Effects of isokinetic resistance training in the rehabilitation of chronic grade 3 anterior cruciate ligament deficiency

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ABSTRACT

Introduction: To investigate the effects of 12 weeks concentric-type isokinetic resistance training using two different angular velocities (120°/s and 240°/s) on isokinetic knee strength and functional ability of patients with chronic (more than three months post-trauma) grade 3 anterior cruciate ligament deficiencies. **Materials and Methods:** Nineteen male patients were included in the study. They were randomly assigned into three groups: control, 120°/s group and 240°/s group. The 120°/s intervention group (mean age: 36.8 ± 7.9 years) and 240°/s intervention group (mean age: 33.0 ± 11.4 years) participated in the prescribed training programme along with their existing conventional physiotherapy which were carried out twice a week. The control group (mean age: 33.5 ± 6.8 years) continued with their conventional physiotherapy only. **Results:** In all the groups, there was a significant improvement ($p<0.05$) in: (i) isokinetic peak torque after 6 weeks and 12 weeks of training periods; (ii) the International Knee Documentation Committee (IKDC) Subjective Knee scores after 12 weeks of training. Although not statistically significant, a trend of an increased knee peak torque and functional outcome was observed in the intervention groups when compared to the control group, with the 120°/s and 240°/s group showing the highest improvement in the isokinetic knee extension strength and knee flexion strength, respectively. **Conclusions:** Knee strength and physical functions improved in all three groups after 12 weeks of training, independently of the treatment applied. Rehabilitation is essential in the management of the chronic grade 3 anterior cruciate ligament deficient patients.

Keywords: Anterior cruciate ligament, exercise therapy, isokinetic, rehabilitation,

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INTRODUCTION

Isokinetic resistance exercise is a type of training in which the muscle shortens or

lengthens at a constant velocity. [1] Following the training, muscular strength of the concentrically and eccentrically trained leg could significantly be increased. [2] It helps to enhance torque production by quadriceps femoris or hamstring muscles and thus prevent loss of knee stability. [3] Isokinetic exercise is possibly more superior compared to isotonic and isometric because of certain aspects such as, providing objective data, reliability, creating the possibility of variations in the preparation of effective rehabilitation programme and maintaining the optimal function once training has ceased. [4-6]

This study aimed to investigate the effects of isokinetic resistance training in the rehabilitation of a chronic grade 3 anterior cruciate ligament (ACL) injuries. Most of the previous studies published in the literature had investigated the effectiveness of general isokinetic exercise programme, and many had included patients following ACL reconstructive surgery. [1, 2, 7-10] To our knowledge, literature reporting the effects of isokinetic resistance training on patients with chronic grade 3 ACL deficiencies who have not undergone reconstructive procedure are scarce and remain unclear. [11]

MATERIALS AND METHODS

Institutional approval was obtained from the Human Ethics Committee, School of Medical Sciences, Universiti Sains Malaysia. Individuals with chronic grade 3 ACL deficiencies that were more than three months post-injury and had a full range of motion of their knees were enrolled into the study. The grade 3 ACL deficiency was clinically diagnosed by a senior sport knee surgeon (SA) after demonstrating a positive soft-end point in the Lachman test, an anterior drawer test of more than 10 mm of translation and a positive pivot shift test with a definitive clunk. Patients meeting the following criteria were excluded from the study: (i) individuals with coexisting cardiorespiratory disorder or uncontrolled hypertension; (ii) abnormal, pathologic contra-lateral knee; (iii) congenital disorder or previous surgery on the investigated knee; (iv) involvement of other ligamentous injury on the knee; and (v) severe knee pain restricting exercise activity.

The sample size was calculated using the PS Power and Sample Size Calculations Version 2.1.30 (Vanderbilt Biostatistics, Nashville, TN) with allowance for a drop-out rate of 20% per group. The power of the study was set at 80% with 95% confidence interval while the standard deviation (σ) observed was 101 (peak torque) and the difference in population means (δ) was set at 150. Previous study by Desnica Bakrac [11] was used as reference. The patients were matched for age and gender before they were randomly assigned into three groups: control, 120°/s intervention group and 240°/s intervention group.

Patients in the control group followed the prescribed physiotherapy programme, which consisted of cycling, proprioception training, leg curl, knee extension and dynamic stabilisation on trampoline. The physiotherapy session was performed twice per week for a period of 12 weeks. For the first intervention group, the angular velocity for the isokinetic resistance training programme was set at 120°/s while the second group trained with angular velocity of 240°/s. All the patients in the intervention groups were re-

required to attend isokinetic training twice per week for a period of 12 weeks, after each physiotherapy session. These patients underwent the same physiotherapy regime as the control group.

Physical function was measured at pre- and post-training, by using a validated International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form. [12] Muscular strength was measured according to a standard protocol using an isokinetic dynamometer (Multi-Joint System 3 Pro, Biodex Medical Systems, USA).

All patients completed a warm-up session which included a 5-minutes cycling set without resistance on a stationary bike (Monark Ergomedic 824E, Sweden), as well as a standard quadriceps and hamstrings stretching exercises. The patients were then instructed to continue with the assessment or training session following a 5-minutes rest.

Preparation of patients was similar in the assessment and training protocols. Patients were seated on the isokinetic machine, leaning against a backrest inclined at 16° from the vertical, with the seat inclined 6° from the horizontal plane. The lateral femoral epicondyle was used as a bony landmark for matching the axis rotation of the knee joint and the axis rotation of the dynamometer exercise arm. For the first six weeks, each training session consisted of three sets of eight repetitions at the prescribed angular velocity, whereas three sets of 10 repetitions were performed during the subsequent six weeks period. The patients were allowed to rest for 30 seconds between each set.

Isokinetic strength assessments were carried out on all the groups at the same intervals: at pre-, mid- (after six weeks), and post-training (after 12 weeks). Two testing angular velocities were used (90°/s and 180°/s) for the isokinetic peak torques measurement. [7, 11, 13] The patients were asked to do five repetitions for each angular velocity. One minute rest was allowed between the two different angular velocity tests performed.

Data analysis was performed using SPSS statistical software, version 14.0 (SPSS Inc.; Chicago, IL, USA). One-way ANOVA and Bonferroni post-hoc test were used to analyse the main effects of time (pre- and post-training) differences. Two-way ANOVA and a simple effect test were used to analyse between group differences in isokinetic strength and physical function score. Significance level was set at $p<0.05$ and all the data were presented as means ± standard deviation (SD).

RESULTS

Twenty-one patients were initially recruited

Table 1: Anthropometric characteristics of the patients.

	Control	120°/s	240°/s
Number of patients	6	6	7
Age (years)	33.5 ± 6.8	36.8 ± 7.9	33 ± 11.4
Height (cm)	165.8 ± 3.8	171.8 ± 2.2	167.7 ± 3.6
Weight (kg)	69.4 ± 9.1	69.7 ± 6.9	61.2 ± 6.3

Values shown as mean ± SD

Table 2: Peak torque/body weight of knee flexion (Nm).

	Control	120°/s	240°/s
Testing at 90°/s			
Pre-training	91.2 ± 37.8	99.1 ± 14.8	98.7 ± 24.4
Mid-training	123.9 ± 39.7 *	123.5 ± 25.1 *	139.2 ± 26.7 *
Post-training	134.1 ± 36.9 *	134.5 ± 26.6 *	155.9 ± 26.8 *
Testing at 180°/s			
Pre-training	94.3 ± 30.7	93.3 ± 18.3	97.1 ± 18.9
Mid-training	115.4 ± 24.7 *	119.1 ± 24.8 *	138.8 ± 26.2 *
Post-training	125.6 ± 24.6 *	127.0 ± 22.8 *	152.9 ± 27.5 *

Values shown as mean ± SD.
* Significantly different from respective pre-training values (p<0.05).

for the study. One patient from the control group discontinued due to time factor while another patient from the 120°/s intervention group withdrew from the study due to personal reason. Thus, 19 participants completed the study successfully. The causes of the ACL deficiency in these patients were sports-related injuries. The average age, height and weight of the patients are shown in Table 1.

Tables 2 and 3 show the measurements of the isokinetic peak torque per body weight in both intervention groups and the control group at various periods. The two-way ANOVA for repeated measures revealed that there was no significant interaction ($p>0.05$) between intervention groups and time on isokinetic knee flexion and extension peak torque at 90°/s and 180°/s testing. There was no significant main effect of intervention on isokinetic knee flexion and extension peak torque, but a significant main effect of time on isokinetic knee flexion and extension peak torque at both velocities testing was found. A pair-wise comparison revealed a significant difference in the peak torque per body weight of isokinetic knee flexion and extension between the pre-and mid-period tests, as well as between the pre- and post-period tests for all the groups ($p<0.05$).

The IKDC Subjective Knee Evaluation

Table 3: Peak torque/body weight of knee extension (Nm).

	Control	120°/s	240°/s
Testing at 90°/s			
Pre-training	195.8 ± 33.2	198.7 ± 44.4	197.9 ± 44.8
Mid-training	222.8 ± 40.1 *	243.3 ± 44.1 *	233.0 ± 53.5 *
Post-training	243.7 ± 38.5 *	271.4 ± 50.6 *	252.7 ± 56.4 *
Testing at 180°/s			
Pre-training	160.9 ± 19.5	168.5 ± 17.8	165.2 ± 50.2
Mid-training	177.1 ± 22.9 *	205.8 ± 30.9 *	202.2 ± 53.3 *
Post-training	191.4 ± 23.2 *	222.5 ± 39.7 *	214.6 ± 52.6 *

Values shown as mean ± SD.
* Significantly different from respective pre-training values (p<0.05).

Table 4: IKDC Subjective Knee Evaluation Score.

	Control	120°/s	240°/s
Pre-training	65.1 ± 6.7	62.6 ± 10.5	61.7 ± 10.2
Post-training	76.4 ± 7.1 *	77.2 ± 8.7 *	80.6 ± 9.6 *

Values shown as mean ± SD.
* Significantly different from respective pre-training values ($p<0.05$).

scores of the control and intervention groups at pre- and post-training are shown in Table 4. The two-way ANOVA with repeated measures revealed that there was no significant interaction ($F = 0.507$; $p>0.05$) between intervention and time on this score. There was no significant main effect of intervention on the IKDC score, but a significant main effect of time on the IKDC score was noted. A pair-wise comparison revealed a significant difference between pre- and post-tests for all the groups ($p<0.05$). Although there were no significant statistical differences in the IKDC scores between the groups, the control group had the lowest improvement in the IKDC score (11.3) when compared to the intervention groups (14.6 and 18.9, in the 120^0/s group and 240^0/s group respectively).

DISCUSSION

In general, there will always be some patients with grade 3 ACL injury who decline reconstructive surgeries, leaving physical therapy as the only option to stabilise their knees. Rehabilitation should focus on the quadriceps and hamstrings muscles strengthening to provide dynamic supports for the knees. [14] Modification of activities is mandatory to avoid activities that involve frequent high-risk behaviour, such as twisting, cutting, and deceleration manoeuvre. [15] Despite these measures, adequate knee function and the ability to perform activities may only be maintained in the short-term and is usually unpredictable. Often the resultant knee function fail to return to the pre-injury level. [16, 17] The present study was designed to elicit whether there is any adjunct modality such as the isokinetic resistance exercise, that can help patients with chronic grade 3 ACL deficiency, in addition to the current gold standard of physiotherapy.

Studies in the past have investigated the effects of isokinetic resistance training on different groups of patients, using several angular velocities. [2, 6-9, 18, 19] Ewing *et al.* [1] showed that muscular strength and power improvement during isokinetic exercise were dependent upon the velocity of training and the test speed used. However, it is still unclear whether a fast or a slow angular velocity should be adopted for knees with chronic grade 3 ACL deficiency. Intense knee pain contributed by increased muscular movement generation capability and exposure time to mechanical load may occur during isokinetic exercise which utilises the slower angular velocities training. [20] The undesirable effect of anterior tibial translation during isokinetic exercise is also inversely related to the extension speed. [21] Furthermore, high speed isokinetic movements can effectively increase the co-activation activity of the hamstrings, [22]

which is useful to reduce anterior tibial translation in ACL-deficient knees. [9] Contrary, isokinetic exercise at fast angular velocities causes coordinative difficulties during the first motions and provides submaximal exercise due to the low resistance and short contraction time. [23] As a right balance of angular velocity is needed in the training, the 120°/s and 240°/s were chosen in our study with the awareness that no published literature has reported on the effects of using such training velocities in this group of patients.

The results of our study showed that there was a continuous improvement in the isokinetic peak torque in both the intervention groups and the control group during the 12 weeks training period. Another study also showed that there was a 150% muscle strength improvement in patients who had not undergone ACL reconstructive surgery, following isokinetic resistance exercise. [11] That study however failed to elaborate the grade of the ACL deficiency suffered by the patients, and therefore the results might be biased and debatable. The angular velocity used to achieve the reported results was also not clear since the isokinetic exercise protocols prescribed were individually designed and adjusted throughout the training period. The result of the present study in contrast showed that there were no statistically significant differences in the isokinetic knee peak torques among the three groups tested after the 12-week treatment period. Despite this, the study demonstrated that there was a improvement in the increased peak torque measurements in the intervention groups compared to the control group. The 120°/s and 240°/s groups showed the highest improvement in isokinetic knee extension and knee flexion strength, at all the assessment times using the two different testing velocities. This is interesting as it may suggest that an isokinetic exercise programme that uses mixed angular velocities (fast and slow) may be better in improving the strength of both the flexors and extensors of the knee.

Although not statistically significant, our study showed that the control group had the lowest improvement in the IKDC score (11.3) compared to the intervention groups (14.6 and 18.9, in the 120^0/s group and 240^0/s group respectively). This suggest that there may be some benefit of adding isokinetic resistance exercise to conventional physiotherapy for patients with chronic grade 3 ACL deficiencies. These results are in accordance with the findings of another study which looked at a rehabilitation programme following ACL reconstruction. [10] This study showed that the patients who received a combined regime of isokinetic-isotonic strengthening exercises had higher functional performance scores compared to those who received only the isotonic strengthening exercises. [10] In line with the results of the study performed by Tsepis *et al*. [24] that showed hamstring weakness as a more useful indicator of poor knee function than the quadriceps status in ACL-deficient knees. We postulate that the larger increment in the IKDC score seen in the 240°/s group, compared to the other two groups was due to the superior improvement in the knee flexion strength observed in this particular group.

We acknowledge that the improvement in knee strength and functional outcome in the isokinetic groups could be possibly be due to the additional exercise prescribed to the interventional groups. However this study

is useful as it demonstrated the importance of choosing the correct angular velocity when prescribing the isokinetic resistance exercise for patients with chronic grade 3 ACL deficiencies. For further research, we suggest the use of various other angular velocities, either in isolation or in combination during the isokinetic exercise. A longer duration of training or a larger cohort size may additionally be required for any significant statistical difference to be detected in the treatment groups. It may also be useful to investigate the effects of the isokinetic exercise alone in comparison to the conventional physiotherapy regime.

In conclusions, knee strength and physical functions improved in all the three groups after 12 weeks of training, independently of the treatment applied. Rehabilitation by physiotherapy, with or without isokinetic exercise, is essential in the conservative management of the chronic grade 3 ACL deficient patients.

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