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Original Research Article

Study of proprioception and muscle strength following arthroscopic anterior cruciate ligament reconstruction

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ABSTRACT

Background: Mechanoreceptors plays a vital role in knee mechanics. Since there are controversies surrounding the overall recovery time of proprioception following surgery, it is necessary to define the factors affecting proprioceptive recovery after anterior cruciate ligament reconstruction and to investigate the relationship between proprioception and muscle strength following surgery.
Methods: Current study is combined prospective and retrospective study done at K. S. hospital Koppal, spanning for a period of one year (December 2019 to December 2020). All patients presented with isolated anterior cruciate ligament (ACL) tear were included in the study. Patients were treated by arthroscopic ACL reconstruction with hamstring graft only and followed up for a period of year. Outcome measures include centre of mass proprioception in AP and medio-lateral direction and muscular strength through force gauze in Newton.
Results: 26 patients (mean age 33) were included in the study, all ACL tears were treated by arthroscopic ACL reconstruction with hamstring graft and they underwent varying period of rehabilitation.
Conclusions: This study shows that our understanding of biomechanics of ACL reconstructed knees is still evolving, and proprioception is found to be a key factor in determining post-op recovery. ACL remnant preservation intra-op along with proper mechanical positioning of the graft may help in better proprioception and functional outcome following the reconstruction.

Keywords: Anterior cruciate ligament, COM, Antero posterior, Proprioception

INTRODUCTION

Mechanoreceptors located in the joint capsule, knee joint ligaments and menisci may be affected by a knee injury involving anterior cruciate ligament (ACL) rupture and disturbances of the afferent activity may occur.[1-4] There's evidence that injury to the anterior cruciate ligament may cause proprioceptive deficits, with several studies showing decreased knee proprioception in people with ACL deficient knees, which may allow inappropriate loading of a joint, this may induce microtrauma.[5-7] Enhancement of the neuromuscular control of the knee following ACL reconstruction may lead to better outcomes in terms of return to functional activities and a reduced rate of re injury. Sjolander and Sojka suggested that stimulation of mechanoreceptors in joint structures may stimulate the sensitivity of muscle spindles around the joint, in turn creating a state of readiness of muscles to reply to destabilizing forces applied to the joint and thereby improve active joint stability.[4] Although injury to the ACL will disrupt local mechano-receptors, compensatory activation of other knee joint mechanoreceptors may produce compensatory muscle activation, for joint stabilization. These compensatory neuromuscular patterns could also be developed and

enhanced by utilizing treatments that incorporate destabilizing activities and exercises. For these reasons, balance and proprioceptive exercises, defined as exercises that challenge stability and neuro-muscular control, are advocated within the clinical setting.[8,9]

METHODS

Current investigation is a combined prospective and retrospective study in which patients were selected by using convenient method. Patients who came to K. S. hospital, Koppal between period of December 2019 to December 2020 with isolated ACL tear which has been diagnosed clinically and by MRI, confirmed by arthroscopy were taken as subjects. So, total subjects included were 26. All patients were treated by arthroscopic ACL reconstruction with hamstring graft only and patients underwent varying period of rehabilitation post-surgery. During period of rehabilitation, patient underwent closed kinematic exercises. Hamstrings and quadriceps core muscle strength was measured at different intervals by force gauge in Newton's. Proprioception was measured by body worn sensors (Balan Sens) to measure the motion of ankle and hip joints in three dimensions. Resulting data was integrated into a two link biomechanical model of the human body for estimating the two dimensional sway of the centre of mass (COM) in anterior-posterior (AP) and medial-lateral (ML) directions. Patients were examined in closed eyes condition for duration of at least 30 seconds and measurements were recorded at 3 months, 6 month and 1 year follow up. Each parameter was compared with the contralateral (uninjured) knee. No ethical committee approval was required for our study.

Statistical analysis

Statistical analysis was executed by an independent statistician who was not involved in the study. Chi square and ANOVA p value tests were used to compare the parameters.

RESULTS

Current study includes 26 patients, who underwent rehabilitation following ACL reconstruction at varying periods. Most of the patients were aged between 20-40 years, constituting about 89% of the study population, and the remaining patients were above 40 years of age (Figure 1). Male constituted 84.6% of the study population and the rest were females (Figure 2). At the end of one year of follow up, there was no statistical difference observed in quadriceps strength between operated knee and contralateral knee. Strength of quadriceps of operated knee remained equal to contralateral knee at beginning of rehabilitation, and later on quadriceps muscle strength of operated knee was found to spike up compared to the contralateral normal knee (Table 1).

Table 1: Comparison of quadriceps muscle strength between different time intervals in operated and contralateral knee.

Quads	Time (months)	N	Mean (Newton)	SD	Minimum	Maximum	ANOVA	
							F	P value*
Operated	**3**	14	205.71	45.07	108	280	0.23	0.80
	6	6	217.83	37.24	160	268		
	12	6	204.33	26.22	160	240		
Contralateral	**3**	14	206.29	33.69	135	250	0.33	0.72
	6	6	205.17	39.15	145	265		
	12	6	193.33	26.39	160	230		

*p<0.05 was considered as statistically significant.

Table 2: Comparison of hamstring muscle strength between different time intervals in operated and contralateral knee.

Hamstrings	Time (months)	N	Mean (Newton)	SD	Minimum	Maximum	ANOVA	
							F	P value*
Operated	**3**	14	89.07	20.97	38	120	1.47	0.25
	6	6	111.67	50.85	60	197		
	12	6	88.33	6.50	80	98		
Contralateral	**3**	14	143.86	40.19	42	210	0.09	0.91
	6	6	146.33	38.10	109	208		
	12	6	138.00	5.62	128	143		

*p<0.05 was considered as statistically significant.

Table 3: Comparison of proprioception-ML between different time intervals in operated and contralateral knee.

Proprioception-ML	Time (months)	N	Mean (Newton)	SD	Minimum	Maximum	ANOVA	
							F	P value*
Operated	**3**	14	2.15	1.67	1.03	6.87	3.00	0.07
	6	6	2.88	2.34	1.70	7.63		
	12	6	5.12	3.98	0.64	10.85		
Contralateral	**3**	14	3.36	1.22	0.82	6.33	16.00	<0.001
	6	6	1.25	0.44	0.60	1.87		
	12	6	5.44	1.87	2.18	7.25		

*p<0.05 was considered as statistically significant.

Table 4: Comparison of proprioception-AP between different time intervals in operated and contralateral knee.

Proprioception-AP	Time (months)	N	Mean (Newton)	SD	Minimum	Maximum	ANOVA	
							F	P value*
Operated	**3**	14	2.39	1.35	0.79	4.84	2.06	0.15
	6	6	2.82	1.21	1.68	5.16		
	12	6	4.02	2.52	1.14	7.24		
Contralateral	**3**	14	2.94	0.95	1.14	4.10	12.82	<0.001
	6	6	2.98	1.33	1.10	4.55		
	12	6	7.05	3.14	2.88	10.86		

*p<0.05 was considered as statistically significant.

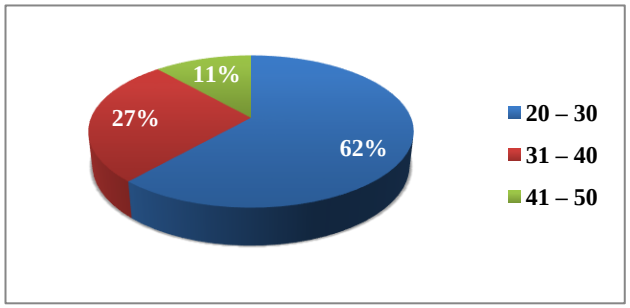

Figure 1: Age distribution.

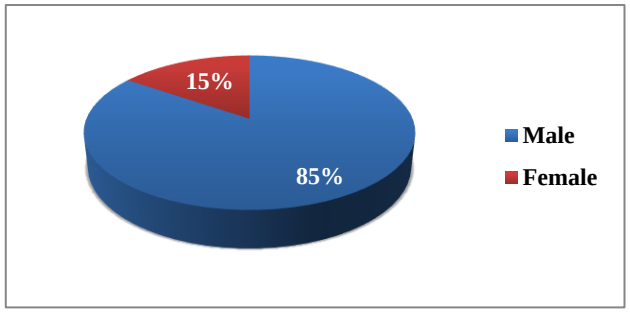

Figure 2: Sex distribution.

At the end of one year follow up there was no statistical difference in hamstring strength between operated knee and contralateral knee. But initially as the time period following rehabilitation goes on, strength of hamstring was found to increase from 3 months to 6 months post-operative compared to contralateral knee with peak post-op strength achieved at 6 months. At one year follow-up post-operatively, it was found that hamstring strength in the operated knee reduced to the 3 month post-operative value (Table 2). When proprioception is compared using two link biomechanical model of the human body for estimating the two dimensional sway of the centre of mass (COM) in medial-lateral (ML) direction, at 3 months follow-up, patients were found to have better proprioception in the operated knee (2.15 cm) when compared to the contralateral normal knee (3.36 cm). At 6 months follow-up, patients were found to have better proprioception in the contralateral knee (1.25 cm) when compared to the operated knee (2.88 cm). At 12 months follow-up, both knees were found to have comparable levels of proprioception. This improvement in proprioception was found to be statistically highly significant (p<0.001) (Table 3).

Similarly, when proprioception is compared using two link biomechanical model of the human body for estimating the two dimensional sway of the centre of mass (COM) in medial-lateral (ML) direction, at 3 months and 6 months follow-up, both knees were found to have comparable levels of proprioception but at one year follow-up operated knee was found to have better proprioception value when compared to contralateral knee and this was found to be highly significant (p<0.001) (Table 4).

DISCUSSION

The anterior cruciate ligament (ACL) plays a major role in maintaining the normal function of the knee and although surgical reconstruction often provides good results, there remains a great deal of scope for improving function after this procedure. Strength training (ST) has been traditionally emphasized after ACL reconstruction. However since

the discovery of mechanoreceptors that can detect changes in tension, speed, acceleration, direction of movement and the position of the knee joint in the human ACL, it has been postulated that information from the ligament assists in dynamic stability of the knee. Thus, an ACL rupture may alter somato-sensory information and impair neuro-muscular control of the affected knee joint. Although proprio-ceptive training (PT) is currently emphases after ACL reconstruction, only few studies have documented the effectiveness of proprioception and muscle strength in restoring neuro-muscular control. 26 patients included in current study underwent arthroscopic ACL reconstruction with hamstring graft. These patients underwent post-operative rehabilitation at different intervals of time and were assessed. Quadriceps and hamstring muscle strength and proprioception data were noted at fixed intervals of rehabilitation. Moritani et al found that neural factors accounted for the larger proportion of the initial strength increment and thereafter both neural factors and hypertrophy took part in the further increase in strength, with hypertrophy becoming the dominant factor in later weeks of rehabilitation.[10] In current study, it was observed that quadriceps muscle strength of operated knee was same as contralateral knee at the beginning of rehabilitation, however during final follow-up strength of quadriceps of operated knee was found to be better than contralateral knee. After ACL reconstruction, the latency of hamstring muscles after a postural disturbance is still longer than in the contralateral, non-reconstructed knee. This longer latency could also be due to the absence of the mechanoreceptors present within the ACL, which also seem to play a crucial role in initiating the reflex contraction of muscles around the knee .The longer latency observed in this study indicates that a direct reflex arc seems to exist between the ACL receptors and the hamstring muscles. After ACL rupture and reconstruction, the reflex arc clearly was not functioning properly. Reflex arc plays a protective and stabilizing role in daily activities, in which stability is continuously necessary.[11,12] When an ACL rupture occurs, instability of the knee is observed and could be aggravated by the longer latency of the ligament-hamstring neural structure. Although ACL reconstruction restores the knee joint stability, the latency of the hamstrings remains longer. Thus, it seems that even after ACL reconstruction, the ligament-hamstring reflex arc isnot functioning properly, either because of the rupture, the surgery itself, or both together due to which muscle activation and strengthening is hampered which was observed in our study. Ambrose et al quoted that there is improved co-ordination in muscular groups iniso-kinetic testing and found that proprioceptive and balance training may improve the nervous system's ability to synchronize muscular activity around a joint improving dynamic knee joint stability, thereby improving outcomes in people surgery to the ACL. In our studies we found both quadriceps and hamstring strength was gradually increasing in operated knee as the period of rehabilitation exercises goes on.[13] Simonian et al showed that knee proprioception returns to normal at 6 months after ACL reconstruction using hamstring graft and they quoted that histological, somato sensory evoked potential and magnetic resonance imaging studies have shown that this is attributed to the regeneration of ACL mechanoreceptors and free nerve endings.[13] The regeneration of the hamstring (gracilis and semitendinosus) grafts is even more impressive, since the bulk of the tendon mass is being removed when harvested to be used as an ACL reconstruction autograft.

In current study, antero-posterior proprioception showed good results in operated knee at 3 months, 6 months and 1 year post-operative rehabilitation whereas medio-lateral sway proprioception showed good results at 3 months follow up of operated knee when compared to contralateral knee but reversed at 6 month follow-up; which might be due to inadequate rehabilitation, poor posture or return to sedentary lifestyle which causes disturbance in the centre of mass as a result of hip and ankle muscle weakness.[13] Bonfim et al postulated that individuals who had undergone ACL reconstruction would show deficits in position perception and in threshold for detection of passive knee motion, would have longer latency onset of hamstring muscles, and would show larger body sway in maintaining the upright stance over the leg which underwent ACL reconstruction. In current study ML perception shows larger sway at 6 months follow up and also have longer latency of hamstring muscle strength.[14]

Limitations

Limitations of current study were; small sample size, follow up at regular intervals was needed for better assessing of functional outcome, there were quite uneven distribution of male and female in study group, the current study did not assess whether people returned to participate in their desired activities following rehabilitation and finally, whether people have reinjured or have returned to participate in their sport or desired societal roles must be assessed to determine whether rehabilitation interventions ultimately have been successful.

CONCLUSION

Current study depicted that our understanding of biomechanics of ACL reconstructed knees is still evolving, and proprioception is found to be a key factor in determining post-op recovery. Better post-operative rehabilitation protocol may be the key to faster recovery of the patient to his pre-operative state and ACL remnant preservation intra-operative along with proper mechanical positioning of the graft may help in better proprioception and functional outcome following the reconstruction.

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Ethical approval: The study was approved by the institutional ethics committee

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