Psychological readiness at 9 months after anterior cruciate ligament reconstruction – which factors affect?

ABSTRACT

Objective: To investigate the association of psychological readiness at 9 months after anterior cruciate ligament reconstruction (ACLR) with knee strength and range-of-motion (ROM) at 3 and 9 months postoperatively.

Design: Retrospective cohort study.

Setting: Private orthopedic hospital.

Participants: Seventy-eight patients after ACLR.

Main Outcomes Measures: The participants completed the anterior cruciate ligament-return to sport after injury (ACL-RSI) scale as an assessment of psychological readiness at 9 months after ACLR. Isometric and isokinetic quadriceps and hamstring strength were measured by a dynamometer at 3 and 9 months postoperatively. Knee extension and flexion ROM were measured in 5° increments with a standard goniometer at 3 and 9 months postoperatively.

Results: Univariate regression analysis showed that age, limb symmetry index (LSI) of quadriceps strength at 3 and 9 months, and knee extension ROM deficit (> 5°) at 3 and 9 months were associated with ACL-RSI scores at 9 months ($P < 0.05$). Age and LSI of quadriceps strength at 3 months remained significant predictors of ACL-RSI scores at 9 months in multiple regression analysis ($R^2 = 0.20$, $P < 0.001$).

Conclusions: Early improvements in quadriceps strength after ACLR may have a positive impact on psychological readiness at 9 months postoperatively.

KEYWORDS

anterior cruciate ligament reconstruction, psychological readiness, quadriceps strength, return to sport

INTRODUCTION

The return-to-sport (RTS) rate after anterior cruciate ligament reconstruction (ACLR) is reported to be approximately 80% for any sport, whereas the rate decreases to 53–65% for a return to the same sports level as before ACL injury (C. L. Ardern, Taylor, Feller, & Webster, 2014; Lindanger, Strand, Molster, Solheim, & Inderhaug, 2019). In addition to age, sex and hopping performance, psychological readiness has received attention as a factor related to RTS after ACLR to the same sports level as before ACL injury (C. L. Ardern, et al., 2014).

The anterior cruciate ligament-return to sport after injury (ACL-RSI) scale is used to assess psychological readiness after ACLR (Webster, Feller, & Lambros, 2008). The ACL-RSI was developed as a measure of psychological readiness to RTS after ACL injury or ACLR (Webster, et al., 2008). The score covers three domains: emotions, confidence in performance, and risk appraisal (Webster, et al., 2008). The ACL-RSI predicted RTS at the same sports level as before ACL injury (Webster & Feller, 2020). However, it was not clear what approaches would be useful for improving ACL-RSI.

The biopsychosocial model shows that there are social, physical and functional factors that influence psychological responses (Clare L. Ardern, Kvist, & Webster, 2016; Wiese-bjornstal, Smith, Shaffer, & Morrey, 1998). Knee muscle weakness and knee range-of-motion (ROM) deficit often occur after ACLR, which may affect the ACL-RSI (Hunnicutt, et al., 2021; Petersen, Taheri, Forkel, & Zantop, 2014). However, there have been few studies on the physical factors associated with the ACL-RSI, and no consensus has been reached (Aizawa, et al., 2020; Lepley, Pietrosimone, & Cormier, 2018; O'Connor, King, Richter, Webster, & Falvey, 2020; Webster, Nagelli, Hewett, & Feller, 2018). Some studies have reported that there was no association between the ACL-RSI and quadriceps

or hamstring strength at 6 to 9 months after ACLR (Aizawa, et al., 2020; O'Connor, et al., 2020). On the other hand, another study reported that the smaller the difference in quadriceps strength between the involved limb and uninvolved limb, the better the ACL-RSI at 6 to 8 months after ACLR (Lepley, et al., 2018). These reports examined relationships between physical factors and ACL-RSI scores at RTS and did not examine relationships between early postoperative physical factors and ACL-RSI scores at RTS. Soccer players with severe musculoskeletal disorders were 2–7 times more likely to develop psychological disorders within 12 months than those without (Kilic, et al., 2018). In addition, muscle strength recovery has a positive effect on psychological readiness (Podlog, Banham, Wadey, & Hannon, 2015). In the early postoperative period after ACLR, patients often have residual knee muscle weakness and ROM deficits that may have an impact on subsequent psychological readiness. However, there have been no reports on associations between knee strength and ROM during the early postoperative period and psychological readiness at 9 months after ACLR.

The purpose of this study was to investigate the associations between knee muscle strength and ROM at 3 and 9 months and psychological readiness at 9 months after ACLR. We hypothesized that knee muscle strength and ROM at 3 months postoperatively would be associated with psychological readiness at 9 months after ACLR.

MATERIALS AND METHODS

Participants

Participants were enrolled from patients who underwent unilateral primary ACLR surgery at an orthopedic hospital between November 2017 and November 2020. Patients were excluded if they did not participate in a sport with a modified Tegner activity score ≥ 6 prior to ACL injury, reported a history of lower extremity surgery other than ACLR, had a time interval between ACL injury and ACLR of more than 1 year, had cartilage injury that required additional surgery. Patients who underwent concomitant meniscus surgery, whether partial meniscectomy or meniscal repair, were included. Furthermore, of the 122 eligible patients, two patients were excluded because of a second ACL injury within 9 months postoperatively. Finally, seventy-eight patients with all available data were included in this study (Fig. 1). The mean age of the patients was 22.9 ± 10.2 years, and 54% were female (Table 1).

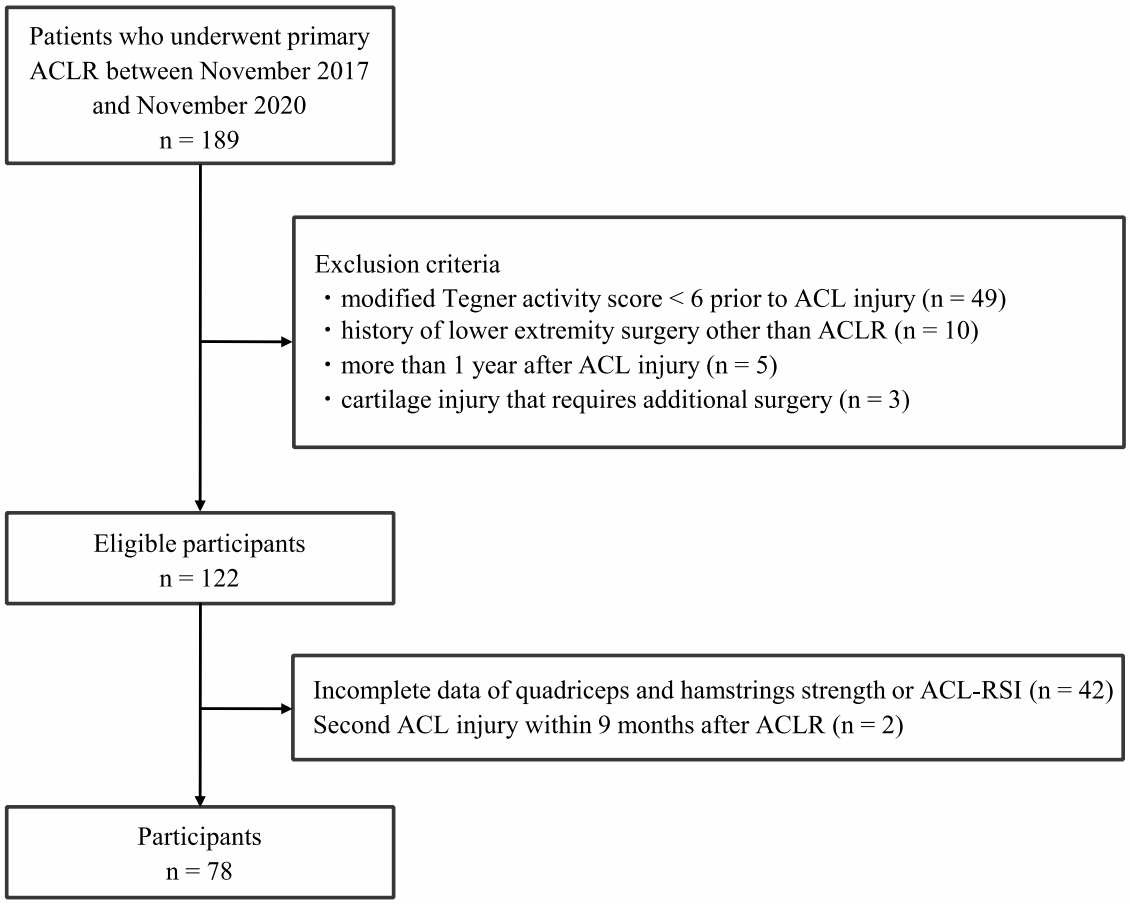

Fig. 1. Flowchart of the study patients

ACLR, anterior cruciate ligament reconstruction; ACL-RSI, anterior cruciate ligament-return to sport after injury

Table 1

Characteristics of the participants

Characteristics	Values
Age, years	22.9 ± 10.2
Sex (female), n (%)	42 (54%)
Preinjury modified Tegner activity score	7.1 ± 0.79
Time interval between injury to surgery, days	77.2 ± 64.7
Meniscus procedure (yes), n (%)	35 (45%)
ACL-RSI scale score at 9 months	64.2 ± 22.0
LSI of quadriceps strength at 3 months, %	71.7 ± 20.8
LSI of hamstring strength at 3 months, %	51.9 ± 19.9
LSI of quadriceps strength at 9 months, %	84.2 ± 15.9
LSI of hamstring strength at 9 months, %	90.1 ± 15.7
Knee extension ROM deficit at 3 months (yes), n (%)	4 (5%)
Knee flexion ROM deficit at 3 months (yes), n (%)	13 (17%)
Knee extension ROM deficit at 9 months (yes), n (%)	2 (3%)
Knee flexion ROM deficit at 9 months (yes), n (%)	0 (0%)

ACL-RSI, anterior cruciate ligament-return to sport after injury; LSI, limb symmetry index; ROM, range-of-motion.

Data are shown as the mean ± standard deviation or number (%).

All ACLR surgeries were performed using hamstring tendon autografts. All the patients completed a standardized rehabilitation protocol in which they started running at 12 weeks and engaging in sports-specific drills without any restrictions after 6 months. All participants signed informed consent forms, and this study was approved by the Institutional Review Board of XXX (Approval number: 21-66).

Assessment of psychological readiness

Psychological readiness at 9 months was assessed using the Japanese version of the ACL-RSI scale. This scale was originally designed to assess psychological readiness to RTS after ACLR or ACL injury, and consists of 12 items (Webster, et al., 2008). The 12 items are categorized into three domains: emotions, confidence in performance, and risk appraisal. The total score can range from 0 to 100, with higher scores indicating a better state of psychological readiness. The Japanese version of the ACL-RSI scale used in the study has been reported to have high validity (Hirohata, et al., 2020).

Knee strength testing

Quadriceps and hamstring strength were assessed using a dynamometer (Biodex System 3; Biodex Medical Systems, Inc., Shirley, NY) at 3 and 9 months after ACLR. Isometric knee extension and flexion torque were measured at 90° of knee flexion at 3 months after ACLR to protect the graft from quadriceps loading (Yasuda & Sasaki, 1987). Isokinetic knee extension and flexion torque were measured at a velocity of 60°/s at 9 months after ACLR. The limb symmetry index (LSI) of the peak torque was calculated as the percentage in the involved limb relative to that in the uninvolved limb.

Range-of-motion

Knee extension and flexion ROM were measured in 5° increments with a standard goniometer at 3 and 9 months postoperatively. Knee ROM deficits were defined as a knee extension deficit of 5° or more and knee flexion deficit of 15° or more compared with the uninvolved knee (Nwachukwu, et al., 2011).

Statistical analysis

Statistical analyses were performed using JMP® Pro 15 (SAS Institute Inc., Cary, NC, USA). Univariate regression analysis was used to examine associations between various predictor variables and ACL-RSI scores. The independent variables were age, sex (0: male, 1: female), time interval between injury and surgery, meniscus procedure (0: none, 1: partial menisectomy or meniscal repair), LSI of quadriceps and hamstring strength at 3 and 9 months, and knee extension and flexion ROM deficits at 3 and 9 months (0: none, 1: deficits). Factors with $P < 0.10$ in the univariate regression analysis were used as candidate variables in the subsequent multiple regression analysis. Multicollinearity was confirmed using variance inflation factor (VIF) (≥ 5). The selection variable criterion of multiple regression analysis was backward stepwise based on the minimum Akaike's information criteria (AIC). The statistical significance level was set at $P < 0.05$.

RESULTS

The mean ACL-RSI score at 9 months after ACLR was 64.2 ± 22.0 (Table 1). Of the 78 patients, 18 patients (23%) were allowed to return to sports between 6 and 9 months, and 51 patients (65%) were allowed to return to sports at 9 months postoperatively. Univariate regression analysis showed that age, LSI of quadriceps strength at 3 and 9 months, and knee extension ROM deficit at 3 and 9 months predicted ACL-RSI scores at 9 months ($P < 0.05$) (Table 2 and Fig. 2). The results indicated that younger age, a larger LSI of quadriceps strength and no restriction of knee extension ROM were associated with better ACL-RSI scores.

According to the results of univariate regression analysis, age, time interval between injury to surgery, LSI of quadriceps strength at 3 and 9 months and knee extension ROM deficit at 3 and 9 months were first entered as the candidate variables in the multiple regression model. As a result of the stepwise analysis, age and the LSI of quadriceps strength at 3 months remained significant predictors of ACL-RSI scores at 9 months ($R^2 = 0.20$, $P < 0.001$) (Table 3).

Table 2

Univariate regression analysis to examine the association between independent variables and ACL-RSI scores

Independent variables	B (95% CI)	Standardized β	*P* value
Age, years	−0.79 (−1.25 to −0.33)	−0.37	**0.001**
Sex (male: 0, female: 1)	−0.82 (−5.86 to 4.21)	−0.04	0.746
Time interval between injury to surgery, days	−0.07 (−0.14 to 0.01)	−0.20	0.087
Meniscus procedure (no: 0, yes: 1)	−0.40 (−5.45 to 4.66)	−0.02	0.876
LSI of quadriceps strength at 3 months, %	25.59 (2.13 to 49.04)	0.24	**0.033**
LSI of hamstring strength at 3 months, %	12.69 (−12.44 to 37.81)	0.11	0.318
LSI of quadriceps strength at 9 months, %	42.92 (12.93 to 72.90)	0.31	**0.006**
LSI of hamstring strength at 9 months, %	−16.27 (−48.00 to 15.45)	−0.12	0.310
Knee extension ROM deficit at 3 months (no: 0, yes: 1)	−11.62 (−22.70 to −0.54)	−0.23	**0.040**
Knee flexion ROM deficit at 3 months (no: 0, yes: 1)	1.04 (−5.70 to 7.78)	0.04	0.759
Knee extension ROM deficit at 9 months (no: 0, yes: 1)	−20.30 (−35.51 to −5.09)	−0.29	**0.010**
Knee flexion ROM deficit at 9 months (no: 0, yes: 1)	–	–	–

Bold indicates statistical significance ($P < 0.05$)

ACL-RSI, anterior cruciate ligament-return to sport after injury; LSI, limb symmetry index; ROM, range-of-motion.

B indicates the partial regression coefficient.

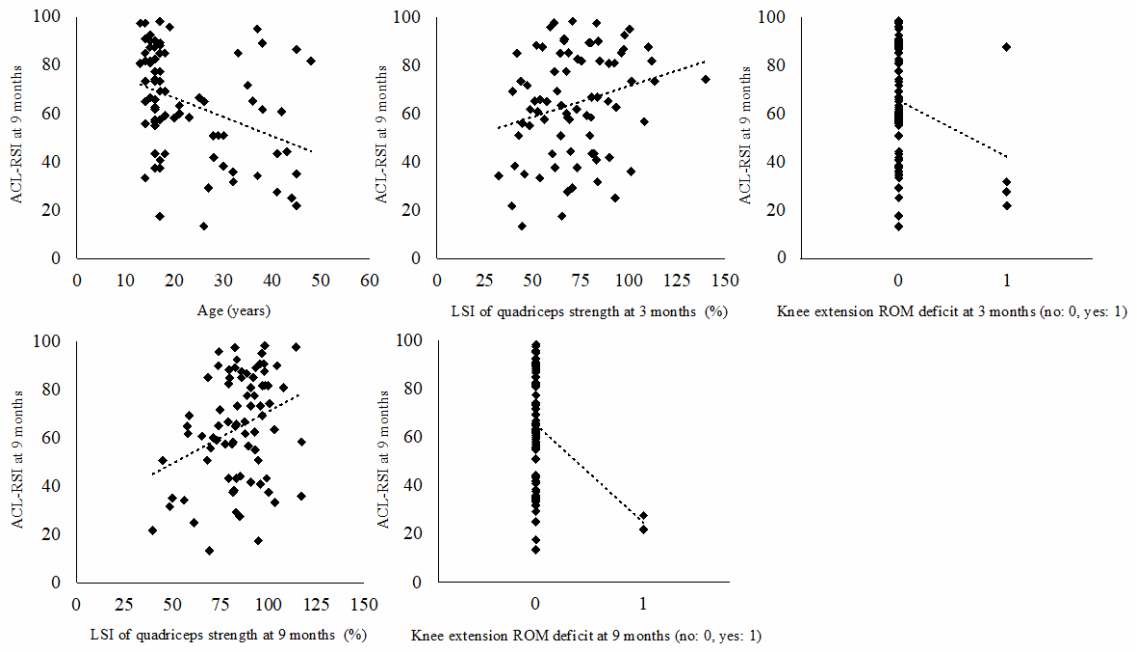

Fig. 2. Associations between ACL-RSI scores and age, LSI of quadriceps strength at 3 and 9 months, and knee extension ROM deficit at 3 and 9 months

ACL-RSI, anterior cruciate ligament-return to sport after injury; LSI, limb symmetry index; ROM, range-of-motion.

Table 3

Multiple regression analysis to examine the associations of independent variables with ACL-RSI scores

Independent variables	B (95% CI)	Standardized β	*P* value	VIF
Age, years	−0.66 (−1.12 to −0.20)	−0.31	**0.006**	1.07
LSI of quadriceps strength at 3 months, %	23.44 (1.46 to 45.43)	0.22	**0.037**	1.01
Knee extension ROM deficit at 3 months (no: 0, yes: 1)	−8.38 (−19.02 to 2.25)	−0.17	0.121	1.07

ACL-RSI, anterior cruciate ligament-return to sport after injury; LSI, limb symmetry index; ROM, range-of-motion.

B indicates the partial regression coefficient.

DISCUSSION

In this study, we investigated the associations of ACL-RSI scores at 9 months after ACLR with knee strength and ROM at 3 and 9 months postoperatively. The results showed that LSI of quadriceps strength at 3 and 9 months and knee extension ROM deficit at 3 and 9 months were associated with ACL-RSI scores at 9 months after ACLR. In the multiple regression analysis, the LSI of quadriceps strength at 3 months remained a significant predictor of ACL-RSI scores at 9 months. These results support the hypothesis that knee strength and ROM at 3 months postoperatively would be associated with psychological readiness at 9 months after ACLR.

The ACL-RSI score at 9 months after ACLR was 64.2 ± 22.0 in the present study, which is comparable to the range of 65.0–67.2 at 6–12 months after ACLR reported in previous studies (Aizawa, et al., 2020; Lepley, et al., 2018; Webster, et al., 2018). The results of the univariate regression analyses showed that the LSI of quadriceps strength and knee extension ROM deficit at 3 and 9 months postoperatively were associated with ACL-RSI scores at 9 months after ACLR. In the biopsychosocial model for RTS after ACL injury, physical factors, psychological factors, social/contextual factors, and functional performance were shown to be related to each other (Clare L. Ardern, et al., 2016), which is consistent with the present results that the quadriceps strength and knee extension ROM at 3 and 9 months postoperatively were associated with ACL-RSI scores at 9 months after ACLR. A previous study reported that quadriceps strength at RTS was associated with ACL-RSI scores at RTS after ACLR (Lepley, et al., 2018), but there have been no reports on the association between early postoperative quadriceps strength and ACL-RSI scores at RTS. Improvements in muscle strength during rehabilitation were shown to have a positive effect on psychological readiness (Podlog, et al., 2015).

Therefore, the acquisition of good quadriceps strength and knee extension ROM at 3 and 9 months after ACLR would have a positive effect on the recovery of psychological readiness.

The multiple regression analysis showed that the LSI of quadriceps strength at 3 months postoperatively and age were the predictors of ACL-RSI scores at 9 months after ACLR among early postoperative physical factors. These results suggest that early improvement in quadriceps strength is most important for the recovery of psychological readiness for RTS at 9 months, a common timing for RTS (Harris, et al., 2014). Positive effects of early postoperative rehabilitation after ACLR on psychological factors such as self-efficacy and fear of exercise have been reported (Chmielewski, et al., 2011). The LSI of quadriceps strength is often used as a criterion for running at approximately 3 months after ACLR (Rambaud, Ardern, Thoreux, Regnaux, & Edouard, 2018). Moreover, many studies have shown that deficits in quadriceps strength affect the interlimb asymmetry of knee kinematics and kinetics during a landing after ACLR (Ishida, et al., 2021; Ithurburn, Paterno, Ford, Hewett, & Schmitt, 2015; Palmieri-Smith & Lepley, 2015; Schmitt, Paterno, Ford, Myer, & Hewett, 2015). Recently, the interlimb asymmetry of knee kinetics during landing has been related to ACL-RSI scores (Peebles, Savla, Ollendick, & Queen, 2021). Therefore, deficits in quadriceps strength in the early postoperative period may affect the subsequent psychological readiness at 9 months as well as interlimb asymmetry of sports movements.

Younger age was also associated with ACL-RSI scores at 9 months after ACLR. These results were consistent with those of a large cohort study of 635 patients after ACLR (Webster, et al., 2018). In a systematic review of RTS after ACLR, the RTS rate was higher in younger patients than in older patients (C. L. Ardern, et al., 2014). One of

the reasons for the high rate of RTS in younger patients may be the good recovery of psychological readiness.

Concerning clinical application, the LSI of quadriceps strength and knee extension ROM deficit at 3 months postoperatively were associated with ACL-RSI scores at 9 months after ACLR. The ACL-RSI scores at RTS were related to the RTS rate to the same sports level as before ACL injury (Webster & Feller, 2020), and improvement in the ACL-RSI scores may lead to a higher RTS rate. Although both the present and previous studies consistently showed ACL-RSI scores of approximately 65 at 6–12 months after ACLR (Aizawa, et al., 2020; Lepley, et al., 2018; Webster, et al., 2018), interventions to improve psychological readiness are not well understood. The present findings suggest the possibility that small deficits in quadriceps strength and normal knee extension ROM at 3 months can lead to good psychological readiness at 9 months, which is a common time for RTS after ACLR (Harris, et al., 2014). Considering the interactivity of physical, psychological, and social factors in the biopsychosocial model (Clare L. Ardern, et al., 2016), this possibility is not contradictory. Many studies have reported the importance of quadriceps strength for RTS at the preinjury level, prevention of second ACL injury, good patient-reported outcomes and symmetrical motion patterns (Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016; Ishida, et al., 2021; Ithurburn, et al., 2015; Kitaguchi, et al., 2020; Kyritsis, Bahr, Landreau, Miladi, & Witvrouw, 2016; Palmieri-Smith & Lepley, 2015; Schmitt, et al., 2015; Zwolski, et al., 2015). However, there have been few reports on the importance of quadriceps strength in the early postoperative period (Rambaud, et al., 2018). The present findings suggest that early improvements in quadriceps strength after ACLR may positively impact psychological readiness at 9 months postoperatively and may lead to safe and valid RTS.

There are some limitations. First, this was a single-center study. Therefore, different types of graft and postoperative rehabilitation protocols may have different results from this study. Second, a higher ACL-RSI scores are not necessarily associated with better outcomes after ACLR. Although the ACL-RSI scores predict RTS to the same level as before ACL injury (Webster & Feller, 2020), patients with high ACL-RSI scores are more likely to suffer second ACL injury (Piussi, et al., 2021). Therefore, the interpretation of ACL-RSI scores needs to continue to be examined. Finally, the exact timing and level of RTS were not investigated. Further studies are needed to investigate the associations of early recovery of quadriceps strength and psychological readiness for RTS considering the timing and level of RTS.

CONCLUSIONS

The LSI of quadriceps strength and knee extension ROM deficit at 3 and 9 months postoperatively and age were associated with ACL-RSI scores at 9 months after ACLR. Among these physical factors, the LSI of quadriceps strength at 3 months postoperatively had a particularly strong effect. The acquisition of good quadriceps strength and knee extension ROM at 3 months postoperatively may improve ACL-RSI scores at 9 months after ACLR.

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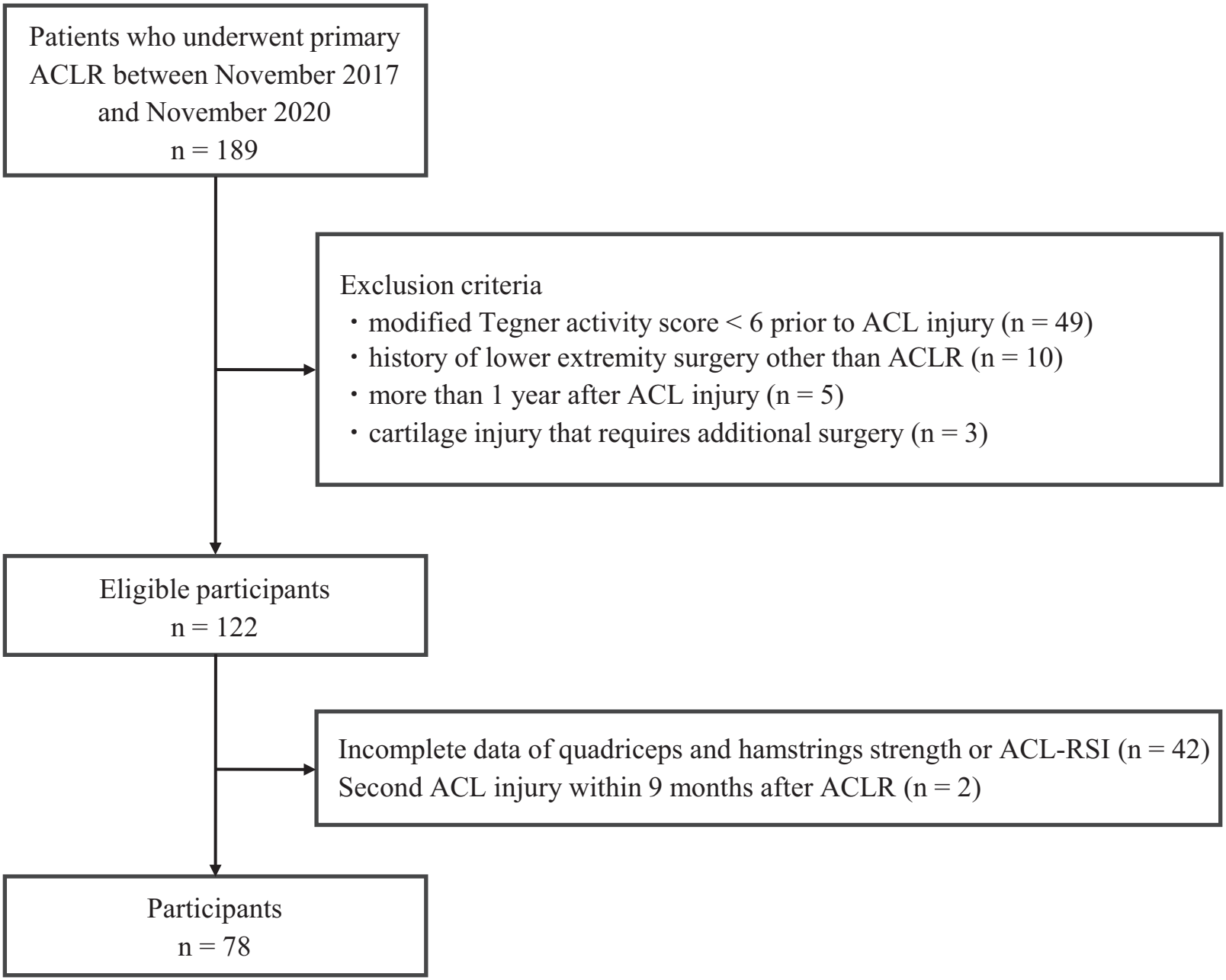
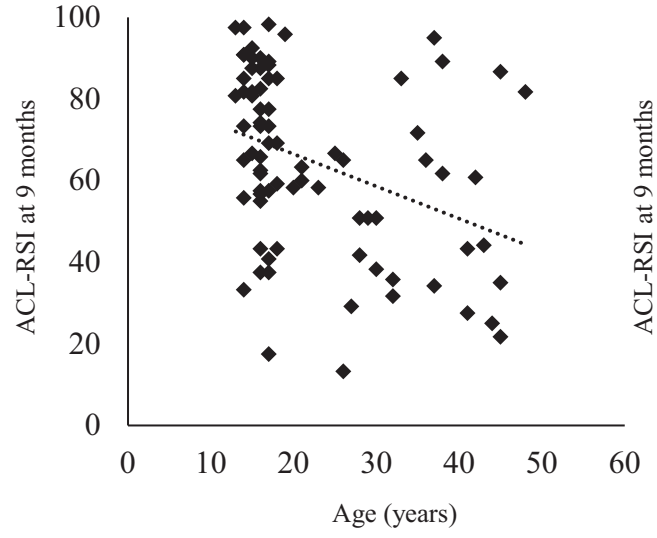
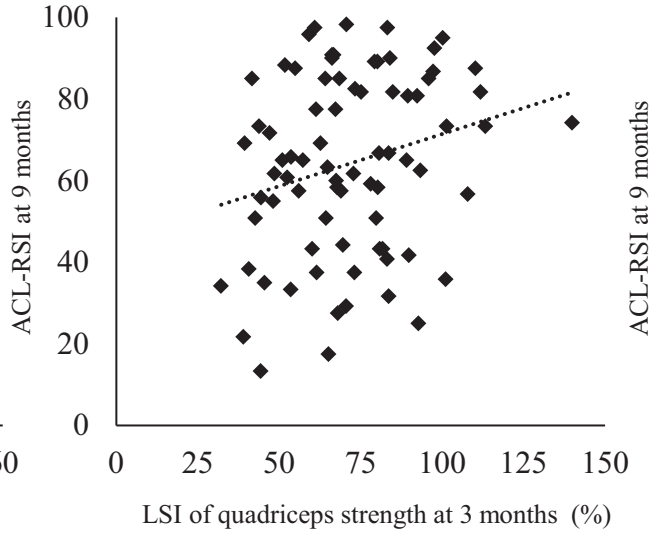
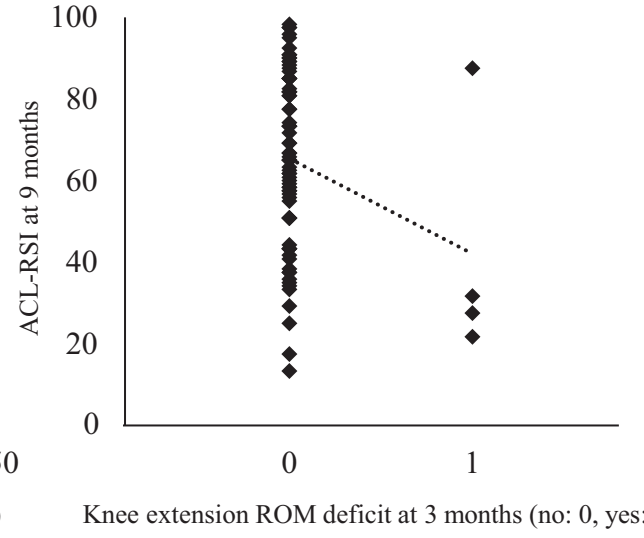
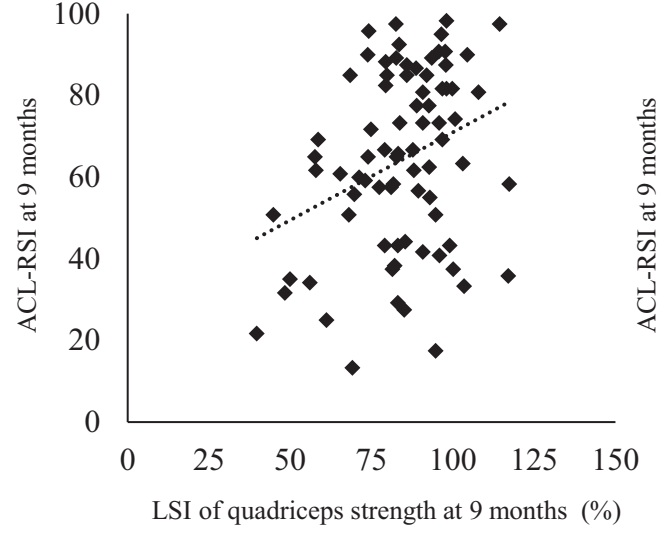
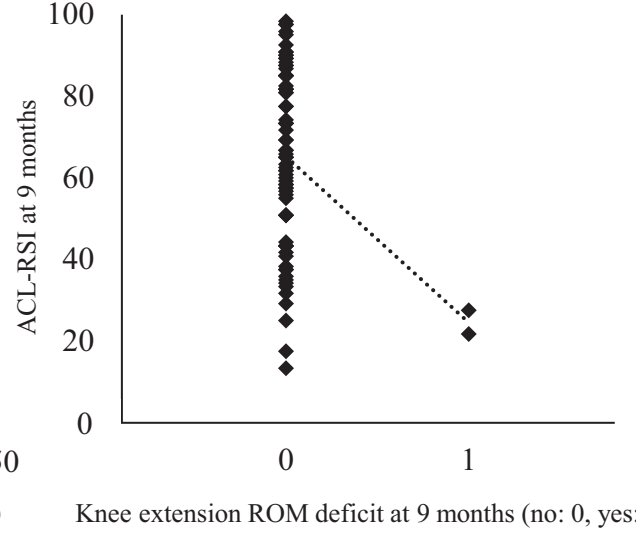

Patients who underwent primary ACLR between November 2017 and November 2020
n = 189
Exclusion criteria
・modified Tegner activity score < 6 prior to ACL injury (n = 49)
・history of lower extremity surgery other than ACLR (n = 10)
・more than 1 year after ACL injury (n = 5)
・cartilage injury that requires additional surgery (n = 3)
Eligible participants
n = 122
Incomplete data of quadriceps and hamstrings strength or ACL-RSI (n = 42)
Second ACL injury within 9 months after ACLR (n = 2)
Participants
n = 78


ACL-RSI at 9 months
100
80
60
40
20
0
0
10
20
30
40
50
60
Age (years)


ACL-RSI at 9 months
100
80
60
40
20
0
0
25
50
75
100
125
150
LSI of quadriceps strength at 3 months (%)


ACL-RSI at 9 months
100
80
60
40
20
0
0
1
Knee extension ROM deficit at 3 months (no: 0, yes: 1)


ACL-RSI at 9 months
100
80
60
40
20
0
0
25
50
75
100
125
150
LSI of quadriceps strength at 9 months (%)


ACL-RSI at 9 months
100
80
60
40
20
0
0
1
Knee extension ROM deficit at 9 months (no: 0, yes: 1)