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Evaluation of Donor Ankle Stability, Function and Body Balance Following Anterior Cruciate Ligament Reconstruction with Peroneus Longus Tendon Graft -A Prospective Cohort Study

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ABSTRACT

Background: The effect of harvesting peroneus longus tendon graft (PLTG) for anterior Cruciate ligament reconstruction (ACLR) on donor ankle stability and function and its effect on overall body balance is not yet investigated. PLT is thought to play some role in the proprioceptive regulation of the ankle joint. ACL too has a vital role in the postural control of the knee joint. This study evaluates and compares the affected and sound limb balance and function in subjects following ACLR with autologous PLTG.

Methods: A total of 44 eligible participants were assessed for balance using the HUMAC balance system and function with the Foot Ankle Ability Measure (FAAM) scale at 6week, 3month, and 6month after ACLR with PLTG. Outcome measures were stability score, path length, average velocity, time on target, and FAAM score.

Results: There was statistically significant improvement in all the parameters of bilateral or unilateral standing balance at 6month post-op [Bilateral: stability score: p=0.001; path length: p=0.000; average velocity: p=0.000; time on target: p=0.006]; [unilateral-affected/sound: path length: p=0.000, p=0.003; average velocity: p=0.000, p=0.009). The difference between affected and sound limb balance was insignificant. Median of FAAM score at 6week, 3month, & 6month were 97.368, 98.809 and 100 respectively.

Conclusion: Balance of the whole body or any single leg stability is impaired after ACLR with PLTG, but it may improve to an optimal level with due time and recover fully by six months. Donor ankle function also restores to 100% at 6month.

Keywords: ACL reconstruction, Peroneus longus, COP, balance, morbidity, function.

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INTRODUCTION

The use of autograft in anterior cruciate ligament reconstruction (ACLR) is considered the best method due to its good histocompatibility, rapid healing ability, less chance of cross-contamination, availability, and cost-effectiveness [1,2]. Bone–patellar tendon-bone (BPTB) and four-strand hamstring autografts are usually preferred by surgeons [1]. Extensive research has been conducted to find In this instance, Peroneus longus tendon graft (PLTG) has been evolving as an alternative autologous graft option for ACLR in recent years [4,5]. It has been used as a graft choice in various reconstructive surgeries [6,7]. Biomechanically it is suitable and even superior to the hamstring graft [5,8]. The added advantage of PLT graft is the regenerative potential of the peroneus longus tendon, as observed in a few MRI studies at 1year follow-up after its removal [9]. But controversial clinical outcomes are reported following ACLR with primary full-thickness PLTG. Some authors designated it as a promising and safe graft option for ACLR.

In contrast, others restricted its use to reconstruction in multi-ligament procedures only when other graft options were exhausted [4,10]. The authors claimed that removing the whole length of PLT could lead to a balanced deficit of donor ankle & hindfoot in the transverse plane, at least for the first year of surgery [10,11]. Although PLT acts as an accessory everter to peroneus brevis, overall eversion force, and power could also be reduced after harvesting PLTG [10]. Thus, upon loading during the stance phase, foot biomechanics may be altered, leading to the joint's inability to adapt to changes in surface, thus resulting in instability of the body and predisposing the foot to cause an inversion moment [12,13]. This is otherwise known as functional ankle instability (FAI). FAI is a feeling of instability that occurs while the ankle would be in inversion during the weight-bearing phase of the gait cycle, and the weak evertors would not be able to counter the inversion moment [12,14]. The possible causes for developing the FAI around the donor site after harvesting PLTG may include donor evertor strength deficits and diminished proprioceptive abilities [15,16]. Moreover, the role of the peroneus longus tendon as a passive stabilizer of the ankle joint is also evident [17].

Then, a simple question could arise. When the knee is already affected, what is the necessity of involving the same side ankle too? Although justifications in favor of PLT graft are many folded such as the dynamic support supplied from intact agonist hamstring muscles to the reconstructed ligament are protected, no extension or flexion loss in the knee joint is expected in the post-op patients, and accelerated rehabilitation protocol can be used as both hamstring & quadriceps are intact in patients after ACL reconstruction with PLT graft. But controversies continue to exist regarding donor ankle morbidity. Hence PLTG was never strongly recommended as a primary option in ACLR, especially for sportspersons, because of insufficient assessment of donor site [10,18]. Moreover, though Many studies investigated the donor foot and ankle function after harvesting full-thickness PLTG and found satisfactory outcomes, they reproduced their conclusion based on functional score, peroneal strength, etc. [18,19].

Furthermore, there is limited literature on other essential aspects of donor site morbidity such as gait, balance, etc. This is probably why PLTG is not accepted globally, and most of the available studies are from the eastern parts of the globe only [18]. After an extensive search of the available literature, not a single study was found on objective documentation of the effect of harvesting PLTG on donor ankle balance and function and its effect on the overall body balance in post-ACLR subjects.

Moreover, all the available studies to date did a cross-sectional evaluation of ankle and foot function at or after six months which might have overlooked the timely detection of donor site impairments. By examining the patients at an early post-op visit and repeating it over some time, we would be able to detect any decrement in the donor ankle stability & function and the overall body balance. This information might be beneficial for planning the post-op management in patients with ACLR with PLTG. So, this study is a novel study of its kind. We hypothesized that Harvesting PLTG might have some effect on donor ankle stability and overall body balance. The study's objective was to evaluate the changes in donor ankle stability, function, and overall body balance following ACLR with PLTG.

METHODOLOGY

Our study was a prospective observational cohort research design, conducted for 24 months from march 2019 to march 2021. It was a part of an ongoing research project approved by the Institutional Ethics Committee (IEC), and the study was performed in agreement with the 'Declaration of Helsinki.' Informed consent was collected from each subject. A total of 44 Patients following ACLR with PLTG, who reported to the physiotherapy OPD of a national rehabilitation hospital within the period and met the inclusion and exclusion criteria, were assessed for donor ankle stability and body balance. Inclusion criteria were a) post-operative patients after ACLR with PLTG, b) within the age group of 18 to 50 years, c) should be comprehensive, mentally stable, d) having bilateral healthy ankle before ACLR surgery. Exclusion criteria were a) patients who were not willing to participate in the study, b) evidence of any other medical or neurological problems affecting posture and balance. The principal investigator did a baseline evaluation at 6week post-op, then follow-up measurements at three months and six months, respectively, to determine the morbidities.

Procedure and outcome measure

The authors emphasized balance assessments for the evaluation of FAI [20]. A literature review stated that 55% of static force plate tests could detect the balance deficits associated s with ankle instability, later supported by others [16,20]. Clinicians also suggested that combining single-leg balance (SLB) with self-reported outcome measures like Foot and Ankle Ability Measure (FAAM) can predict balance deficits associated with FAI [21].

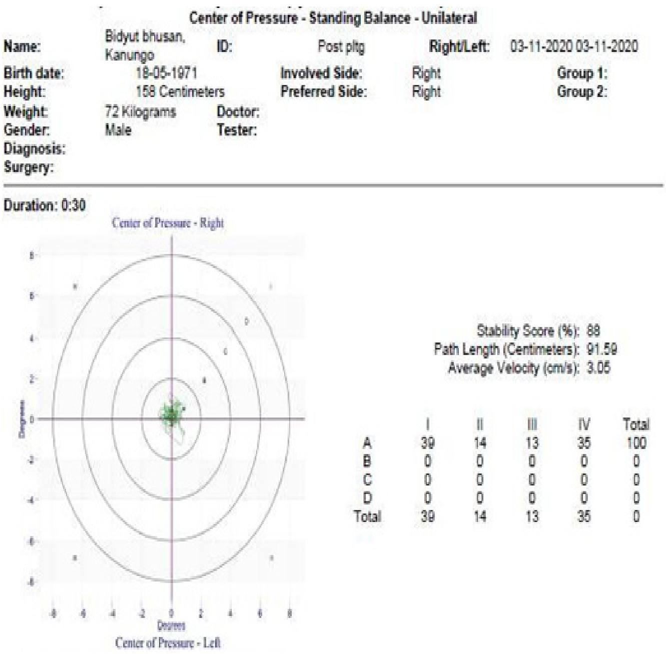
Instrumentation

We used the Humac Balance system (HUMAC2015® Version: 15.000.0103 © Computer Sports Medicine, Inc.) (www.csmisolutions.com) for the balance assessment. It is a valid instrument and consists of a force plate and user-friendly software that objectively and reliably tests static and dynamic body balance [22]. The provision of a display monitor provides visual feedback to aid maximal performance by the subjects [16,22]. Participants stood atop the balance platform barefoot at the desired place, arms at the hip, and their eyes open and fixed on the magenta shown on the display monitor. Static measures required the subjects to stand either double-legged or single-legged, keeping the non-weight-bearing leg slightly flexed at the hip & knee. If required, the subject could wear the hinged knee brace on the involved side. [figure 1]

The subjects were asked to follow a moving target on the display board [20]. Human response is influenced by practice; hence, the first trial made the subject accustomed to the procedure. The best one of the remaining three testing trials was taken for the study data.

Figure1: Unilateral stance balance assessment

Figure2: Centre of pressure parameters



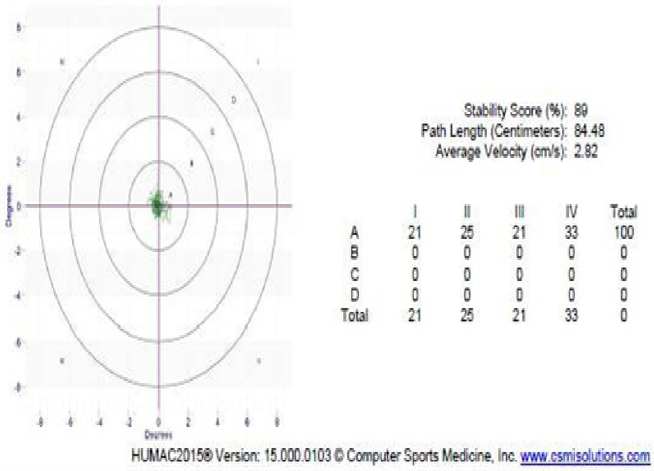
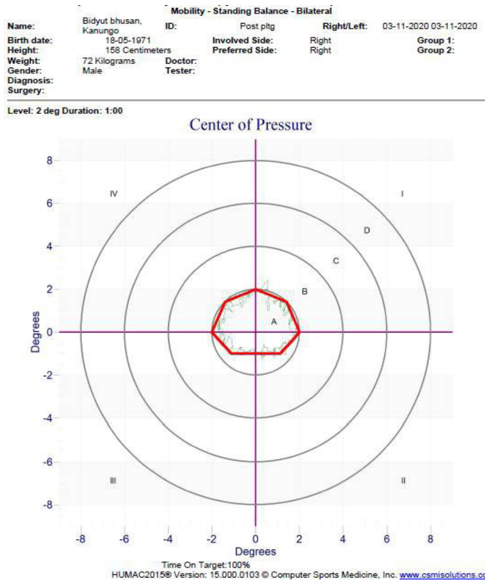


Figure3: Time on target score



Outcome measures

Outcome measures for our study were the evaluation of static balance by the measurement of bilateral and unilateral center of pressure (COP), each for 30 sec. The parameters included Stability Score (%), Path Length (cm) & Average Velocity (cm/s). Assessment of dynamic body balance was done by evaluating the Time on Target (%) parameter at level 2 for 1 minute. [figure 2, 3,]

We also used the FAAM scale, a patient-reported outcome measure for assessing ankle balance & function. It is a questionnaire comprised of 21 activities of daily living (ADL) and eight items of sports subscales. It is a reliable, valid, and responsive measure of self-reported physical function for patients with musculoskeletal disorders of the lower leg, ankle & foot. In addition, it can detect deficits associated with FAI [23,24]. As we had included both players and non-players, the sports subscale was omitted from our data collection sheet in our subject list.

Statistical analysis

The data were analyzed using SPSS Version 18.0. The normality of data was confirmed using Shapiro-Wilk's test. Mean & Standard Deviation was computed for balance variables. An Independent 't' test was used to compare affected and sound limbs at each study visit. Repeated measure ANOVA was employed to compare study groups at various study visits. Wilk's Lambda was calculated, followed by appropriate Mauchly's test of sphericity, and Pairwise comparisons between study visits were made with Post-Hoc. Tukey's test after the Bonferroni adjustment for multiple comparisons. For FAAM score analysis, the Mann-Whitney test for group comparison between sound & affected leg, Friedman test to compare study groups at various study visits, and Wilcoxon rank test for Pairwise comparisons between study visits were done after Bonferroni adjustment for multiple comparisons. A $p<0.05$ was considered significant for all statistical inferences.

RESULTS

Detailed demographic data of our 44 study participants are given in *Table1*.

Table 1: Demographic details of study participants

Variable	Mean	Std. Deviation	Std. Error
Age	31.20	9.293	1.401
Height	1.67	0.074	0.011
Weight	68.45	11.884	1.792
BMI	24.42	4.155	0.626
	Category	Frequency	Percent
Gender	Female	7	15.9
	Male	37	84.1
Affected side	Left	19	43.2
	Right	25	56.8
Dominant Side	Left	0	0
	Right	44	100

Statistically, significant improvements were observed in all the static and dynamic balance variables in bilateral and unilateral stance on affected and sound limbs during all study visits. The Mean, Lambda & P-values are given in *Table 2*. So Post- hoc analysis was done with Bonferroni adjustments, and F & p values for each are shown in *Table 3*.

Table 2: Repeated measure ANOVA for balance score among various study visits

Variable	Group	6week (Mean± S.D.)	3month (Mean± S.D.)	6month (Mean± S.D.)	Wilks' Lambda	*p*	F	*p*
Stability score	Bilateral	87.95± 7.508[a]	89.77± 7.380	92.34± 3.403[b]	0.751	.002	7.688	.001
	Affected	81.00± 12.599[a]	85.57± 4.613	87.52± 2.805[b]	0.759	.004	8.175	.004
	Sound	84.57± 4.855[a]	86.57± 3.864[b]	87.60± 3.261[b]	0.747	.003	8.965	.000
Path length	Bilateral	39.96± 18.889[a]	32.67± 12.353[a]	27.34± 9.079[b]	0.627	.000	11.877	.000
	Affected	117.16± 35.008[a]	103.14± 24.958[ba]	94.65± 21.564[bb]	0.701	.001	11.523	.000
	Sound	109.63± 30.038[a]	101.11± 21.922[a]	93.56± 25.401[b]	0.775	.006	7.586	.003
Average Velocity	Bilateral	1.22± .483[a]	1.08± .412[a]	0.90± .301[b]	0.664	.000	9.505	.000
	Affected	3.84± 1.109[a]	3.43± .832[ba]	3.14± .725[bb]	0.733	.002	10.410	.000
	Sound	3.58± .956[a]	3.36± .735[a]	3.13± .845[b]	0.818	.018	5.580	.010
Time target		88.14± 11.933[a]	90.43± 9.749	93.14± 8.883[b]	0.812	.013	4.955	.011

(S.D.- Standard Deviation)

the significance of difference over time was assessed by Repeated Measure ANOVA and Tukey's multiple comparison ([a,b] represent $p \leq 0.017$)

Table 3: Post hoc Pairwise comparison for balance scores

Variable	TIME	Comparison	Mean Difference	Std. Error	*p*	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Bilateral Stability score	6 week	3month	-1.818	1.107	.108	-4.051	.414
		6month	-4.386*	1.170	.001	-6.746	-2.027
	3 month	6month	-2.568*	1.094	.024	-4.774	-.363
Affected Stability score	6 week	3month	-4.571*	1.905	.021	-8.418	-.725
		6month	-6.524*	1.989	.002	-10.540	-2.508
	3 month	6month	-1.952*	.804	.020	-3.577	-.328
Sound Stability score	6 week	3month	-2.000*	.708	.007	-3.431	-.569
		6month	-3.024*	.819	.001	-4.678	-1.370
	3 month	6month	-1.024	.641	.118	-2.318	.270
Bilateral Path-length	6 week	3month	7.297*	3.049	.021	1.148	13.446
		6month	12.618*	2.767	.000	7.038	18.198
	3 month	6month	5.321*	1.822	.006	1.648	8.995
Affected Path-length	6 week	3month	14.028*	5.072	.008	3.784	24.272
		6month	22.515*	5.491	.000	11.425	33.605
	3 month	6month	8.487*	3.382	.016	1.657	15.318
Sound Path-length	6 week	3month	8.526	4.299	.054	-.156	17.207
		6month	16.071*	4.991	.003	5.992	26.150
	3 month	6month	7.545*	2.783	.010	1.925	13.165
Bilateral Average velocity	6 week	3month	.138	.083	.103	-.029	.304
		6month	.318*	.075	.000	.167	.469
	3 month	6month	.180*	.061	.005	.058	.303
Affected Average velocity	6 week	3month	.410*	.156	.012	.095	.724
		6month	.695*	.182	.000	.328	1.063
	3 month	6month	.286*	.114	.016	.056	.516
Sound Average velocity	6 week	3month	.223	.141	.121	-.062	.508
		6month	.457*	.166	.009	.122	.791
	3 month	6month	.234*	.094	.017	.044	.423
Time on target	6 week	3month	-2.295	1.744	.195	-5.812	1.221
		6month	-5.000*	1.716	.006	-8.461	-1.539
	3 month	6month	-2.705*	1.264	.038	-5.255	-.154

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Pair-wise analysis of unilateral standing balance showed significant improvement of stability score in the affected limb at 6month only, as compared to 6week value (p=0.002) whereas, during sound leg standing, significant increments were observed at both 3month and 6month as compared to 6week (p=0.007, 0.001 respectively). Improvement in Path length and average velocity were observed statistically for both sides of single-leg standing. Affected leg showed significant improvements, for all the pairwise comparisons between 6week & 3month, 6week & 6month, and 3month

& 6month scores (path length: p=0.008, p=0.000, p=0.016; average velocity: p=0.012, p=0.000, p=0.016 respectively). But in the sound side, significant improvements were observed only for comparisons between 6week & 6month and 3month & 6month (path length: p=0.003, p=0.010; average velocity: p=0.009, p=0.017 respectively). [*Table3*]

Bilateral leg standing balance showed statistically significant improvement for the comparison between 6week & 6month scores for all the three parameters such as stability score (p=0.001), path length (p=0.000), and average velocity (p=0.000). But path length and average velocity scores also showed significant differences for comparisons between 3month & 6month (p=0.006, p=0.005 respectively). Time on target score was statistically significant for pair-wise comparison between 6week & 6month scores only (p=0.006). [*Table 3*]Group comparison between affected and sound limb balance variables did not show any significant differences statistically at any point in time. *[Table 4]*.

Table 4: Group comparison between affected and sound limb balance at different study visits.

Variable	Study visit	Affected (Mean± S.D.)	Sound (Mean± S.D.)	Mean Difference	95% Confidence Interval	t	p
Stability score	6 week	81.00 ± 12.599	84.57± 4.855	-3.571	-7.716= 0.573	-1.714	.090
	3 month	85.61 ± 4.540	86.05± 5.536	-0.432	-2.57= 1.715	-0.400	.690
	6 month	87.43 ± 2.872	87.59± 3.187	-0.159	-1.445= 1.127	-0.246	.806
Path length	6 week	117.16± 35.008	109.63± 30.038	7.530	-6.634= 21.694	1.058	.293
	3 month	102.63± 24.604	101.70± 23.684	0.928	-9.306= 11.164	0.180	.857
	6 month	94.94± 21.430	93.54± 24.834	1.405	-8.428= 11.239	0.284	.777
Average velocity	6 week	3.844± 1.109	3.587± 0.956	0.257	-0.192= 0.707	1.140	.258
	3 month	3.418± 0.820	3.383± 0.793	0.034	-0.307= 0.376	0.199	.842
	6 month	3.159± 0.721	3.129± 0.826	0.030	-0.298= 0.359	0.186	.853

t: Independent t test, SD: Standard deviation

The group comparison between the affected and the sound side FAAM score at different post-ACLR follow-ups such as 6week, 3month & 6month showed statistically greater values for the sound ankle than the affected ankle (p = .000, p = .000, p = .006 respectively). [*Table 5*] Statistically significant improvement was observed in the FAAM score among study visits (Chi square (2) = 39.597, p = 0.000). Median and inter quartile range(IQR) were 97.368 (95.011 to 98.684), 98.809 (97.529 to 100) and 100 (100 to 100) respectively. *[Table 5]*There were significant differences in the FAAM score between study visits such as 6week & 3month (p = .011); 6week & 6month (p = .000) and 3month &6month (p = .000). [*Table 6*]

Table 5: Time and group comparison of FAAM score

	*Mann-Whitney U & p (2-tailed)	Percentiles			#Chi-Square (df) and p
		25th	50th (Median)	75th	
faam6wk	176.000 (.000)	95.011	97.368	98.684	39.597(2) .000
faam3mth	440.000 (.000)	97.529	98.809	100	
faam6mth	814.000 (.006)	100	100	100	

*Mann-Whitney test for comparison between the affected and sound side

#Friedman test for comparison between study visits

Table 6: Wilcoxon Signed Rank Test (Post hoc) for FAAM score

	faam3mth - faam6wk	faam6mth - faam6wk	faam6mth - faam3mth
Z	-2.543b	-4.868b	-3.692b
p (2-tailed)	.011	.000	.000

b. Based on negative ranks.

DISCUSSION

The COP is a commonly used parameter for evaluating postural competence on a force plate [25]. Path length shows the average displacement of COP from the center position, and COP velocity measures the displacement of COP data points per unit of time [20]. Observation of a greater stability score and a decrement in the path length & average velocity indicates improvement of static balance, and increment in time on target score indicates improvement of dynamic balance [26].

To summarize our study results, static and dynamic balance during bilateral and unilateral standing on any leg showed significant improvement in all balance parameters by six months following ACLR. FAAM score of the donor's ankle also showed significant improvement by six months. The Means of all these variables showed a gradual and linear improvement from 6 weeks to 6 months. So, we infer that even though the balance of the whole body or any single leg stability decreased following ACLR with PLTG, it could be regained to an optimal level in due course of follow-ups.

The authors stated that single-leg balance is helpful to assess postural control in ACLR patients [27,28]. Our assessment of SLB showed significant improvement in all COP parameters at both 3month and 6month post-ops, compared to the 6week score. In our study, we could not investigate the participants preoperatively. So, whether the noticed balance deficit at 6week post ACLR follow-up was present before surgery or after the graft harvest could not be explained. But our results are comparable with studies on postural balance in ACLR with other grafts. Some researchers showed higher mean COP velocities in the ACL reconstructed limb [29,30]. Others demonstrated altered single-limb postural sway following ACLR in athletes compared to control [28].

Path length and velocity are the commonly used measures in the balance assessment [20]. Based on these scores, we observed that affected leg standing balance gradually improved from 6 weeks to 6 months, but the sound leg scores remained the same up to 3 months then increased at 6month. Thus, the overall body balance improved significantly at 6month only. Balance and postural control mutually involve coordinated sensory inputs from the visual, vestibular, and somatosensory systems. Inputs from receptors of peripheral joints play an essential role, and the ankle joint being the most distal part of the body and lies close to the base of support, its stability plays a key role in controlling postural sway and maintaining whole-body balance [12]. So, we could infer that after harvesting PLTG for ACLR, the single-leg standing balance on the involved side is slightly more affected than the sound side. But it improves continuously with time and becomes almost the same as the sound leg at 3month. This is because postural control mechanisms are centrally mediated. It always tries to maintain the symmetry between the two legs to achieve the overall body balance [30,31]. So, there was a greater scope for the affected side to improve in due time. As bilateral standing represents an overall balance of the body and depends on each leg's postural stability, the improvement was more significant at 6month only.

In our research, the group comparison between affected and sound leg standing balance was not statistically significant at any point in time. But, we clinically observed minimal differences in all the variables only at 6week post ACLR visits. After that, the differences were only marginal for the subsequent follow-ups. Many researchers agreed to a common conclusion that, Postural stability deficits were predictors of FAI, and a distinctly higher value of path length and average velocity was usually used to discriminate between the FAI and Stable ankle [16,20,27] Thus, the insignificant minimal deterioration in single leg balance on the affected side at 6week as compared to the sound leg found in our observation could be attributed to multiple factors. Assumed causes included postural deficit associated with ACLR, presence of FAI, or any other causes related to surgery.

The studies found that the deficit in SLB on the operated limb persisted even after ACLR with other grafts [28,32]. Though it was better than the ACL deficient limb balance, it showed more significant sway than healthy volunteers [33]. Rather postural stability of both affected and sound leg and overall body balance was compromised after ACLR [34]. While there is limited research evaluating the COP function in the HUMAC balance system, there were varied results from different studies concerning widths traveled and velocity. However, the Mean difference in COP velocity, observed in our study (6week=0.257, 3month=0.034, 6month=0.030), was found to be within the cut-off range (1.56 cm/sec) [27]. As velocity is the most sensitive parameter to distinguish between FAI and normal [16,27], the observed normal range in our study could imply the exclusion of FAI of the donor's ankle. Other ACLR-related reasons included prescribed restrictions during initial post-op days, usual postoperative complaints, decreased ROM, scar-related complaints, protective attitude during initial post-op weeks, etc. Together, all these factors could influence the result at 6week but improved later with time with proper management protocol.

Our study is the first, to our knowledge, that used Humac to investigate the change in postural stability after harvesting PLTG for ACLR.So, it isn't easy to compare our results with others directly. However, if we assume that FAI could exist after PLTG harvest, we observed significant improvement in bilateral and unilateral static and dynamic balance to the optimal level by six months. This is again consistent with the results of other studies, which showed that the postural control returned to normal condition in patients with CAI after a few months [35,26].

Group comparison between affected and sound side FAAM scores showed a statistically significant difference during post-ACLR follow-ups. However, we got the affected side Median at 6week=97.368, 3month=98.809, and 6month=100. The sound side score being '100' during all visits, a very minimal reduction in the affected leg score was observed at 6week. Whereas at 6month, the score became 100. This indicated a gradual improvement of the donor ankle function with time and full recovery by six months. Our results are consistent with the previous study, which emphasized that the minimally clinically relevant differences patients perceived for the FAAM-ADL subscales to detect any ankle impairments were 8% [35,24]. In our study, the observed difference remained within 3%. This could explain the exclusion of a gross functional deficit of the donor's ankle after harvesting PLTG. Moreover, the Peroneus Brevis muscle is intact in our subjects, and the synergistic function of this muscle might have contributed to the restoration of the postural stability of the donor's ankle. Some studies have found it a dominant everter in the peronei group, justifying the harvest of the peroneus longus tendon [36].

CONCLUSION

Significant improvement was observed in all the parameters of COP for both static and dynamic balance at 6month post-op. This indicates that balance of the whole body or any single leg stability is impaired after ACLR with PLTG, but it improved to an optimal level with due time and recovered fully by six months. However, a significant difference was not observed in any of the balance variables for the group comparisons between affected and sound limbs during any post-op visit. Donor ankle functional score also improved linearly and became 100% at 6month.

Study limitations and suggestions

A small number of female participants limited comparing gender effect on postural control following ACLR with PLTG. The unavailability of the pre-ACLR scores did not let the researchers predict the possibility of the balance morbidities due to ACL injury or the loss of tendon at the donor ankle site. We also recommend long-term studies on these aspects of research.

Implications on Physiotherapy practice

This study results would justify the efficacy of PLTG as a suitable graft option for ACLR. It would also help to plan the therapeutic exercises to treat the reported impairments. There is a lack of post-op physiotherapy protocol for ACLR with PLTG to date, and our findings would help future researchers to work on the same.

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