Evaluation of Potential Factors Affecting Knee Function in Athletes Following Anterior Cruciate Ligament Reconstruction

Aynollah Naderi [a], Maryam Piry [b*]

a Department of Sport Science, Shahrood University of Technology, Shahrood, Semnan, Iran; **b** Department of Sports Injuries and Corrective Exercises, University Colleague Omran and Tosee, Hamadan, Iran

* ***Corresponding author***: Maryam Piry, Department of Sports Injuries and Corrective Exercises, University Colleague Omran and Tosee, Hamadan, Iran.
E-mail: piri.trainer@gmail.com

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Abstract

Introduction: A review of previous studies showed conflicting findings regarding the relationship between athlete-related factors and knee function following ACL reconstruction. Therefore, this study aimed to investigate the relationship between athlete-related factors and knee functional outcomes after ACL reconstruction. **Materials and Methods:** this study was a cross sectional study which carried out between October 2021 and March 2022 in the city of Sanandaj, Iran. The statistical sample of the study consisted of 43 athletes aged 19–43 years who underwent ACL reconstruction. For assessing Knee function the Osteoarthritis and Knee Injury Outcome Questionnaire (KOOS) was used. Athletes' characteristics such as weight, height, body mass index, and activity levels (recreational, competitive, and elite) were recorded using a researcher-made demographic questionnaire. The smoking habit, type of graft used, and affected foot were also assessed. **Results:** Age, body mass index, weight, and gender can predict various ACL reconstruction outcomes (P<0.05). Age predicted 29% of changes in symptoms and knee stiffness predicted 18% of changes in quality of life of athlete. Body mass index predicted 29% of changes in knee pain, 19% of changes in symptoms and knee stiffness, 17% of changes in ADL, 19% of changes in sports activity, and 13% of changes in athletes' quality of life (P<0.05). Weight only predicted 12% of changes in athletes' sports activities (P<0.05). Gender was able to predict 15% of changes in activities of daily livings, 13% of sports activity, and 12% of changes in athletes' quality of life (P<0.05). **Conclusion:** According to the findings of the present study, there is a relationship between age, weight, body mass index, and sex and knee functions following ACL reconstruction. Due to the limitations of this study, it is better to examine this issue longitudinally in future studies.

Keywords: ACL Reconstruction; Body Mass Index; Knee Outcome

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Introduction

A tear in the Anterior Cruciate Ligament (ACL) is a common knee injury often seen in sports. Such injuries may cause joint instability, muscle weakness, and pain (1) and can also be associated with damage to the meniscus and cartilage, leading to an increased risk of osteoarthritis (2, 3). To restore stability and function and prevent future osteoarthritis, athletes commonly undergo ACL Reconstruction (ACLR) (3, 4). After the surgery, a 6-month rehabilitation period is typically recommended to aid in recovery (5). Despite being considered effective, studies have revealed that the clinical outcomes of ACLR are not always satisfactory. A Meta-analysis study has concluded that only 37% of patients who have undergone ACLR achieve normal knee function, whereas a high prevalence of joint laxity has also been observed, with 31.8% testing positively for the Lachman test and 21.7% for the shift-axis test (6). Additionally, a lower percentage of patients (65-70%) can return to their pre-injury levels of physical activity after ACL reconstruction (7, 8). Moreover, ACLR does not appear to reduce the risk of developing osteoarthritis post-injury (9, 10). Because of the varying responses observed in patients Understanding the prognostic factors that contribute to successful outcome post-ACLR is semms to be crucial.

Both modifiable and non-modifiable factors influence functional outcomes following ACLR. Factors such as older age, being a smoker, muscle weakness, and high body mass index (BMI) have been associated with poorer functional outcomes after ACLR in Knee muscles and joint. High level of BMI, in particular, increase the compressive forces on the knee joint, thus increasing the risk of cartilage and meniscus damage and

negatively impacting knee function (11). Despite of different results in previous studies, some studies have indeed found an association between BMI and knee function in post-ACLR. Given the strong Vaso-constrictive effect of cigarettes on microcirculation, it is reasonable to suspect that smoking may have a negative impact on ACLR. In recent years, some studies about the effect of smoking on ACLR in different populations have shown conflicting results. Some studies have shown that smoking is a risk factor for functional knee outcomes (12) whereas others have reported that smoking does not have a negative effect on knee function after ACLR (1).

The effect of foot dominance on functional outcomes and return to exercise after ACLR has been evaluated too, and different results have been reported in this regard (1, 13). However, because of better motor and muscular performance in the superior leg after ACLR, knee performance is better than that in the non-superior leg (14). Foot dominance in studies is defined as the foot used to manipulate an object or guide movement, the foot used to stand during one-sided standing tasks, or the foot used to shoot a ball. However, a recent study found that "the foot used to kick the ball" corresponds 100% between the top leg reported by the individual and the foot used to shoot for men and women (15). As a result the aim of present study was to determine the relationship between age, gender, weight, BMI, type of connective tissue, level of exercise activity, affected limb, smoking status, and marital status of an athlete and the knee function and health-related quality of life as well as the rate of surgical resurgence and return to exercise after arthroscopic ACLR in athletes.

Materials and Methods

Participants

This study was approved by the Ethics Committee of Shahrood University of Technology under the ethical code IR.SHAHROODUT.REC.1401.013. Initially, the necessary research permits were secured from the relevant university, for data gathereing, a list of professional, amateur, and recreational athletes of both genders who had undergone ACL reconstruction, along with their contact details, was compiled by reaching out to physiotherapy, Occupational Therapy clinics, orthopedic centers, and the Department of Sports and Youth. Subsequently, the athletes were informed about the study and its procedures and provided with relevant instructions on how to complete the questionnaires. The statistical population for this study comprised 43 athletes who had undergone ACL reconstruction and were selected via the available sampling method based on their availability and volunteering participation. Inclusion and exclusion criteria were as follows: individuals who were older than 18 years, age with a history of unilateral ACL reconstruction, at least 6 months post-reconstruction, completed the rehabilitation programs, and filled the from an orthopedic surgeon to resume athletic activities were included and athlete who had previous ACL reconstruction failure, surgery, multi-ligament injury, meniscus or joint injury, confirmed osteoarthritis or patella-femoral instability, severe ankle sprain within the past six months, or rheumatologic disease or diabetes diagnosis were excluded from this study. Upon the athlete's agreement to participate, the informed consent form and the research-related questionnaires were forwarded to each participant online for completion. Initially, the participants signed the informed consent form.

Procedure

the participants demographic information including gender, age, height, weight, limb involvement (dominant/non-dominant), injury mechanism (contact/non-contact), exercise level (recreational/amateur/professional), type of tendon transplant (hamstring/patellar tendon), and concurrent meniscus surgery (yes/no) were recorded. In addition, details regarding the injury type, smoking habits, cartilage degeneration, time interval between injury and surgery, duration between surgery and initiation of rehabilitation, and re-operation rate were documented. The dominant leg was determined by inquiring about the leg used for shooting a ball and/or standing on one leg.

Knee function assessment was conducted online using the KOOS questionnaire. This questionnaire assesses the knee function through five subscales, which include symptoms and knee stiffness (7 items), knee pain (9 items), Activities of Daily Living (ADL) (17 items), performance during exercise (5 items), and quality of life (4 items). Each question in the questionnaire is rated on a 5-point Likert scale ranging from 0 to 4. The score for each subscale was computed by summing up the scores of individual questions, and the overall score was expressed as a percentage. A lower percentage score indicates a higher level of disability.

Statistical Analysis

The data were analyzed using SPSS version 21, and descriptive and inferential statistical methods were employed for data description and analysis. The Pearson correlation test was used to explore the relationship between the relevant variables and knee function with demographic factors. Furthermore, univariate regression analysis was performed to predict knee function based on demographic variables. All assessments were conducted at significance level of $P \leq 0.05$.

Results

Table 1 provides demographic data for the study participants, showing mean values for age (28.1±5.1 years), height (180.1±8.3 cm), weight (82.6±9.2 kg), and BMI) 25.4±1.9.

Table 2 shows the demographic characteristics of the participants. Key findings include that 60% were male, 58% were single, and 14% were smokers. About 74.5% of the injuries were non-contact, and 70% of ACL tears affected the dominant limb. Most surgeries (70%) used patellar tendon grafts, and 11.5% of the reconstructions required revision surgery.

Table 3 summarizes the regression analysis results predicting performance based on demographic factors. Age and Body Mass Index (BMI) emerged as significant predictors across various outcomes, including symptom severity and stiffness (P<0.01), daily living performance (P<0.01), and quality of life (P<0.01). Weight significantly influenced sports performance (P=0.01) and KOOS score (P=0.02), while gender impacted daily living performance (P=0.01) and sports performance (P=0.02). Other factors, such as the type of graft used, activity level, involved limb, smoking status, and marital status, showed no significant effects (P>0.05) on the dependent variables. Age and BMI emerged as the most critical factors affecting performance outcomes following anterior cruciate ligament reconstruction.

Table 1. Mean (SD) of participants' profiles

Variables	Mean (SD)	Min–Max
Age (years)	5.1 (28.1)	19–43
Height(m)	8.3 (180.1)	163–198
Weight(kg)	9.2 (82.6)	68–110
Body mass index (kg/m2)	1.9 (25.4)	21-31

Table 2. Demographic characteristics and general information about the participants

variables	Number (percentage)
Gender	Female=17 (40%) Male=26 (60%)
Activity level	Recreation=4 (9.3%) Amateur=1 (2.3%) Professional=38 (88.4%)
Marital status	Single=25 (58%) Married=18 (42%)
Smoking status	Yes= 6 (14%) No= 37 (86%)
Mechanism of injury	Contact=11 (25.5%) Non-Contact=32 (74.5%)
Affected limbs	Superior=30 (70%) Non-superior=13 (30%)
Dominant limb	Right=31 (72%) Left=12 (28%)
The type of connective tissue	Hamstring=13 (30%) Patella-femoral tendon=30 (70%)
Knee Looseness	Yes=18 (42%) No=25 (58%)
Damage associated	Yes=16 (37%) No=27 (63%)
Ankle Injury	Yes=19 (44%) No=24 (55.8%)
Revision surgery	Yes=5 (11.5%) No=38 (88.5%)

Discussion

This study aimed to investigate the relationship between athlete-related factors and functional outcomes after ACL reconstruction. The results showed that age, BMI, weight, and gender can predict different components of ACL reconstruction outcomes.

The studies conducted by Kowalchuk *et al.* (16), Abd Razak *et al.* (17), and Harput *et al.* (18) indicated that being overweight negatively affects knee function after ACL reconstruction in athletes at different time points. These studies suggested that excess weight puts excessive stress on the knee, leading to degenerative changes that negatively impact knee function. Harpot *et al.*'s (18) research also found that a higher BMI after ACL reconstruction led to decreased quadriceps muscle strength, lower performance capacity, and lower scores on the International Knee Documentation Committee (IKDC) scale. However; Simone *et al.*'s study reported a weak relationship between BMI and IKDC scores in patients undergoing ACL reconstruction, but they suggested that BMI was not a strong predictor for successful outcomes due to most participants having normal BMI levels during evaluation times ranging from 3.9 months to 301.2 months after ACL reconstruction. These findings highlight the significance of considering the evaluation time and the BMI levels of participants in investigating the relationship between BMI and knee function after ACL reconstruction.

Individuals with higher BMI may encounter challenges during ACL reconstruction rehabilitation due to unique biomechanical differences in muscle control during exercise. Previous studies have shown that body weight prediction for women undergoing ACL revision surgery is accurate only if their weight exceeds 1 standard deviation (19). Weight-bearing exercises are prescribed in the early stages of rehabilitation because they are safer for the healing process of transplantation than non-weight-bearing exercises (20). However, individuals with higher BMI may have weaker quadriceps muscles that struggle to control the knee joint during weight-bearing exercises, particularly within the required range of motion (21). This can negatively affect the knee treatment process after ACL reconstruction and increase the likelihood of osteoarthritis. The compression forces applied to the knee due to higher BMI also

Table 3. Results of regression analysis related to prediction of knee performance by demographic factors.

Dependent variable	Pain Severity	Symptoms and stiffness	Function of ADL	Sports Performance	Quality of life	KOOS Score
Age (years)	r2=0.03 *P*=0.12	r2=0.29 *P*=0.01	r2=0.04 *P*=0.09	r2=0.06 *P*=0.07	r2=0.18 *P*=0.01	r2=0.13 *P*=0.01
Weight (kg)	r2=0.04 *P*=0.1	r2=0.04 *P*=0.1	r2=0.01 *P*=0.4	r2=0.12 *P*=0.01	r2=0.01 *P*=0.2	r2=0.11 *P*=0.02
BMI (kg/m2)	r2=0.29 *P*= 0.001	r2=0.19 *P*=0.002	r2=0.17 *P*=0.003	r2=0.19 *P*=0.002	r2=0.13 *P*=0.01	r2=0.26 *P*=0.001
Gender (female=0 and male=1)	r2=0.02 *P*=0.2	r2=0.05 *P*=0.1	r2=0.15 *P*=0.01	r2=0.13 *P*=0.02	r2=0.12 *P*=0.02	r2=0.13 *P*=0.02
Connective tissue type (Patellar tendon=1 Hamstring=0)	r2=0.02 P=0.7	r2=0.02 *P*=0.6	r2=0.02 *P*=0.9	r2=0.03 *P*=0.5	r2=0.02 *P*=0.8	r2=0.02 *P*=0.7
Activity level (professional=1, amateur=0)	r2=0.04 *P*=0.2	r2=0.06 *P*=0.15	r2=0.03 *P*=0.6	r2=0.08 *P*=0.1	r2=0.07 *P*=0.1	r2=0.05 *P*=0.17
Involved limb (superior=1 and non-superior=0)	r2=0.03 *P*=0.6	r2=0.02 *P*=0.7	r2=0.01 *P*=0.9	r2=0.07 *P*=0.12	r2=0.02 *P*=0.8	r2=0.02 *P*=0.7
Smoking status (non-smoking=1 and smoker=0)	r2=0.02 *P*=0.6	r2=0.02 *P*=0.7	r2=0.02 *P*=0.8	r2=0.02 *P*=0.9	r2=0.02 *P*= 0.7	r2=0.02 *P*=0.6
Marital status	r2=0.03 *P*=0.6	r2=0.04 *P*=0.5	r2=0.03 *P*=0.7	r2=0.03 *P*=0.7	r2=0.05 *P*=0.5	r2=0.03 *P*=0.8

increase the likelihood of ACL re-injury and joint erosion (22). Health professionals should pay more attention to athletes' BMI levels before and after ACL reconstruction to develop individualized rehabilitation plans that address these challenges.

Smoking is one of the factors that can have negative effects on the outcomes of ACL reconstruction. However, the results of the current study showed that there was no significant relationship between smoking and knee function after ACL reconstruction. Karim *et al.* (23) compared the outcomes of ACL reconstruction between smokers and non-smokers. They showed that knee looseness and IKDC scores were weaker for smokers than non-smokers. In their study, the IKDC score was 60.8 in the smoker group and 70.1 in the non-smoker group. Kim *et al.* (24) also showed that the smoker group scored lower than the non-smoker group on the Lichlum and IKDC scale. The findings are likely because the number of smokers in the current study was very low (approximately 14 percent). Therefore, more extensive studies with more subjects are required to obtain more accurate results. The presence of cigarette smoke in blood vessels causes significant vasoconstrictive effect, which can reduce oxygen supply to tissues by reducing microcirculation. In addition, carbon monoxide interferes with oxygen transport by hemoglobin, and hydrogen cyanide reduces the oxidative metabolism required for cellular repair. Therefore, it is reasonable to suspect that smoking could have a negative impact on the outcomes of ACL reconstruction. In addition, people who use tobacco are at a higher risk of side effects such as infection and venous thromboembolism after ACL reconstruction (12).

Based on the information provided, it seems that the study by Uzun *et al.* (1) reported that foot dominance did have a significant effect on knee function after ACL reconstruction in terms of patient satisfaction and ACLR rates. However, this finding is not consistent with the results of the study by Boo *et al.* (13). The reasons for this discrepancy are unclear as both studies used similar outcome measures such as Tegner scale, Lichlum scale, and IKDC scores. It is possible that the sample sizes or patient populations in the two studies were different, which could have contributed to the divergent results. Further research with larger sample sizes and more diverse patient populations may be needed to clarify the relationship between foot dominance and knee function after ACL reconstruction.

The present study found that gender had a significant relationship with the outcomes following ACL reconstruction, with female patients reporting lower performance in ADLs, athletic performance, and quality of life compared to male patients. This finding is consistent with previous studies by Ageberg *et al.* (25) and Spindler *et al.* (26). Spinder *et al.* (26) found that female sexuality was a predictor of lower levels of activity, while Ageberg *et al.* (25) reported worse knee function outcomes in female patients both before and after ACL reconstruction. Gobi *et al.* (27) also found an increase in anterior-posterior laxity in women compared to men after ACL reconstruction with soft tissue grafts, which could contribute to these differences. Other factors, such as activity level and age, may also play a role in these differences between male and female patients.

Some studies have suggested that the choice of transplant type strongly influences the degree of post-ACL reconstruction looseness and graft rupture risk, with differences noted for male and female patients. Nonetheless, the results of the current study indicated that the type of connective tissue didn't have relationship with the knee outcomes following ACL reconstruction. Gobi *et al*. also found patellar tendon auto grafts and hamstring tendons to be excellent options for ACL reconstruction, with both techniques providing similar joint stability. Nonetheless, hamstring tendon auto grafts are preferable for patients with extensor mechanism issues or those involved in sports with a high incidence of patellar tendinitis. This study showed a significant relationship between age and knee function indices after ACL surgery. The results of statistical analysis showed that age explained 29 % of changes in symptoms and knee stiffness and 18 % of changes in athletes' quality of life following ACL reconstruction. Age is a key factor that can influence outcomes after ACL reconstruction through inherent biological characteristics. Some studies have shown that young patients (≤20 years) show both higher IKDC scores and faster return to exercise, possibly because of these intrinsic biological traits (26, 28, 29). In addition, younger patients had higher pre-injury activity levels (Tagner 8.3 vs. 7.3) and higher participation rates in rehabilitation (20% vs. 15%), and these factors may play a role in their better outcomes. In this regard, Della Villa *et al*. (29) also showed that young patients who had higher tenner's activity level before injury or who performed exercise at a professional level had better clinical outcomes after surgery and returned to activity in a shorter time.

The study found that the level of athletic activity, whether professional, amateur, or recreational, hadn't have relationship with the postoperative outcomes of ACL reconstruction. This differs from previous studies by Villa *et al*. (30), which found that professional athletes recovered faster than amateur and recreational athletes due to their higher level of athletic activity (27, 29-33). The discrepancy may be due to the fact that the subgroup of athletes in this study was not homogeneous, with a much larger percentage of professional athletes (88.4%) than amateur (2.3%) and recreational (9.3%) athletes. Since sport is the main occupation of professional athletes, they may have more time for rehabilitation and higher rehabilitation costs, leading to more intensive rehabilitation and faster recovery. The study's limitations include its retrospective design, which does not establish a causal relationship between the research variables, a participant population consisting only of athletes, a small sample size, and a lack of homogeneity in the subgroup of athletes, and the fact that participants received varying levels of supervision and rehabilitation. Future studies with a larger sample size of homogeneous subgroups, equally supervised and rehabilitated participants, and objective assessment of athletes' performance are recommended to address these limitations.

Conclusion

The results of present study showed that age, BMI, weight, and gender can predict different components of ACL reconstruction. However, due to the limitations of this study, it is better to investigate this issue in a longitudinal and prospective manner to clarify this issue.

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Ethical considerations
Ethical considerations are considered in accordance with the guidelines of the ethics committee of the Institute of Civil and Development Higher Education.

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Authors' contributions
All authors have contributed equally to the preparation of this article.

Conflict of interest
None.

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