Comparing the muscle strength recovery between Knee Rehabilitation with Hybrid Assistive Limb and Conventional Rehabilitation after ACL reconstruction

Yuichiro Soma[1,2], Hirotaka Mutsuzaki[3,4], Tomokazu Yoshioka[1,2], Shigeki Kubota[5], Koichi Iwai[6], Yukiyo Shimizu[7], Akihiro Kanamori[1], Masashi Yamazaki[1]
[1]Department of Orthopaedic Surgery, Faculty of Medicine, University of Tsukuba, Japan,
[2]Division of Regenerative Medicine for Musculoskeletal System, Faculty of Medicine, University of Tsukuba, Japan
[3]Center for Medical Sciences, Ibaraki Prefectural University of Health Sciences Hospital, Japan
[4]Department of Orthopaedic Surgery, Ibaraki Prefectural University of Health Sciences Hospital, Japan
[5]Department of Orthopaedic Surgery, Ibaraki Prefectural University of Health Sciences, Japan
[6]Ibaraki Prefectural University of Health Sciences, Japan
[7]Department of Rehabilitation Medicine, Faculty of Medicine, University of Tsukuba, Japan
ysoma@md.tsukuba.ac.jp

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INTRODUCTION: Anterior cruciate ligament (ACL) injury is the most common occurrence in sports injuries. ACL reconstruction is performed for patients with an ACL injury to restore knee joint stability, improve self-reported function, and facilitate a safe return to sports participation. A physical therapist can use several treatment modalities during postoperative rehabilitation. Several studies have suggested that postoperative rehabilitation should include neuromuscular training to improve outcomes after surgery. A single-joint hybrid assistive limb (HAL-SJ) has been developed for use in rehabilitation training. Our research delved into the viability and safety of the knee HAL-SJ training, along with its potential to enhance functional outcomes following ACL reconstruction. A preceding study suggested the safety of knee HAL-SJ training as a rehabilitative approach for individuals with ACL injuries, with potential contributions to enhanced muscle activity efficiency. To ascertain the impact of HAL on muscle recovery, in this study, we conducted a statistical comparison with a control group. The employment of a two-way analysis of variance revealed a notable interaction effect, leading us to employ a t-test for analyzing the isokinetic muscle strength and ratios of the hamstrings and quadriceps muscle groups (H-Q ratio) outcomes within each group.

METHODS: The study cohort comprised 18 participants (ten males, eight females; mean age: 23.4 ± 7.0 years; height: 168.0 ± 8.9 cm; weight: 66.7 ± 13.0 kg) who had undergone arthroscopic ACL reconstruction employing soft tissue graft materials (anatomic single-bundle: n = 13; anatomic double-bundle: n = 5). The control group encompassed 9 patients (three males, three females; mean age: 20.2 ± 1.7 years; height: 162.7 ± 10.0 cm; weight: 64.9 ± 10.7 kg) who had also undergone arthroscopic ACL reconstruction with identical graft materials, comprising anatomic single-bundle (n = 9) and anatomic double-bundle (n = 0) cases. The initiation of knee HAL-SJ training took place 18 weeks post ACL reconstruction and was conducted on a weekly basis, amounting to a total of three sessions. Each session comprised five sets of knee HAL single-joint training exercises targeting knee extension and flexion. Both the HAL and control groups were assessed an isokinetic muscle strength at postoperative week 17 and 21 using an isokinetic dynamometer (Biodex System III) across three distinct velocities: 60°/s, 180°/s, and 300°/s. The Limb Symmetry Index (LSI) was computed to quantify the disparity in muscle strength between the injured and non-injured sides (injured/non-injured × 100%). Paired-samples t-tests were employed to assess differences in LSI between pre- and post-assessments within both groups. Similarly, the rate of change of the LSI underwent calculation and was subjected to the t-test. Independent t-tests were employed to ascertain the discrepancies in muscle strength outcomes between the HAL group and the Control group for each measurement (Pre-assessment, Post-assessment, H-Q ratio and the rate of change of the LSI). Additionally, the two-way analysis of variance was utilized to compare LSI results between pre- and post-assessments within both the HAL and control groups. Ethical approval for the study was granted by the ethics committees of Tsukuba University Faculty of Medicine (approval number TCRB18-077). Prior to enrollment, all participants provided written informed consent.

RESULTS: In the HAL group, the LSI displayed a significant increase post-HAL intervention for peak extension torque across all velocities (Fig 1A) and for peak flexion torque at 60°/s and 300°/s (Fig 1B). Conversely, within the Control group, the LSI did not exhibit a significant increase post-assessment for peak extension and flexion torque across all velocities (Fig 2A,B). The independent t-tests disclosed a notable effect size, particularly for the post-peak flexion torque at 300°/s ($p = .052$; $d = 0.865$). Moreover, the rate of change of the LSI for peak extension torque at 300°/s and for all peak flexion torque exhibited a medium to large effect size (extension at 300°/s; $d = 0.728$, flexion at 60°/s; $d = 0.464$, 180°/s; $d = 0.552$). Specifically, the rate of change of the LSI for peak flexion torque at 300°/s demonstrated a significant difference ($p = .023$; $d = 1.031$), and the H-Q ratio at 300°/s also exhibited significant differences in post-assessments ($p = .043$; $d = 0.905$) (Fig 3B). In the context of a two-way analysis of variance, the peak flexion torque at 300°/s yielded significant differences (Interaction effects $p = .014$, $\eta p2 = 0.245$, Power = 0.723).

DISCUSSION: Distinguishing between the recuperation resulting from ACL reconstruction and the influence of knee HAL-SJ training is of paramount importance. It is worth noting that the independent t-tests, conducted to compare isokinetic muscle strength between the HAL group and the Control group at all velocities, unveiled a substantial effect size, particularly for the post-peak flexion torque at 300°/s. Similarly, the two-way analysis of variance highlighted a noteworthy interaction effect for the peak flexion torque at 300°/s. Furthermore, a considerable effect size was observed for the rate of change of the LSI in both peak extension torque at 300°/s and flexion torque across all velocities. The inclusion of paired-samples t-test outcomes for the LSI in the Control group, where differences were not significant, and in the HAL group, where they were significant except at 180°/s, enriches the contextual understanding. These observations serve to emphasize the influence of HAL intervention within the group analysis.

SIGNIFICANCE/CLINICAL RELEVANCE: Knee HAL-SJ training has the potential to optimize muscle activities, resulting in differences in muscle strength compared to the control group at each velocity of isokinetic muscle strength testing. These results indicate a tendency for differences in highly accelerated movements.

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Figure 1 Limb symmetry index (LSI) for the HAL group at (A) peak extension torque and (B) peak flexion torque at each velocity

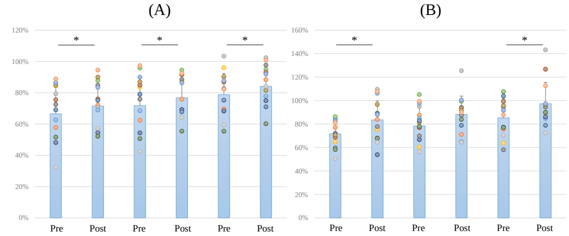

Figure 2 LSI for the Control group at (A) peak extension torque and (B) peak flexion torque at each velocity

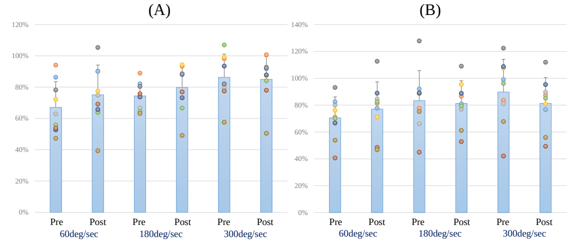

Figure 3 Independent t-tests comparing Hamstring/Quadriceps ratio between the HAL and Control groups. Pre (A)- and Post (B)-assessments