercises given are straight leg raise (SLR), hamstring curls, knee extension, leg press, and terminal knee extension. The results of the two-way ANOVA test ($p<0.05$) describe existing influence giving OKC practice against strength post quadriceps femoris muscle anterior cruciate ligament (ACL) surgery.

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For all age groups, engagement in physical activity is more common in men than in women. Returning to an active lifestyle after an ACL injury is based on restoring knee stability. During puberty, boys show faster increases in muscle strength (Dietvorst et al., 2020). Respondent in study this aged 18-25 years, with the results of the data analysis test stated age many respondents experience enhancement strength muscle is respondents aged 18-25 years. Strength muscle start arises since born until mature and continue increase especially in the 20s to 30s and gradually decreases along with enhancement age. In general that man more strong compared to with woman. Strength muscle man young almost the same with woman young until approaching age puberty, after that man will experience enhancement strength significant muscle compared women, and differences biggest arise during age middle.

This increase in strength is related to the increase in muscle mass after puberty, because after puberty men's muscle mass is 50% greater than women's muscle mass. There are differences in the anatomical structure, both morphological and histological, between men and women. These differences begin to appear clearly at the end of adolescence, namely in the age range of 17-18 years. These differences occur in the cardiovascular and respiratory systems, hormonal systems, nervous systems as well as the musculoskeletal system. Differences in the musculoskeletal system appear in body shape where women have narrower shoulders than men. Apart from that, differences can also occur in muscle structure, where muscles in men contain less fat. So, the muscle capacity of men has the potential to have greater strength than women. Apart from different energy issues, the structural differences between men and women are also different where men have the potential to have stronger muscle strength than women, so the impact of training can also be expected to be different. This gender difference also includes the development of muscle strength. In theory, muscle strength is obtained from the principle of weight training which is overloaded, progressive and starts from large muscles to small muscles (Lesmana, 2012).

The strength capacity of a muscle is directly related to the cross-sectional physiology of the muscle fiber area. Singht (2016) explains that doing Quadriceps Femoris exercises can increase stimulation of afferent fibers in the cutaneous layer and trigger stimulation of mechanoreceptors. This can increase proprioception and produce muscle recovery which will be channeled through the central nervous system to increase muscle strength in the quadriceps femoris. Types of exercise, especially exercises that use weights, can cause large and rapid increases in muscle strength. Increased strength at this early stage can occur in trained people after training for 4 weeks (Prentice, 2016). Exercise that is not done regularly or is not continued will cause a decrease in muscle strength in the muscles involved. Therefore, strengthening training

requires quite a long time and requires consistency in training to see the development of an increase in muscle strength in accordance with the training principles.

Closed kinetic chain training provides a proprioceptive stimulus through the movement of two or more joints (multiple joints) so that it can stimulate mechanoreceptors around the joints which function to help control movement (Bousquet, 2016). The exercises provided are squats, lunges, step-ups, wall sits, and single balance. According to the results of the two-way ANOVA test, there is a significan difference, so these results illustrate the influence of CKC training on Quadriceps Femoris muscle strength after anterior cruciate ligament (ACL) surgery.

RF has larger EMG amplitude in OKC when it is the first muscle to activate compared to smaller amplitude in CKC where EMG onset occurs later (Stensdotter et al., 2003). Other study states that muscle thickness increased after OKC training (Cheon et al., 2020). Meanwhile, in CKC training where the VMO is activated earlier, the amplitude is greater compared to OKC, where the onset of activity is slower. This may indicate that the relative initial contribution of muscles with early activity is greater than that of muscles with late activity. The differences in EMG generation and RF amplitude in the two conditions can be explained by their nature as two-joint muscles. In OKC where the force is directed upward, the RF contribution is increased, perhaps due to its dual function as a knee extensor and hip flexor. In CKC, where the force is directed downward, this is more similar to hip and knee extension. The subject must be securely restrained during testing conditions, to prevent extension of the hip in CKC. In contrast, in OKC, the tendency to extend at the hips is less. In CKC extension, the onset of EMG activity from four different parts of the quadriceps muscle was more simultaneous compared with OKC. In OKC, the rectus femoris (RF) had the earliest EMG onset while the VMO activated last and with smaller amplitude than in CKC. Exercises in CKC promoted more balanced initial activation of the quadriceps compared to exercises in OKC.

Conclusions

The results of measurements based on training factors stated that there was an influence of OKC and CKC training on quadriceps femoris muscle strength after anterior cruciate ligament (ACL) surgery. Meanwhile, the age factor shows the influence of training on Quadriceps Femoris muscle strength after anterior cruciate ligament (ACL) surgery. The results of measuring muscle strength showed an increase in muscle strength from before training to after OKC training. The average increase in muscle strength in adolescents and adults after training OKC was 10.91% and 12.23% respectively. In addition, muscle strength increased from before training to after CKC training. The average increase in muscle strength in adolescents and adults after CKC training was sequential, also amounted to 11.43% and 12.55%. Thus, for knee rehabilitation in general CKC training is preferred over OKC, because CKC training is considered more functional, safe and effective. The variable influence of CKC training in the adult age category has an average of the highest average among other variables.

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