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# Factors Affecting Body Composition: Study on Athletes After ACL Injury

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**Abstract**

*Background*. Following an anterior cruciate ligament (ACL) injury, many athletes experience decreased physical activity and altered body composition.

*Aim*. This study aims to determine the factors that affect body composition after athletes experience ACL injuries.

*Methods*. This cross-sectional study examined factors influencing body composition in 18 athletes from State University of Jakarta (UNJ) recovering from ACL injuries. The gender percentage was 61.11% males and 38.89% females, and the age range was 20–27 years. Data on current age, sex, age of injury, and surgical treatment were collected via questionnaire. Height was measured with a stadiometer, and weight, body mass index (BMI), and body composition parameters (body fat percentage, muscle mass, water content, protein, and bone density) were assessed using biological impedance analysis (BIA). Bivariate analyses (Pearson Product-Moment Correlation) identified significant associations between body composition and demographic or clinical variables.

*Results.* Results showed that sex significantly influenced body fat ($p = 0.008$), muscle mass ($p = 0.000$), body water ($p = 0.018$), and bone density ($p = 0.000$). Age correlated with body fat ($p = 0.037$), protein ($p = 0.002$), and bone density ($p = 0.010$). BMI was linked to fat percentage ($p = 0.025$) and water content ($p = 0.012$). Body weight strongly associated with muscle mass ($p = 0.000$) and borderline with bone density ($p = 0.050$). Age of injury, intervention type, and height showed no consistent effects.

*Conclusions*. The study concluded that body composition after ACL injury was influenced mainly by current age, sex, body weight, and BMI, while age of injury, intervention type, and height had minimal impact.

**Keywords:** factors; body composition; athletes; ACL injury

## 1. INTRODUCTION

The anterior cruciate ligament (ACL) is a key structure within the knee joint, primarily responsible for limiting forward movement of the tibia relative to the femur and helping to stabilise the knee during rotational motions (Diwakar, 2018). ACL injuries occur frequently, with a notable rise observed over the last two decades. In Australian hospitals, the rate of these injuries has grown steadily, increasing each year by approximately 5.2% in men and 6.2% in women (Maniar et al., 2022). In Olmsted County, the United States, an annual ACL injury incidence rate of 68.6 per 100,000 people was reported (Sanders et al., 2016). Meanwhile, other reports state the incidence of ACL injuries, especially in athletes, reached 700 ACL injuries in 11,239,029 exposure events (Gronitzky et al., 2016). Finally, another study found that 1,235 ACL injuries were identified in 17,824,251 athlete-exposure events (Bram et al., 2021).

Based on data from the Ministry of Health of the Republic of Indonesia, tears in the ACL can occur through direct contact with a prevalence of 30%, or without involving direct contact with a prevalence of 70–78% (Rahayu et al., 2020). Rupture in the ACL often occurs due to an impact when falling from a pedestal on the knee. In addition, the cause of injury to the ACL can be physical contact, stopping movements, and abrupt changes in direction, such as rotating excessively or moving forward or backward (Syafa'at & Rosyida, 2020).

ACL injuries generally occur in sports that involve movements such as jumping, turning, and cutting movements (Sadeqi et al., 2018). The highest risk of ACL injury is relative to basketball and football (Gronitzky et al., 2016). ACL injuries are a problem for society, especially for young people involved in competitive sports. It is noted that many athletes do not return to the same exercise intensity as before the ACL injury and after ACL reconstruction (Kuenze et al., 2022). Only 55% of patients return to competitive levels of exercise after ACL reconstruction (Ardern et al., 2014). In addition, ACL injuries impair functional ability, cause psychological stress and increased risk of re-injury, limit sports or activities performed, and induce fear of re-injury (Chan et al., 2017). Finally, ACL injuries may cause such long-term effects as knee instability, meniscus tears, cartilage injuries, and osteoarthritis (Acevedo et al., 2014).

Knee joint instability is a problem that is often discovered after a person experiences ACL injury (Felix et al., 2022; Paravlic, 2022). This is because ACL tears cause reduced afferent information that affects the neuromuscular function of the knee towards the maintenance of balance and joint function (Negahban et al., 2014). In addition, when the afferent information system is reduced and insufficient excitatory input to the motoneurons occurs, it affects the motor control of the quadricep and hamstring muscles, causing a decrease in quadricep activation and knee flexor muscle activity, ultimately resulting in reduced muscle strength (Nuccio et al., 2021). Meanwhile, athletes who lose knee joint stability after ACL injury experience restrictions on exercise or physical activity performed. Knee joint stability plays an important role in the ability to cope with sudden displacement or shift (Schmitt & Rudolph, 2008), or the ability to remain stable when joint load changes rapidly during activity (Williams et al., 2001). This enhances the comprehension of knee instability following ACL injury and supports the creation of targeted rehabilitation strategies. Athletes aiming to resume physical activity post-ACL injury need to prioritise building the ability to effectively manage dynamic neuromuscular control and maintain joint stability during movement (Nyland et al., 2020). This research aims to determine the factors that affect body composition after athletes experience ACL injuries.

## 2. METHODS

This study used a cross-sectional design and included 18 athletes from State University of Jakarta (UNJ) who had sustained anterior cruciate ligament (ACL) injuries. All participants voluntarily provided written informed consent before taking part in the study. Among them, 61.11% were male and

38.89% were female, with ages ranging from 20 to 27 years. The study received ethical approval from the Research Ethics Commission of the Bandung Institute of Technology (Ethical Clearance No. KEP/II/2024/X/M210524YSK-EON).

Participants were provided with verbal explanations of the study procedures prior to signing a written consent form confirming their willingness to participate. The study was conducted at the UNJ Sports Hall Clinic in Jakarta. A total of 18 student-athletes from UNJ were targeted as research subjects. Participants were selected according to predefined inclusion and exclusion criteria as follows:

1. Inclusion criteria
    a. Recorded ACL injury based on a diagnosis from a doctor.
    b. Suffered ACL injury due to sports or other activities and received treatment surgically or non-surgically.
    c. Surgical treatment (ACL reconstruction surgery) received ≥6 months ago.
    d. Willingness to be a research subject marked by signing written informed consent.
2. Exclusion criteria
    a. Diagnosed with other than ACL injuries before or after ACL injury or injuries to other legs.
    b. There are still signs of inflammation in the knee joint, and the range of motion is still below 50% compared to normal parameters.
    c. Circumstances that interfere with participant's ability to give consent to participate in the study.
    d. Other health problems that can hinder the examination and testing in this study.

This study employed purposive sampling, a non-probability sampling technique in which participants are intentionally selected based on specific characteristics that align with the research objectives. Participant selection followed predetermined inclusion and exclusion criteria, resulting in a total of 18 respondents (n = 18). Although the sample size is relatively small, this limitation reflects the specificity of the target population, as only a limited number of individuals met the inclusion criteria. Such sample size is common in purposive sampling studies, where the emphasis lies on the relevance and suitability of participants rather than the sample quantity. Therefore, despite its modest size, the data obtained are considered representative of the population that fits the research focus.

Demographic data, including current age, gender, age at the time of injury, and type of intervention received, were collected using a structured questionnaire. Height was measured with a stadiometer, while weight, body mass index (BMI), and body composition parameters – including body fat percentage, muscle mass, total body water, protein content, and bone mineral density – were assessed using bioelectrical impedance analysis (BIA).

Bivariate statistical tests were employed to determine the relationships between variables influencing body composition. Due to the limited sample size, multivariate analyses could not be performed, which restricted the ability to identify the most dominant influencing factors. The bivariate analysis was conducted using the Pearson Product-Moment Correlation test. Data collection and form completion were directly supervised by the researcher. Results are presented as means and standard deviations (SD), and statistical significance was set at $p < 0.05$.

## 3. RESULTS

This section outlines the results of the study examining the factors that influence body composition in individuals recovering from ACL injuries. The findings are divided into two main parts: a de-

scriptive analysis that highlights participant characteristics and body composition data, and a bivariate correlation analysis that explores the relationships among key variables.

Table 1. **Descriptive statistics**

| | **Minimum** | **Maximum** | **Mean ± SD** | **Std. error** |
|---|---|---|---|---|
| Age at time of injury (years) | 19 | 24 | 22 ± 1.41 | 0.41 |
| Type of intervention | 0.00 | 1 | 0.50 ± 0.51 | 0.12 |
| Gender | 0.00 | 1 | 0.72 ± 0.46 | 0.11 |
| Current age (years) | 20 | 27 | 22.11 ± 2.11 | 0.50 |
| Height (cm) | 157 | 185 | 163.57 ± 15.53 | 3.66 |
| Weight (kg) | 56 | 86.10 | 71.80 ± 11.09 | 2.61 |
| BMI (kg/m²) | 20.60 | 30.70 | 25.81 ± 3.36 | 0.79 |
| Body fat (%) | 13.50 | 35.60 | 26.06 ± 6.14 | 1.45 |
| Muscle mass (kg) | 36.10 | 62.48 | 49.59 ± 8.35 | 1.97 |
| Water (%) | 41.50 | 59.30 | 51.73 ± 4.47 | 1.05 |
| Protein (%) | 12.60 | 22.60 | 17.21 ± 3.35 | 0.79 |
| Bone mass (kg) | 2.39 | 3.85 | 3.03 ± 0.39 | 0.09 |

Table 1 presents the participants' demographic and physiological data. The age at time of injury ranged from 19 to 24 years, with a mean value of 22 ± 1.41 years and a standard error (SE) of 0.41. The type of intervention, categorised as a binary variable, showed a mean of 0.50 ± 0.51 (SE = 0.12), reflecting a balanced distribution. The gender variable had an average of 0.72 ± 0.46 (SE = 0.11), indicating a larger proportion of male participants. Participants' current ages spanned from 20 to 27 years, with a mean of 22.11 ± 2.11 years (SE = 0.50). Heights ranged from 157 cm to 185 cm, with an average of 163.57 ± 15.53 cm (SE = 3.66), while weights varied between 56 and 86.10 kg, averaging 71.80 ± 11.09 kg (SE = 2.61). The body mass index (BMI) ranged from 20.60 to 30.70 kg/m², with a mean of 25.81 ± 3.36 kg/m² (SE = 0.79), suggesting that most participants fell within the normal to slightly overweight range. Body fat values were between 13.50 and 35.60%, with an average of 26.06 ± 6.14% (SE = 1.45). Muscle mass was recorded between 36.10 and 62.48 kg, with a mean of 49.59 ± 8.35 kg (SE = 1.97). The body water percentage ranged from 41.50% to 59.30%, averaging 51.73 ± 4.47% (SE = 1.05), while protein levels ranged from 12.60% to 22.60%, with a mean of 17.21 ± 3.35% (SE = 0.79). Bone density ranged from 2.39 to 3.85 kg, averaging 3.03 ± 0.39 kg (SE = 0.09).

Table 2. **Results of factors affecting body composition post ACL injury**

| | **Body fat** | **Muscle mass** | **Water** | **Protein** | **Bone mass** |
|---|---|---|---|---|---|
| Age at time of injury | 0.335 | 0.392 | 0.319 | 0.227 | 0.443 |
| Type of intervention | 0.826 | 0.792 | 0.315 | 0.726 | 0.23 |
| Gender | 0.008* | 0.000* | 0.018* | 0.080 | 0.000* |
| Current age | 0.037* | 0.198 | 0.532 | 0.002* | 0.010* |
| Height | 0.457 | 0.118 | 0.544 | 0.86 | 0.139 |
| Weight | 0.391 | 0.000* | 0.306 | 0.756 | 0.050* |
| BMI | 0.025* | 0.069 | 0.012* | 0.188 | 0.227 |

**Note:** *$p < 0.05$.

The bivariate correlation analysis revealed several important links between the independent variables and different components of body composition in individuals recovering from ACL injuries. Gender showed significant relationships with most assessed body composition measures, including body fat ($p = 0.008$), muscle mass ($p = 0.000$), body water ($p = 0.018$), and bone mass ($p = 0.000$), indicating clear differences between males and females. Current age was significantly associated with body fat ($p = 0.037$), protein ($p = 0.002$), and bone mass ($p = 0.010$), suggesting that these aspects change with advancing age. BMI demonstrated significant connections with body fat ($p = 0.025$) and water content ($p = 0.012$), pointing to its role as a key factor in body composition variation. Body weight correlated strongly with muscle mass ($p = 0.000$) and had a borderline link with bone mass ($p = 0.050$). Conversely, factors such as the age at time of injury, type of intervention, and height showed no consistent correlations with body composition, despite some moderate associations, e.g. between age at time of injury and bone mass ($p = 0.443$) or muscle mass ($p = 0.392$). In summary, the findings highlight age, gender, weight, and BMI as the main influencers of body composition following ACL injury.

## 4. DISCUSSION

This research found that there are several factors that affect body composition components. Gender affected most components of body composition (except for protein). Meanwhile, current age had an impact on the percentage of body fat, protein, and bone mass. Weight affected muscle mass and bone mass and BMI affected body fat and water. Thus, the results showed that the factors that affected body composition in athletes with ACL injuries were gender, current age, weight, and BMI, while the time since injury, the type of intervention, and height did not affect body composition.

The analysis of body composition data for the athletes showed that most measurements fell within normal ranges. Muscle mass, protein levels, and water content were all within expected limits. However, body fat and bone mass require closer examination. Studies on body weight, composition, and their influencing factors remain diverse and often yield inconsistent results (Abarghoueinejad et al., 2021; Lubis et al., 2022). Several studies indicate that diet and nutritional status play a significant role in influencing body composition (Alhamdan et al., 2021; Devlin et al., 2017). Other studies suggest that physical activity has a direct impact on body weight and body composition (Ten Hoor et al., 2018; Valentini et al., 2020). Among males, body composition appears to be strongly influenced by body weight, with a leaner body weight generally indicating a healthier composition (Oliveira et al., 2021; Requena et al., 2017).

Athletes recovering from ACL injuries tend to have slightly elevated body fat levels. Body fat is generally influenced by factors such as diet and physical activity. When body fat remains within a normal range, it typically does not affect sport performance or physical fitness. However, if body fat exceeds healthy levels, it can significantly hinder both athletic skill and overall fitness (Jiang et al., 2018; Listiandi et al., 2020; Mighra & Djaali, 2021; Nikolaidis et al., 2021). Therefore, athletes need to maintain proper body composition both during competition periods and in the off-season (McEwan et al., 2020; Oliveira et al., 2021; Requena et al., 2017).

Bone mass, which measures the amount of mineral in a given volume of bone, is a widely accepted standard for assessing bone strength and plays a key role in evaluating bone quality. Research has shown that lower bone mass increases the likelihood of fractures (Curtis et al., 2016). Nutrition plays a crucial role in maintaining bone health and is one of the modifiable factors influencing it. Improved adherence to a balanced diet positively impacts bone mass, with protein intake also contributing, though to a smaller degree. Moreover, both hormonal balance and regular physical activity affect bone mineral density in the general population as well as in athletes (Milanese et al., 2021).

There are several limitations in this study that should be acknowledged. First, due to its cross-sectional design, it is not possible to establish causal relationships between the analysed variables through multivariate analysis. Second, although the sample size was adequate for the statistical analyses performed, it was too small to allow for meaningful subgroup analyses based on sport type. Third, the dietary habits of the participants were not assessed, which may have influenced the outcomes and highlights the need for further investigation into this factor.

Future studies should include larger and more diverse samples, as well as additional variables such as nutrition, training load, and rehabilitation stage, to obtain a more comprehensive understanding of body composition and its determinants in athletes. The relatively small and homogeneous sample in the present study, consisting solely of individuals who met the specific inclusion criteria, may limit the generalisability of the findings. Nevertheless, the results provide valuable insights and serve as a useful foundation for future longitudinal research examining athletes recovering from ACL injuries.

## 5. CONCLUSIONS AND PERSPECTIVES

The findings indicate that current age, gender, weight, and body mass index significantly influenced body composition in athletes following ACL injury. In contrast, factors such as age of injury, type of intervention, and height showed no meaningful impact. Future studies should consider a longitudinal design to track changes in body composition over time after ACL injury. Increasing sample size and participant diversity, as well as including variables such as rehabilitation intensity, dietary habits, and hormonal status, would offer a more detailed understanding of how body composition evolves in this population.

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# Veiksniai, darantys įtaką kūno sudėčiai: sportininkų, patyrusių PKR traumą, tyrimas

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**Santrauka**

*Tyrimo pagrindimas*. Po priekinio kryžminio raiščio (PKR) traumos daugelis sportininkų patiria fizinio aktyvumo sumažėjimą ir kūno sudėties pokyčius.

*Tikslas*. Šio tyrimo tikslas – nustatyti veiksnius, turinčius įtakos sportininkų kūno sudėčiai po PKR traumos.

*Metodai*. Šiame skerspjūvio tyrime buvo nagrinėjami kūno sudėties pokyčius lemiantys veiksniai tarp 18 Džakartos nacionalinio universiteto (UNJ) sportininkų po PKR traumos. Tarp tiriamųjų buvo 61,11 % vyrų ir 38,89 % moterų, amžiaus intervalas – 20–27 metai. Duomenys apie turimą amžių, lytį, metus, kada patirta trauma, ir chirurginį gydymą buvo surinkti naudojant klausimyną. Ūgis matuotas stadiometru, o svoris, kūno masės indeksas (KMI) ir kūno sudėties rodikliai (kūno riebalų procentas, raumenų masė, vandens kiekis, baltymų kiekis ir kaulų tankis) vertinti pasitelkus bioelektrinės varžos analizę (BVA). Dviejų kintamųjų analizė (Pirsono tiesinė koreliacija) padėjo nustatyti reikšmingas sąsajas tarp kūno sudėties ir demografinių ar klinikinių kintamųjų.

*Rezultatai.* Rezultatai parodė, kad lytis reikšmingai veikė kūno riebalų kiekį ($p = 0,008$), raumenų masę ($p = 0,000$), vandens kiekį ($p = 0,018$) ir kaulų tankį ($p = 0,000$). Turimas amžius koreliavo su kūno riebalais ($p = 0,037$), baltymų kiekiu ($p = 0,002$) ir kaulų tankiu ($p = 0,010$). KMI buvo susijęs su riebalų ($p = 0,025$) ir vandens ($p = 0,012$) procentu. Kūno svoris reikšmingai siejosi su raumenų mase ($p = 0,000$) ir, ribiniu ryšiu, su kaulų tankiu ($p = 0,050$). Metai, kada patirta trauma, taikytas gydymas ir ūgis neturėjo reikšmingos įtakos.

*Išvados*. Tyrimo rezultatai rodo, kad kūno sudėtis po PKR traumos daugiausia priklauso nuo turimo amžiaus, lyties, kūno svorio ir KMI, o metai, kada patirta trauma, taikytas gydymas ir ūgis daro minimalią įtaką.

**Reikšminiai žodžiai:** veiksniai; kūno sudėtis; sportininkai; PKR trauma

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