# BODY COMPOSITION AND ITS RELATIONSHIP TO SPORTS INJURIES IN YOUNG FEMALE ACROBATIC GYMNASTS

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***Abstract***
*The risk of injury is associated with elite sport. There is evidence that body composition may affect injury risk. The aim of this study was to analyze the incidence of injuries, and to determine the relationship of body composition with the incidence, typology and severity of injuries in female acrobatic gymnasts.*
*The sample included 92 female acrobatic gymnasts aged between 9 and 20 years (13.66 ± 2.66 years), 33 tops (11.06 and 1.41 age) and 59 bases (15.11 and 2.00 age). Body measurements (fat percentage, muscle percentage and the sum of 6 skinfolds), and body mass index (BMI) and their categorization into underweight, normal weight and overweight, were measured. Data about injuries were collected through a self-completed questionnaire at the end of the season, where it was recorded whether they had suffered injuries, the type of injury (joint, ligament, tendon or bone) and its severity (minor, moderate or severe). A descriptive, comparative and relational analysis of the studied variables and between groups was carried out.*
*The results obtained in this study indicate a higher percentage of uninjured gymnasts, but also a high percentage of injured gymnasts, with ligament injuries being the most frequent. As for the relationship with body composition and BMI, no significant relationships were observed in the incidence, typology or severity of injuries suffered by these athletes. It only seems to affect tendon injuries in the bases, with the injured gymnasts having a higher BMI, fat percentage and the sum of six skinfolds.*

**Keywords:** *gymnastics; anthropometry; body composition; injuries; acrobatic gymnastics.*

## INTRODUCTION

In any sport, and especially in competition at highest levels, injuries are an unavoidable inconvenience, therefore their prevention is essential to optimize sports performance. The importance of recording injuries associated with their causal factors can therefore be an excellent method for determining their influence on sport performance (Kolt & Kirby, 1999).

Numerous studies have investigated the incidence and prevalence of injuries in the gymnastic disciplines that have been incorporated into the FIG for the longest time, such as men's and women's artistic gymnastics and rhythmic gymnastics (Abalo et al., 2013). Recent reviews indicate a relatively high incidence of injury in artistic gymnastics (Cambell et al., 2019; Thomas & Thomas, 2019). One of these reviews includes 12 studies with 843 women evaluated for the type and frequency of injuries; it showed that the lower extremities were the most affected, followed by the upper extremities, spine and neck. (Thomas & Thomas, 2019). As a limitation of these studies, we found that they varied widely according to their demographic data and the type of injuries recorded, since there were no individual gymnasts' data. Likewise, only four of these studies reflected injury data in elite gymnasts. However, the data were collected either from the athletes'medical history, or from coaches' or physiotherapists' reports. In most studies on amateur athletes, the mean number of hours of training per year was not collected. This type of studies can help sports medicine specialists identify the most common injuries so that appropriate preventive actions can be taken. However, studies in acrobatic gymnastics (AG) are still somewhat limited. (Grapton et al., 2013; Purnell et al., 2010; Vernetta et al., 2018; Vernetta-Santana et al., 2022). It is noteworthy that of the 73 gymnasts in the study by Purnell et al. (2010), 50.7% have suffered some type of injury during training in the last 12 months, from contractures to bone fractures or muscle tears. These authors found that being over 13 years old and training ≥ 8 hours per week at 11 years of age were potential risk factors.

Currently the International Gymnastics Federation (FIG) comprises eight disciplines, including artistic gymnastics and rhythmic gymnastics. More studies on their anthropometric profiles have been conducted in these disciplines as we pointed out in relation to injuries. Body composition is considered a determinant of performance in these disciplines, especially at a high competitive level. The systematic review by Bacciotti et al. (2017) of seven articles in women's artistic gymnastics shows that a lower percentage of body fat is associated with better performance in competition. In other sports, increased body mass index (BMI) has been associated with an increased incidence of injuries, e.g., in women's soccer, and at lower age categories of soccer. (Brumitt et al., 2020; Sugimoto et al., 2018). Similarly, in the study by Ezzat et al. (2016) with a sample of 12,407 adolescents aged 12-19 years, no significant association was found between sports injuries and being overweight, but a secondary analysis revealed that overweight youth with the highest activity level were more likely to suffer sports injuries. A recent study of women's artistic gymnastics analyzed body composition (mean BMI =21.5 and % body fat = 21.9), training volume and injuries in 17 high-performance gymnasts, and found that the most injured areas were ankles and lower back, followed by knees, which mostly affected the gymnasts' training volume. (Jakše et al., 2021).

AG is characterized as a cooperative sport with two distinct roles, bases and tops. The difference between the roles is evident both in their function and in their physical characteristics. The base is the holder and supports the top. The top performs on the base, executing elements of flexibility and balance. (Vernetta et al., 2007). The constant inclusion in the Scoring Code of elements of great difficulty requires gymnasts to perform technically demanding elements and display a high technical level which could lead to an increased risk of injury (Vernetta et al., 2018), as hypothesized by Anwajler et al. (2005). These same authors point out that in a sample of 40 women in AG, the number of injuries in training is higher than those occurring in competition with statistically significant differences, as occurs in studies of AG (Purnell et al., 2010; Vernetta-Santana et al., 2022) and other gymnastic disciplines (Abalo et al., 2013a; 2013b; Vernetta et al., 2016).

Anthropometric studies on this gymnastic discipline have established that the bases show larger body dimensions than the tops, showing significant differences in the mean values of BMI ($p<0.01$) (bases: 20.28 kg/m2 and tops: 16.4 kg/m2) as well as in other somatotype variables analyzed, except for mesomorphy ($p=0.7$). The endomorphic component was higher in the bases (3.17) than in the tops (2.45), whereas the ectomorphic component was higher in the tops (3.27) compared to the bases (2.82). (Taboada-Iglesias et al., 2016). The study by Vernetta et al, (2018) finds a higher percentage of injuries in female bases than in tops, as does the study by Vernetta-Santana et al (2022), where this percentage affects both men and women. AG routines involve dynamic and static group performance skills, therefore the competition groups are configured and maintained according to the individual morphology of each gymnast. Hence, when an injury occurs in one of its components, it is not easy to replace it, which means in most cases the withdrawal of the entire team from the competition (Purnell et al., 2010). It should be noted that in this study 58.8% of the injuries occurred during the performance of a group skill, with the bases suffering more than half of all chronic injuries (52.9%), although no significant correlation was found between BMI and the occurrence of injuries. The identification of the incidence of injuries and the factors associated with their occurrence in AG is a fundamental issue for training, which will facilitate a safer and more effective practice, as well as enable the development of preventive programs. (Cai et al., 2018).

Given the limited evidence, the aim of this study was to analyze the incidence, typology and severity of injuries in female AG athletes and their relationship with different variables of body composition in one season.

## METHODS

Participation was voluntary in all the procedures, and the participants could terminate participation at any time. Given that the majority were minors, it was the parents or legal guardians who gave their consent. All measurement procedures were approved by the Autonomous Committee on Research Ethics of the Xunta de Galicia (Spain) (reference number 2015/672) in compliance with the Declaration of Helsinki.

The present study included a sample of 92 women participating in national AG competitions (33 tops and 59 bases), in all age categories, and belonging to seven clubs from all over Spain. Gymnasts between 9 and 20 years old were analyzed. Younger gymnasts were left out due to the difficulty in filling out self-reports. The mean age (X) was 13.66 years with a standard deviation (SD) of 2.66 (tops 11.06 (1.41) age; bases 15.11(2.00) age).

A series of direct measurements were taken to calculate body composition variables following the procedures of the International Society for the Advancement of Kineanthropometry (ISAK). (Marfell-Jones et al., 2006).

The measurements included: weight (kg), taken with a Tanita digital scale with 100g sensitivity, and height (m), using a portable stadiometer. Six skinfolds (triceps, subscapular, supraspinal, abdominal, thigh and medial calf) (mm) were measured with a 0.2 mm precision plicometer. Two bone diameters were also measured in cm (bistiloid diameter of the wrist and femoral bicondylar diameter) with a Holtain caliper of 1mm precision.

The variables that were calculated were BMI, percentage of body fat, percentage of muscle, and skinfold sum.

BMI was calculated using the formula BMI = weight/height$^2$ (kg/m$^2$). This variable was taken into consideration as a continuous numerical and categorical variable for its division into underweight, normal weight and overweight. For this interpretation, the percentiles established by the World Health Organization were used as a reference (WHO, 2007) for girls aged 5 to 19 years, marking overweight at the 85th percentile. For the categorization of underweight, the international cut-off point for thinness grade 1 was adopted, proposed by Cole et al. (2007) for the classification of thinness based on BMI in children. For the 20-year-old participants, the standard WHO classifications for adult subjects were taken into consideration. For body composition, the percentage of body fat was calculated using the formula by Slaughter et al. (1988) indicated for girls and proposed by the consensus of the Spanish Group of Cineanthropometry (GREC). (Alvero et al., 2010).

- *Slaughter (1988): % body fat =0.610 x (Sk triceps + Sk* medial calf*) + 5.1*

The De Rose and Guimarães (1980) strategy, based on the four-component method proposed by Matiekga (1921), was used to calculate the percentage of muscle mass.

- *Muscle weight = total weight - (fat weight + bone weight + residual weight).*

Finally, the sum of six skinfolds was calculated:

- *Σ6 skinfolds (mm) = Sk triceps + Sk subscapular + Sk supraspinal + Sk abdominal + Sk* thigh + *Sk* medial calf

The data related to the injury profile of this study were collected by using a self-completed questionnaire. This questionnaire is an adaptation of the one developed by Navarro (2003) and validated in Aerobic Gymnastics (Abalo Nuñez et al., 2013b) for the purposes of AG (Taboada-Iglesias & Gutiérrez-Sánchez, 2015; Vernetta et al., 2018; Vernetta et al., 2021;). For this work, the following variables were considered:

- injured or not during the season;
- type of injury: injuries were classified as joint, muscle, ligament, tendon, bone or various types of injuries;
- severity of injury: grade I or minor (1 to 7 days of recovery), grade II or moderate (8 to 21 days of recovery) and grade III or severe (22 days or more or permanent disability depending on the time of functional impairment).

Data collection (questionnaire and measurements) was carried out at the end of the season, at the training place of each participating club, in small groups, and always in the presence of one of the authors. First, the injury questionnaire was filled out in paper format, lasting approximately 5 minutes. This resolved any doubts about the questions and helped the younger gymnasts to complete the survey. The questionnaire consisted of questions about the participant's characteristics (role, club, competition level and age) and whether he/she suffered injuries during the season (yes or no, number of injuries, type of injury and severity of the injury). In the case of suffering more than one injury, they were recorded with the value of various types of injury, or various types of severity if applicable. Finally, the anthropometric tests were performed according to the protocol and recommendations established by the ISAK.

A descriptive and comparative analysis of the variables was performed, selecting the mean (X) as the measure of central tendency and the standard deviation (SD) for numerical variables, and frequencies and percentages (%) for categorical variables as measures of dispersion. A comparative analysis between groups was also performed. To check the normality of the groups, the data were subjected to the Shapiro-Wilk test and the homogeneity of variance with Levene's statistic. The Student's t-test was performed to evaluate the differences in body composition measurements between the gymnasts who did or did not suffer an injury, and between the body composition of gymnasts who did or did not suffer each type of injury. The comparison of numerical variables between 3 or more groups or categories was performed using one-factor Anova or Kruskall-Wallis for the comparison of non-normal variables to analyse the differences in body composition between the different injury typologies and the relationship between the body composition and injury severity. The Chi-square test was used to analyze the relationship between categorical variables, as in the analysis of BMI categorization between the injured and the non-injured gymnasts. The data were analyzed using the SPSS 22.0 statistical program, with a significance level of $p<0.05$ for all tests.

## RESULTS

The results will be explained starting with the descriptive analysis of the injury profile and then the comparative relationship between the different variables of body composition, with the incidence, type and severity of injuries.

Table 1 shows the frequencies and percentages of gymnasts who suffered or not injuries during the season. At the same time, the type of injuries and their severity are indicated. Regarding the type and severity of the injuries, the percentages are established with respect to the number of gymnasts injured and with respect to the total, since they are included in the comparative analysis.

Table 1
*Frequencies and percentages of gymnasts with and without injury during the season, typology and severity of the injuries.*

| | | Full sample | | | Tops (n=33) | | Bases (n=59) | |
|---|---|---|---|---|---|---|---|---|
| | | Frequency (n) | Percentage (%) | | n | % | n | % |
| Injuries during the season | YES | 33 | 35.9 | | 13 | 39.4 | 20 | 33.9 |
| | NO | 59 | 64.1 | | 20 | 60.6 | 39 | 66.1 |
| | Total | 92 | 100.0 | | 33 | 100.0 | 59 | 100.0 |
| | | | Regarding injured (n= 33) | Regarding total cases | Regarding injured (n=13) | | Regarding injured (n=20) | |
| Type of injury | Joint injury | 3 | 9.1 | 3.3 | 0 | 0 | 3 | 15.0 |
| | Muscle injury | 5 | 15.2 | 7.6 | 1 | 7.7 | 4 | 20.0 |
| | Ligament injury | 8 | 24.2 | 12.0 | 3 | 23.1 | 5 | 25.0 |
| | Tendon injury | 6 | 18.2 | 8.7 | 3 | 23.1 | 4 | 15.0 |
| | Bone injuries | 6 | 18.2 | 9.8 | 5 | 38.5 | 1 | 5.0 |
| | Various | 5 | 15.2 | | 1 | 7.7 | 4 | 20.0 |
| | Total | 33 | 100.0 | | 13 | 100.0 | 20 | 100.0 |
| Severity of injury | Grade 1 or minor | 15 | 45.5 | 16.3 | 3 | 23.1 | 12 | 60.0 |
| | Grade 2 or moderate | 11 | 33.3 | 13.0 | 6 | 46.2 | 5 | 25.0 |
| | Grade 3 or severe | 7 | 21.2 | 7.6 | 4 | 30.8 | 3 | 15.0 |
| | Total | 33 | 100.0 | | 13 | 100.0 | 20 | 100.0 |

There are 64.1% of gymnasts who did not suffer any injury during the season, compared to 35.9% of those who did. Within this group of gymnasts who suffered injuries, there were 24.2% ligament injuries, while the least frequent injury was joint injury (9.1%). Finally, 45.5% of injuries that occurred were grade 1 or minor, followed by grade 2 or moderate injuries (33.3%), and grade 3 or severe (21.2%), that caused a limitation for more than 22 days. The separate analysis of the tops and the bases shows a very similar distribution in terms of the incidence of injuries. However, in terms of typology, female bases have a greater number of joint, muscle, tendon and ligament injuries, while in the tops group, bone injuries predominate. Finally, in terms of severity, female bases suffer more minor and moderate injuries, while in the tops, moderate and severe injuries dominate.

***Relationship between body composition and injury incidence***

In the analysis between the variables of body composition and the incidence of injuries occurring during the season, it is observed that there are no significant differences ($p<0.05$) between the groups that suffered injuries and those that did not, in any of the variables studied (Table 2).

The relationship between BMI categorization into underweight, normal weight and overweight, and the groups of injured and non-injured gymnasts was also not significant ($p=0.431$) for the total sample, neither for top ($p=0.528$) nor for bases ($p=0.435$) individually.

Table 3 shows how the gymnasts are distributed according to the BMI categories with respect to having suffered or not injuries. Across the board, it is much less frequent to suffer injuries than not.

Table 2.
*Comparison of BMI, % body fat, % muscle mass and sum of 6 skinfolds between gymnasts who suffered injuries and those who did not.*

| | Full sample | | | | Tops | | | | Bases | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Injuries during the season | X | SD | Sig. (bila-teral) | Injuries during the season | X | SD | Sig. (bila-teral) | Injuries during the season | X | SD | Sig. (bila-teral) |
| BMI | Yes (n=33) | 18.59 | 2.57 | | Yes (n=13) | 16.57 | 1.79 | | Yes (n=20) | 19.90 | 2.14 | |
| | No (n=59) | 19.03 | 2.91 | .464 | No (n=20) | 16.56 | 1.62 | .754 | No (n=39) | 20.30 | 2.59 | .630 |
| % body fat | Yes (n=33) | 17.99 | 3.22 | | Yes (n=13) | 16.01 | 2.11 | | Yes (n=20) | 19.28 | 3.19 | |
| | No (n=59) | 18.59 | 4.88 | .485 | No (n=20) | 15.05 | 3.06 | .364 | No (n=39) | 20.40 | 4.66 | .059 |
| % muscle mass | Yes (n=33) | 45.82 | 1.51 | | Yes (n=13) | 45.47 | 1.18 | | Yes (n=20) | 46.04 | 1.68 | |
| | No (n=59) | 45.75 | 2.29 | .870 | No (n=20) | 46.50 | 1.96 | .244 | No (n=39) | 45.37 | 2.38 | .090 |
| ∑6Sk (mm) | Yes (n=33) | 61.90 | 15.58 | | Yes (n=13) | 51.58 | 10.45 | | Yes (n=20) | 68.62 | 14.8 | |
| | No (n=59) | 64.86 | 23.14 | .468 | No (n=20) | 47.70 | 15.50 | .410 | No (n=39) | 73.66 | 21.5 | .065 |

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); *Sum of 6 skinfolds* (∑6Pl)] *p<0.05

Table 1
*Incidence of injuries according to BMI categories (underweight, normal weight and overweight).*

| | | | Full sample | | | Tops | | | Bases | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Injuries during the season | | | Injuries during the season | | | Injuries during the season | | |
| | | | YES (n=33) | NO (n=59) | Total (n=92) | YES (n=13) | NO (n=20) | Total (n=33) | YES (n=20) | NO (n=39) | Total (n=59) |
| BMI (Categories) | Underweight (n=12; 13,0%) | Recount % within BMI (Categories) | 4 | 8 | 12 | 2 | 5 | 7 | 2 | 3 | 5 |
| | | | 50.0% | 50.0% | 100.0% | 15.4% | 25% | 100.0% | 10.0% | 7.7% | 100.0% |
| | Normal weight (n=74; 80,4%) | | 27 | 47 | 74 | 9 | 14 | 23 | 18 | 33 | 51 |
| | | | 32.9% | 67.1% | 100.0% | 69.2% | 70.0% | 100.0% | 90% | 84.6% | 100.0% |
| | Overweight (n=6; 6,5%) | | 2 | 4 | 6 | 2 | 1 | 3 | 0 | 3 | 3 |
| | | | 33.3% | 66.7% | 100.0% | 15.4% | 5.0% | 100.0% | 0% | 7.7% | 100.0% |

Body Mass Index (BMI)

***Relationship between body composition and injury typology.***

The relationship between body composition and the type of injury suffered was analyzed from two perspectives. First, the total sample was analyzed by dividing the groups that had or had not suffered each type of injury independently. The analysis indicated that there were no significant differences between the groups. Therefore, it is understood that in the complete sample, there are no significant differences in body composition between gymnasts who had joint injuries and those who did not, as well as in muscular, ligament, tendon and bone injuries (Table 4).

Table 5 shows that there were no significant differences in the tops. However, Table 6 shows that in the group of female gymnasts with differences in BMI, percentage of fat and the sum of skinfolds, higher values were presented by those gymnasts who suffered tendon injuries.

On the other hand, a comparison was conducted among all the injury groups in order to analyze if there were anthropometric differences among them. The statistical analysis indicated that there were no significant differences in BMI (p=0.197), body fat percentage (p=0.448), muscle mass percentage (0.396), or in the sum of 6 skinfolds (p=0.218). The behavior of the groups in these variables in the complete sample can be seen in Figure 4. Although no significant differences were found, it should be noted that joint injuries were the highest across the board.

Our analysis of the tops group did not show significant differences for BMI (p=0.533), fat percentage (p=0.203), muscle percentage (0.437), or the sum of 6 skinfolds (p=0.273). The same applies to the bases (BMI (p=0.357), fat percentage (p=0.332), muscle percentage (0.371), the sum of 6 skinfolds (p=0.181)).

Table 4
*Comparison of BMI, % body fat, % muscle mass and sum of folds between gymnasts who did or did not suffer each type of injury.*

| | | X | SD | Sig. (bilateral) | | X | SD | Sig. (bilateral) |
|---|---|---|---|---|---|---|---|---|
| | **Joint injuries** | | | | **Muscle injuries** | | | |
| **BMI** | No (n=89) | 18.77 | 2.77 | | No (n=85) | 18.88 | 2.81 | |
| | Yes (n=3) | 21.96 | 1.40 | .051 | Yes (n=7) | 18.82 | 2.74 | .960 |
| **% body fat** | No (n=89) | 18.28 | 4.38 | | No (n=85) | 18.46 | 4.37 | |
| | Yes (n=3) | 21.14 | 2.34 | .264 | Yes (n=7) | 17.31 | 4.25 | .504 |
| **% muscle mass** | No (n=89) | 45.75 | 2.03 | | No (n=85) | 45.79 | 2.02 | |
| | Yes (n=3) | 46.50 | 2.52 | .532 | Yes (n=7) | 45.52 | 2.37 | .737 |
| **∑6Sk(mm)** | No (n=89) | 63.16 | 20.63 | | No (n=85) | 63.99 | 20.99 | |
| | Yes (n=3) | 82.93 | 14.35 | .104 | Yes (n=7) | 61.43 | 18.07 | .754 |
| | **Ligament injuries** | | | | **Tendon injuries** | | | |
| **BMI** | No (n=81) | 18.86 | 2.79 | | No (n=84) | 18.92 | 2.85 | |
| | Yes (n=11) | 19.00 | 2.87 | .875 | Yes (n=8) | 18.35 | 2.03 | .583 |
| **% body fat** | No (n=81) | 18.42 | 4.44 | | No (n=84) | 18.48 | 4.48 | |
| | Yes (n=11) | 18.02 | 3.77 | .774 | Yes (n=8) | 17.28 | 2.42 | .247 |
| **% muscle mass** | No (n=81) | 45.72 | 2.08 | | No (n=84) | 45.73 | 2.12 | |
| | Yes (n=11) | 46.17 | 1.71 | .491 | Yes (n=8) | 46.20 | .73 | .190 |
| **∑6Sk(mm)** | No (n=81) | 64.06 | 21.33 | | No (n=84) | 64.55 | 21.25 | |
| | Yes (n=11) | 61.87 | 16.03 | .744 | Yes (n=8) | 55.95 | 11.92 | .264 |
| | **Bone injuries** | | | | | | | |
| **BMI** | No (n=83) | 19.01 | 2.82 | | | | | |
| | Yes (n=9) | 17.56 | 2.16 | .139 | | | | |
| **% body fat** | No (n=83) | 18.44 | 4.51 | | | | | |
| | Yes (n=9) | 17.77 | 2.48 | .667 | | | | |
| **% muscle mass** | No (n=83) | 45.79 | 2.12 | | | | | |
| | Yes (n=9) | 45.60 | 1.02 | .791 | | | | |
| **∑6Sk(mm)** | No (n=83) | 64.30 | 21.50 | | | | | |
| | Yes (n=9) | 59.21 | 10.57 | .247 | | | | |

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

Table 5
*Comparison of BMI, % body fat, % muscle mass, and sum of folds between gymnasts who did or did not suffer each type of injury as tops*

| | | X | SD | Sig. (bilateral) | | X | SD | Sig. (bilateral) |
|---|---|---|---|---|---|---|---|---|
| | **Joint injuries** | | | | **Muscle injuries** | | | |
| **BMI** | No (n=32) | 16.56 | 1.69 | | No (n=31) | 16.54 | 1.71 | |
| | Yes (n=1) | 16.67 | | .950 | Yes (n=2) | 16.96 | .37 | .735 |
| **% body fat** | No (n=32) | 15.38 | 2.75 | | No (n=31) | 15.61 | 2.72 | |
| | Yes (n=1) | 17.12 | | .538 | Yes (n=2) | 12.69 | .22 | .146 |
| **% muscle mass** | No (n=32) | 46.11 | 1.78 | | No (n=31) | 46.12 | 1.80 | |
| | Yes (n=1) | 45.48 | | .729 | Yes (n=2) | 45.65 | .53 | .717 |
| **∑6Sk(mm)** | No (n=32) | 49.12 | 13.89 | | No (n=31) | 49.82 | 13.92 | |
| | Yes (n=1) | 52.70 | | .801 | Yes (n=2) | 40.05 | .92 | .336 |
| | **Ligament injuries** | | | | **Tendon injuries** | | | |
| **BMI** | No (n=31) | 16.65 | 1.68 | | No (n=32) | 16.60 | 1.68 | |
| | Yes (n=2) | 15.24 | .34 | .525 | Yes (n=1) | 15.57 | | .552 |
| **% body fat** | No (n=31) | 15.52 | 2.66 | | No (n=32) | 15.43 | 2.77 | |
| | Yes (n=2) | 14.01 | 4.66 | .455 | Yes (n=1) | 15.35 | | .976 |
| **% muscle mass** | No (n=31) | 46.08 | 1.77 | | No (n=32) | 46.09 | 1.78 | |
| | Yes (n=2) | 46.21 | 1.89 | .926 | Yes (n=1) | 46.11 | | .991 |
| **∑6Sk(mm)** | No (n=31) | 49.90 | 13.6. | | No (n=32) | 49.37 | 13.88 | |
| | Yes (n=2) | 38.85 | 14.21 | .275 | Yes (n=1) | 44.60 | | .737 |
| | **Bone injuries** | | | | | | | |
| **BMI** | No (n=31) | 16.56 | 1.71 | | | | | |
| | Yes (n=2) | 16.59 | 1.02 | .983 | | | | |
| **% body fat** | No (n=31) | 15.54 | 2.77 | | | | | |
| | Yes (n=2) | 13.67 | 1.08 | .355 | | | | |
| **% muscle mass** | No (n=31) | 46.08 | 1.81 | | | | | |
| | Yes (n=2) | 46.25 | .20 | .897 | | | | |
| **∑6Sk(mm)** | No (n=31) | 49.83 | 13.4 | | | | | |
| | Yes (n=2) | 39.85 | 7.71 | .325 | | | | |

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

Table 6
*Comparison of BMI, % body fat, % muscle mass, and sum of folds between gymnasts who did or did not suffer each type of injury as bases*

| | | X | SD | Sig. (bilateral) | | X | SD | Sig. (bilateral) |
|---|---|---|---|---|---|---|---|---|
| | **Joint injuries** | | | | **Muscle injuries** | | | |
| **BMI** | No (n=59) | 20.16 | 2.43 | | No (n=54) | 20.19 | 2.39 | |
| | Yes (n=0) | | | | Yes (n=5) | 19.86 | 3.14 | .772 |
| **% body fat** | No (n=59) | 20.02 | 4.23 | | No (n=54) | 20.05 | 4.16 | |
| | Yes (n=0) | | | | Yes (n=5) | 19.70 | 5.40 | .864 |
| **% muscle mass** | No (n=59) | 45.60 | 2.17 | | No (n=54) | 45.62 | 2.21 | |
| | Yes (n=0) | | | | Yes (n=5) | 45.34 | 1.94 | .784 |
| **∑6Sk(mm)** | No (n=59) | 71.95 | 19.51 | | No (n=54) | 71.99 | 18.90 | |
| | Yes (n=0) | | | | Yes (n=5) | 71.48 | 28.06 | .956 |
| | **Ligament injuries** | | | | **Tendon injuries** | | | |
| **BMI** | No (n=48) | 20.06 | 2.51 | | No (n=55) | 19.92 | 2.24 | |
| | Yes (n=11) | 20.61 | 2.13 | .503 | Yes (n=4) | 23.45 | 3.04 | **.004*** |
| **% body fat** | No (n=48) | 19.89 | 4.39 | | No (n=55) | 19.68 | 4.05 | |
| | Yes (n=11) | 20.58 | 3.55 | .631 | Yes (n=4) | 24.71 | 4.30 | **.020*** |
| **% muscle mass** | No (n=48) | 45.58 | 2.25 | | No (n=55) | 45.57 | 1.95 | |
| | Yes (n=11) | 45.66 | 1.89 | .921 | Yes (n=4) | 45.99 | 4.77 | .713 |
| **∑6Sk(mm)** | No (n=48) | 71.22 | 2.53 | | No (n=55) | 69.62 | 16.95 | |
| | Yes (n=11) | 75.13 | 14.60 | .554 | Yes (n=4) | 104.03 | 26.78 | **.000*** |
| | **Bone injuries** | | | | | | | |
| **BMI** | No (n=58) | 20.21 | 2,43 | | | | | |
| | Yes (n=1) | 17.36 | | .249 | | | | |
| **% body fat** | No (n=58) | 20.11 | 4,21 | | | | | |
| | Yes (n=1) | 14.86 | | .221 | | | | |
| **% muscle mass** | No (n=58) | 45.58 | 2,19 | | | | | |
| | Yes (n=1) | 46.79 | | .585 | | | | |
| **∑6Sk(mm)** | No (n=58) | 72.42 | 19,35 | | | | | |
| | Yes (n=1) | 44.90 | | .164 | | | | |

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

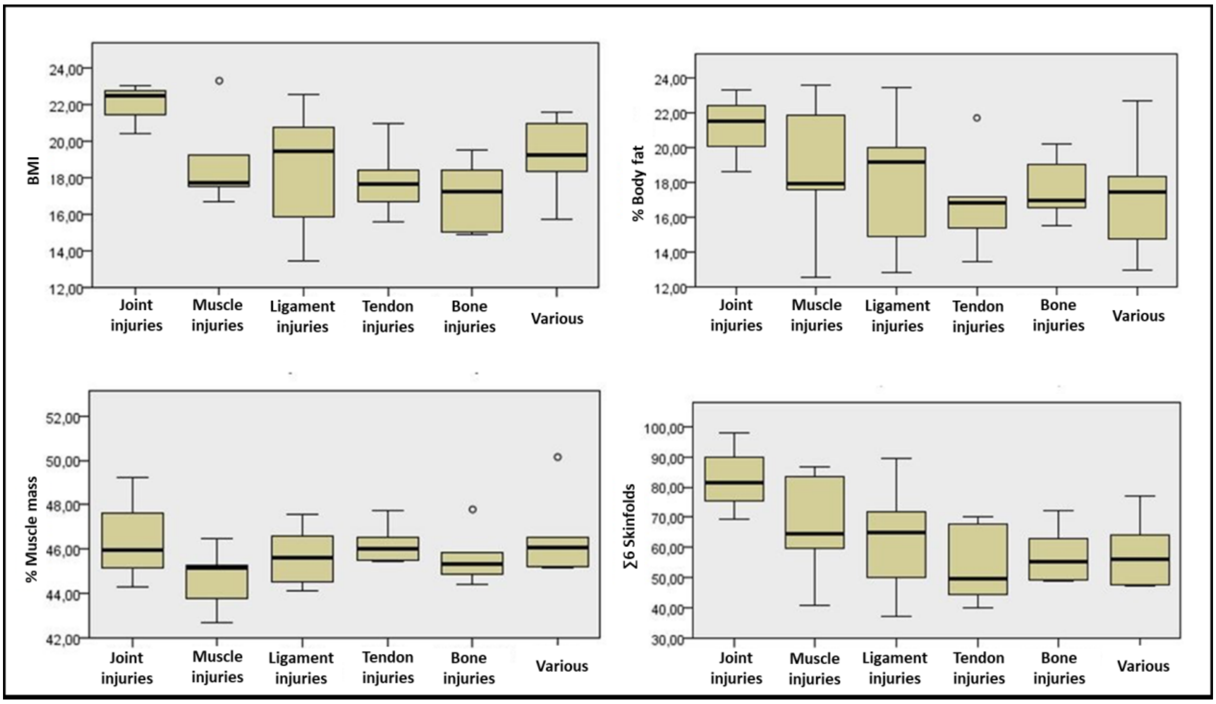


*Figure 1 BMI, % body fat, % muscle mass and the sum of 6 skinfolds in different types of injuries.*

***Relationship between body composition and severity of injuries***

The relationship between the body composition and injury severity indicated that there were also no significant differences in BMI (p=0.508), body fat percentage (p=0.518), muscle mass percentage (0.879), or in the sum of 6 skinfolds (p=0.598). Figure 5 shows the behavior of the groups of gymnasts in the complete sample, with grade 1, grade 2 or grade 3 injuries within the different body composition variables. It shows the anthropometric homogeneity in the three groups.

In the tops group, no significant differences were obtained for BMI (p=0.467), the body fat percentage (p=0.121), the muscle percentage (0.964) and in the sum of 6 skinfolds (p=0.172). The same applies to the group of bases for BMI (p=0.315), the body fat percentage (p=0.378), the muscle percentage (0.651) and the sum of 6 skinfolds (p=0.217).

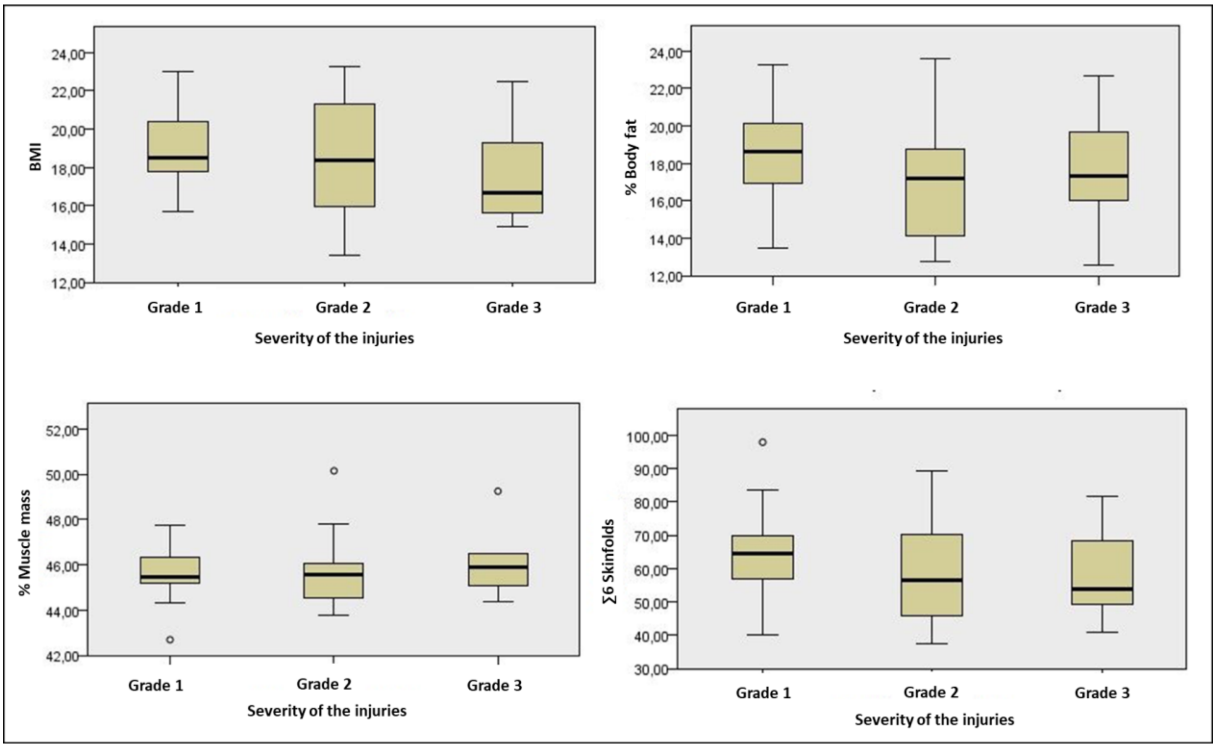

*Figure 5 BMI, % body fat, % muscle mass, and sum of 6 skinfolds in the different grades of injury severity.*

## DISCUSSION

To the authors' knowledge, this is the first study to analyze anthropometric indices and body composition as possible predictors of injury in GA. The relationship between morphological profile and injury incidence was investigated in a sample of female AG practitioners. The results of our analysis revealed no significant differences between any of the variables analyzed except for the tendon injuries, where the injured gymnasts had a higher BMI, the percentage of body fat and the total sum of skinfolds. This may be due to the small size of the sample or to the existence of variables that may have a greater influence on the injuries, such as the motor pattern and the intrinsic characteristics of this gymnastic discipline. These results are consistent with those of Seow & Massey (2022), where no significant correlation was found between injury incidence and body composition variables in pre-season soccer players. On the contrary, in the sample of 160 female youth soccer players researched by Sugimoto et al. (2018) no correlation was found between higher weight/BMI and previous musculoskeletal injuries. However, our results are not in agreement with those found in the 606 climbers in the study by Backe et al. (2009) where a higher BMI was significantly associated with a higher risk of injury.

Based on the type of injury, the most frequent were ligament injuries followed by tendon and bone injuries. This result is in line with the studies of Grapton et al. (2013), Vernetta et al., (2018) and Vernetta-Santana et al. (2022).

Although this study highlights a higher proportion of gymnasts who did not suffer injuries throughout the season, it should be noted that the number of injured gymnasts remained high. As for the severity of these injuries, they were mostly mild or grade 1, followed by moderate or grade 2, corroborating the results of other research in Spanish gymnasts and gymnasts from other countries. (Cainer & Nassar, 2005; Grapton et al., 2013; Purnell et al., 2010; Vernetta et al., 2018; Vernetta-Santana et al., 2022). It should be noted that a non-negligible percentage (21.2%) of the gymnasts in this study had a severe or grade 3 injury, which made them unable to return to training for a long period of time (more than 22 days).

In the study by Ursej et al. (2019) that included 129 competitive hip hop dancers, 114 of them female, no significant difference was found between anthropometric and body development variables associated with the occurrence of injury. It should be pointed out that our gymnasts, categorized as underweight, and overweight, posted no significant differences between those who suffered injury and those who were not injured.

The studies by Vernetta et al. (2018) and Vernetta-Santana et al. (2022) point out that in acrobatic gymnasts there is a higher percentage of injuries. These data may agree with those of our study, although without significant differences, since gymnasts with joint injury have higher values for BMI, percentage of body fat and the sum of skinfolds. It should be noted that in the artistic gymnasts in the study by Jakše et al. (2021), there is a high number of injuries in gymnasts with both the higher BMI and the percentage of body fat than the average of the gymnasts in our study. Age could also influence this differentiation, 13.66 years is the mean age of our gymnasts compared to 17.4 years for the mentioned artistic gymnasts. In AG, Purnell et al. (2010) point out that the critical age for injury is between 11 and 15 years old. The sample of their study has a mean age similar to that of our gymnasts, 13.4 years (SD=3.6) and 13.6 years (SD=2.6) respectively. On the other hand, the sample of trampoline, tumbling and AG gymnasts analyzed by Grapton et al. (2013) presented a mean age somewhat above the highest risk range (15±3 years).

No significant differences were found between the severity of injuries grade 1, 2 and 3 and the analyzed variables of body composition. The main limitation was the lack of evidence from other sports to compare these results.

## CONCLUSIONS

From the results obtained in this study we can conclude that there is a high percentage of injured gymnasts, with ligament injuries being the most frequent, but anthropometric indices and body composition do not seem to be related to the occurrence of injuries in AG women. It only seems to affect tendon injuries in the bases, with the injured gymnasts having a higher BMI, fat percentage and skinfold sum. Further studies with international level gymnasts are necessary.

It is important for coaches, gymnasts, physiotherapists and researchers to address the challenge of maintaining proper body composition, optimal recovery for return to training, and, most importantly, improved injury prevention that will enhance gymnasts' performance and health.

More studies are needed to investigate the prevalence of AG injuries as well as the factors associated with the occurrence of such injuries including among international level gymnasts, but also among initiation level gymnasts where the variation in body composition may be greater and could influence the injury profile in a more direct way. It would also be interesting to analyze whether the physical characteristics of one member of a competition group, and their relationship with those of their peers, can influence the injury tendency of the rest.

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