



Original Article

# Comprehensive inpatient rehabilitation for elite athletes after anterior cruciate ligament reconstruction

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**Abstract.** [Purpose] The authors' institute offers a comprehensive inpatient approach to rehabilitation after anterior cruciate ligament reconstruction surgery, providing nutritional and psychological support in addition to exercise and physical therapy. This study aimed to determine the outcomes of athletes undergoing this comprehensive rehabilitation program and to compare the outcomes of bone-patellar tendon-bone and semitendinosus/gracilis autograft recipients. [Participants and Methods] Elite athletes who underwent comprehensive inpatient rehabilitation at the authors' institute for at least two weeks after anterior cruciate ligament reconstruction were mailed a questionnaire. Their recovery levels, which were measured against preinjury performance, and secondary anterior cruciate ligament injury rates, were evaluated and compared according to graft type. [Results] Valid responses from 45 athletes were analyzed (bone-patellar tendon-bone [n=12]; semitendinosus/gracilis [n=33]). The frequency of return to preinjury activity levels and secondary anterior cruciate ligament injury were comparable between bone-patellar tendon-bone and semitendinosus/gracilis graft recipients. A greater proportion of athletes returned to preinjury activity levels, while a lower percentage experienced re-rupture compared to previous studies. [Conclusion] A comprehensive rehabilitative approach after anterior cruciate ligament reconstruction may contribute to improved postoperative performance irrespective of graft type. Objective evaluations are needed in the future to clarify the benefits of specific rehabilitative approaches.

**Key words:** Comprehensive rehabilitative approach, Bone-patellar tendon-bone autograft, Semitendinosus/gracilis autograft

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## INTRODUCTION

Reconstructive surgery is usually required for athletes who experience anterior cruciate ligament (ACL) injury, which is followed by a long recovery period of 9 months or more before return to play<sup>1)</sup>. In Japan, student athletes sustain nearly 3,000 ACL injuries per year between the first year of junior-high school and the third year of high school<sup>2)</sup>; at the high school level, the incidence of ACL injury among boys and girls have been estimated to be 2.6 and 8.9 injuries, respectively, per 100,000 practice sessions or sporting events<sup>3)</sup>.

Various methods of rehabilitation after ACL reconstructive surgery are under consideration, including new approaches to quadriceps muscle strengthening exercises<sup>4)</sup>, focus on neurosensory components<sup>5)</sup>, and the use of neuromuscular electrical stimulation<sup>6)</sup>. However, many athletes are still unable to return to competitive sports, with a return rate of only 44–55% after ACL reconstruction<sup>7, 8)</sup>, necessitating new approaches that can improve performance after ACL reconstruction. Our institute

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provides an environment where top athletes can stay for a long time and receive psychological and nutritional support along with athletic rehabilitation. In addition to rehabilitation through exercise therapy, psychological readiness to return to sports may influence the return to preinjury activity levels (RPALs)<sup>9</sup>, and postoperative nutritional supplementation was associated with increasing thigh circumference<sup>10</sup>. The importance of each of these factors has been addressed in previous studies. However, since a single approach alone is unlikely to lead to favorable outcomes, a comprehensive inpatient approach that combines elements of each may constitute an effective rehabilitation strategy to improve performance after ACL reconstruction surgery.

Differences in graft type should not be ignored when evaluating postoperative outcomes. In a New Zealand study, preinjury activity levels were reached by 23.3% of patients undergoing bone-patellar tendon-bone (BTB) autograft compared with 13.3% of those undergoing semitendinosus/gracilis (STG) tendon autograft at the two year follow-up<sup>11</sup>. Thus, graft type may be a differentiating factor in the assessment of the postoperative results.

The purpose of this study was to evaluate new approaches to ACL reconstruction recovery, assess the outcomes of athletes after a comprehensive inpatient rehabilitation approach, and compare outcomes according to the BTB and STG graft types. Therefore, although there is a difference in the RPALs between patients treated with the BTB and STG grafts, we hypothesized that the proportion of RPAL in athletes who underwent the comprehensive inpatient approach is higher than that in patients shown in previous studies who received conventional rehabilitation.

## PARTICIPANTS AND METHODS

This retrospective cohort study gathered data via a questionnaire survey. The study included all 93 athletes who underwent comprehensive rehabilitation and hospitalization at our institute for at least two weeks after ACL reconstruction between April 2009 and November 2019. The participants were reserve athletes for the Olympics (i.e., they could represent their nation in an event held at the Olympic Games) or for a national sports association with an active national team. Patients who underwent hospitalization for less than two weeks were excluded because two weeks is often the minimum time period for comparisons of postoperative outcomes<sup>12</sup>. Paralympic athletes were also excluded, to rule out the effects of disability. The comprehensive approach refers to athletic rehabilitation combined with psychological and nutritional support. Each modality was conducted by skilled personnel with specialized qualifications. The content of the program was individualized to the needs of each participant and, therefore, not standardized. For example, the psychological approach for one athlete entailed weekly counseling for athletes' anxiety about returning to play, and the nutritional approach entailed advice once a week based on weekly food records. Surgery was performed at another hospital.

We recruited participants by mailing a paper questionnaire to all 93 athletes in May 2021, with participation defined as the return of the completed questionnaire. We asked four questions related to the athletes' RPAL after ACL reconstruction and subsequent inpatient rehabilitation: (1) "Have you resumed your preinjury performance?"; (2) "If you resumed preinjury performance, how many months after surgery?"; (3) "What was your performance level at the end of the comprehensive rehabilitation with hospitalization?" (respondents rated their performance level subjectively as a percentage of their preinjury performance, which was considered 100%); and (4) "Have you experienced a second ligament rupture since your ACL reconstruction?".

All participants provided written informed consent before participating in the study. This investigation was conducted according to the principles expressed in the Declaration of Helsinki, seventh edition, and received approval from the institutional review board of the Japan Institute for Sports Sciences (approval no. 2021-007). Each participant was informed that their data would be anonymized and submitted for publication. This study handled the participants' responses to the questionnaire survey as analytical data. The participants played no role in study design, results interpretation, or drafting of this manuscript.

We analyzed the data of respondents who underwent BTB and STG autograft procedures. Data on the graft type were obtained from the medical records of our institution. All data were analyzed using IBM SPSS Statistics, version 24 (IBM Corp., Armonk, NY, USA). We used Fisher's exact test to compare RPAL and secondary ACL injury between the BTB and STG graft groups. We used the Mann-Whitney U test to evaluate differences in the RPAL (for athletes who achieved RPAL) between the BTB and STG graft types. The time interval between the postoperative period to questionnaire response, time from the postoperative period to the start of inpatient rehabilitation, and the duration of inpatient rehabilitation were compared between the BTB and STG groups using Welch's t-test. We also used Welch's t-test to compare post-rehabilitation performance levels in athletes who achieved versus those who did not achieve RPAL for the BTB and STG graft types respectively. Differences with  $p < 0.05$  were considered statistically significant.

## RESULTS

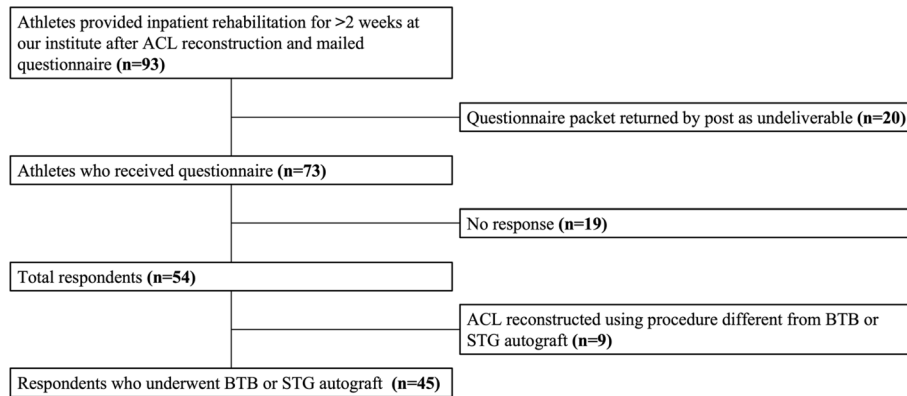
Twenty of the 93 questionnaire packets mailed were returned due to undeliverable addresses. Valid responses were received from 54 (effective response rate: 74%, male/female:  $n=25/29$ , age:  $24 \pm 4.6/25.7 \pm 4.1$  years) of the remaining 73 athletes. We analyzed data for 45 respondents who had undergone the BTB or STG autograft procedures (male/female: 20/25, Fig. 1). The time interval between the postoperative period and participant's response to the questionnaire was  $5.1 \pm 2.2/4.5$

± 2.4 years, the postoperative period at the commencement of inpatient rehabilitation was 40.5 ± 42.0/36.5 ± 25.2 days, and the duration of inpatient rehabilitation was 8.8 ± 5.9/10.9 ± 5.2 weeks in the BTB and STG groups, respectively. None of the differences were significant (p=0.41, p=0.76, p=0.28).

The results of comparison of RPAL and re-rupture status between the BTB and STG groups are shown in Table 1. The differences were not statistically significant (p=0.54, p=1, respectively). The time to RPAL (months after surgery) in athletes who achieved RPAL did not differ significantly between the BTB (n=9) and STG (n=26) groups (Table 1, p=0.89). Table 2 shows the results of comparison between of athletes who achieving versus those who did not achieve RPAL after BTB and STG. Neither BTB nor STG was associated with a significant variation in the performance level at the end of comprehensive rehabilitation with hospitalization (p=0.51, p=0.10, respectively).

## DISCUSSION

In this study, we evaluated a comprehensive and intensive approach to rehabilitation after ACL reconstruction and its influence on postoperative outcomes. Herein, the comprehensive and intensive approach refers to an inpatient program combining nutritional and psychological support with general physical and exercise therapy during special hospitalization after ACL reconstruction.



**Fig. 1.** Flowchart showing the process of participant recruitment and data analysis. ACL: anterior cruciate ligament; BTB: bone-patellar tendon-bone; STG: semitendinosus/gracilis.

**Table 1.** Return to preinjury activity level and secondary anterior cruciate ligament injury

|  | BTB             | STG             |
|--|-----------------|-----------------|
|  | n=12            | n=33            |
| Return to preinjury activity level (%)                             |                 |                 |
| Return   | 9 (75.0)        | 26 (78.8)       |
| No return  | 3 (25.0)        | 7 (21.2)        |
| Secondary ACL injury (%)   |                 |                 |
| None   | 10 (83.3)       | 27 (81.8)       |
| Ipsilateral  | 1 (8.3)         | 4 (12.1)        |
| Contralateral  | 1 (8.3)         | 2 (6.0)         |
|  | n=9             | n=26            |
| Time required for return to preinjury activity level; months (IQR) | 10.0 (8.0–13.5) | 10.0 (8.0–12.0) |

BTB: bone-patellar tendon-bone; STG: semitendinosus/gracilis; ACL: anterior cruciate ligament; IQR: interquartile range.

**Table 2.** Performance level at the end of comprehensive rehabilitation with hospitalization

|             | Return to preinjury activity level | No return to preinjury activity level |
|-------------|------------------------------------|---------------------------------------|
|             | n=9                                | n=3                                   |
| BTB; % ± SD | 103.9 ± 15.8                       | 90.0 ± 30.0                           |
|             | n=26                               | n=7                                   |
| STG; % ± SD | 97.1 ± 18.9                        | 76.7 ± 24.2                           |

BTB: bone-patellar tendon-bone; STG: semitendinosus/gracilis; SD: standard deviation.

All athletes in this study underwent the comprehensive and intensive inpatient approach for at least two weeks. Of those who received a BTB graft, 75% achieved RPAL; 78.8% of STG-graft treated athletes achieved RPAL. These RPAL results were better than 64.6% RPAL (the results included both BTB and STG) reported by a previous Japanese study<sup>13</sup>). The secondary ACL injury rates were 16% (8% ipsilateral, 8% contralateral) for BTB and 18% (6% ipsilateral, 12% contralateral) for STG graft patients. A systematic review and meta-analysis of secondary ACL injury rates reported that re-rupture after return to competition occurred ipsilaterally in 8% and contralaterally in 12% of patients<sup>14</sup>). Another study comparing outcomes of graft techniques at two years post-reconstruction reported a re-rupture rate of 28.2% for BTB and 30.3% for STG grafts<sup>15</sup>). Thus, our results showed comparable or lower re-rupture rates than those reported by previous studies. Although it is not possible to derive a definitive conclusion based purely on comparison with previous studies, the comprehensive and intensive inpatient approach shows promise and may be effective in improving postoperative outcomes after ACL reconstruction. The characteristics of this comprehensive and intensive approach include rehabilitation with hospitalization and psychological and nutritional support combined with exercise and physical therapy. In recent years, the frequency of ACL reconstruction using ambulatory surgery has increased in the United States and elsewhere, and the proportion of inpatient rehabilitation has decreased<sup>16</sup>). A review of supervised rehabilitation after ACL reconstruction surgery reported that, while minimally supervised rehabilitation can be as effective as highly supervised rehabilitation, highly supervised rehabilitation can also result in a higher degree of recovery compared to preinjury levels<sup>17</sup>). We found that it was easier for specialists to control the amount of load on the surgical wounds and provide intensive rehabilitation at a higher frequency during inpatient rehabilitation.

Psychological responses before ACL reconstruction surgery and during early postoperative rehabilitation have been observed to influence the return to sports<sup>18</sup>). Top athletes report more severe symptoms of depression than recreational-level athletes and are more likely to suffer from depressive symptoms for 6 weeks postoperatively<sup>19</sup>). These findings suggest that psychological interventions play an important role in postoperative ACL recovery. For example, we present a case study of psychological support at our facility. A female athlete expressed anxiety regarding her return to athletics and the risk of recurrent injury. By providing her with an approach to relieve anxiety by understanding her psychological state, she was able to think positively about her future and set goals, which itself accelerated recovery.

Nutritional management was included within the rehabilitation program after the suggestion that it promoted recovery in the case study of a rugby player recovering from an ACL injury<sup>20</sup>). At our institute, we adjusted for the increase in body fat percentage due to decreased activity after surgery. Regular body composition measurements and modifying nutritional intake according to activity level shortened athletes' recovery time and assisted the return to competition; the changes in weight were minimal and did not prevent athletes from returning to play. The fact that more athletes in this study were able to achieve RPAL, and the secondary ACL injury rate was slightly lower than that of most studies suggests that supplemental psychological and nutritional interventions may have been helpful.

When evaluating the postoperative rehabilitation approach to an ACL injury, the influence of different graft types should not be ignored. A previous study also compared postoperative outcomes between BTB and STG type grafts and reported a higher rate of RPAL with BTB than that with STG; however, the rate of contralateral re-rupture was higher for BTB<sup>11</sup>). However, we observed no association between the graft type and the percentage of athletes achieving RPAL or the secondary ACL injury rate. The duration required for the return to sports was  $9.7 \pm 2$  months for BTB graft recipients and  $10.7 \pm 2$  months for STG graft recipients<sup>21</sup>). Studies have reported that many patients with ACL injury resume sports without achieving RPAL<sup>22</sup>). The similarity between the timing of return to sports in the previous study and the timing of RPAL in the present study suggests that athletes may have returned to sports in a better condition compared to the previous study. In the present study, the comprehensive and intensive rehabilitative approach yielded comparable or better recovery for BTB and STG. Stańczak et al. also found comparable functional outcomes for both BTB and STG graft types at the one-year postoperative follow-up, when knee function, knee pain, activity level, and degree of knee injury and osteoarthritis were investigated<sup>23</sup>). The inclusion of psychological and nutritional support may have contributed to positive results, as it led to multifaceted assessment of each individual's condition and enabled us to provide rehabilitation tailored to the needs of the graft type and the individual. Subjective performance post-rehabilitation was comparable for both BTB and STG grafting in athletes who achieved RPAL and those who did not. However, the percentage scores for subjective performance were approximately 20% lower for athletes with STG grafts who had not achieved RPAL versus those who achieved RPAL. Although there was no difference in the time interval between the postoperative period and the start of inpatient rehabilitation and the time point at which inpatient rehabilitation was initiated after surgery for BTB and STG grafting, extending the duration of rehabilitation until subjective performance levels increase might allow more athletes to achieve RPAL after STG. The athlete's subjective perception of performance could be considered when determining the length of the inpatient rehabilitation program after STG grafts.

In conclusion, irrespective of the graft type used, many athletes indicated that they achieved RPAL, although these were the results of a subjective assessment. This suggests that a comprehensive approach to rehabilitation may be effective in improving performance after ACL reconstruction. The limitations of this study include the fact that the comprehensive approach was an individualized program and not standardized; thus, the aspect of the approach that affected postoperative outcomes is unclear, and objective data on postoperative performance are not available. In the future, specific approaches should be further examined, and their effectiveness should be supported by objective evaluation.

### *Conflict of interest*

The authors declare no conflicts of interest associated with this study.

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