

**Title: Does Body Composition Play a Role in Predicting Sports Injuries? A Systematic Review**

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To appear in: Journal of Exercise Science and Medicine

This is a "Just Accepted" manuscript, which has been examined by the peer-review process and has been accepted for publication. A "Just Accepted" manuscript is published online shortly after its acceptance, which is prior to technical editing and formatting and author proofing. *Journal of Exercise Science and Medicine* provides "Just Accepted" as an optional and free service which allows authors to make their results available to the research community as soon as possible after acceptance. After a manuscript has been technically edited and formatted, it will be removed from the "Just Accepted" Web site and published as a published article. Please note that technical editing may introduce minor changes to the manuscript text and/or graphics which may affect the content, and all legal disclaimers that apply to the journal pertain.

**Please cite this article as:**

Amirshaghghi F, Pournemati P, Zandi Sh. (In Press). Does Body Composition Play a Role in Predicting Sports Injuries? A Systematic Review. *Journal of Exercise Science and Medicine*. Just Accepted publication Sep. 8, 2020. Doi: <http://dx.doi.org/10.32598/JSMED.11.2.1>

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Accepted Manuscript (Uncorrected Proof)

## **Abstract**

**Introduction:** This study is designed to review the literature on the role of body composition as a risk factor for injury in an athletic population.

**Materials and Methods:** We searched articles in English in Google Scholar Science direct, PubMed, WOS, Scopus, ProQuest, and Cochrane Library databases without time limit until 2020 using keywords related to "body composition" and "sports injury".

**Results:** Based on inclusion and exclusion criteria, 10 papers out of 1322 studies were comprehensively reviewed. It was found that body composition components are related to musculoskeletal injuries in the athletic population. Body mass index, weight and bone density are known as risk factors in the development of sports injuries.

**Conclusion:** This systematic review provides preliminary evidence of the association between body composition and prediction of injury in athletes. Defects in various aspects of body composition were recognized as potential risk factors for lower extremity injuries. Likewise, body composition should be considered when screening athletes.

**Keywords:** Body composition, Risk factor, Sports injury, Prevention

## Introduction

While physical activity is recommended as a beneficial healthy behavior, participation in sports and physical activities runs the risk of musculoskeletal injury[1]. Also, the costs of physical activity injuries are relatively high. In the Netherlands, for example, one in six injuries sustained during sports generates indirect costs attributable to the inability to attend work due to physical activity injuries, which is estimated at \$525 million a year [2]. Injury is likely to happen when the stress exerted on a tissue exceeds its capacity to sustain acute or chronic stress. Injury is the outcome of complex interactions between internal and external risk factors.[3] Striking a balance between absorbed and applied stress is usually essential for injury prevention programs. One of the most challenging issues in sports is Injury prediction and is considered as a key component of injury prevention, because the successful detection of a risk predictor prepares the ground for the adoption of effective preventive measures. On the other hand, ensuring safety in sports and other forms of physical activity is a prerequisite for sustained engagement in sports and preservation of a healthy and active lifestyle. Accordingly, the prevention, reduction and control of internal risk factors are major goals for sports specialists in particular and the society in general. A key factor in preventing sports injuries is identifying risk factors and causes of the injury[3].

Abnormal body composition is a known risk factor for many diseases, including cardiovascular disease (CVD)[4], chronic kidney disease [5], and type 2 diabetes (DM)[6]. Musculoskeletal disorders associated with abnormal body composition are often attributed to elevated mechanical load[7], which by increasing microtrauma in tissues can eventually cause acute and chronic damage. For example, one of the musculoskeletal injuries, tendon injury, is increasingly recognized as a major cause of complications in the labor force[8] as well as active [9] and inactive [9] individuals. Abnormal body composition may also be related to poor fitness (e.g., strength and endurance) and poor neuromuscular control, such as coordination and balance, which increases the risk of injury for people. Given the growing tendency to engage in any type of physical activity, it is essential to appreciate the predictor of sports injury so that proper interventions can be designed and adopted in order to decrease the risk of injury[3]. Therefore, the purpose of this systematic review is to look into the role of body composition as risk factor for prediction of sport injuries.

## Methodology:

### Criteria for selecting articles:

After searching several databases, all the identified articles were initially added to the Endnote software and duplicates were removed. After the omission of duplicates, all titles and abstracts were reviewed to identify articles relevant to the research topic. Inclusion criteria involved research that predicted injury or examined risk factors, their study population had physical activity (athlete), or any sporting experiences (such as recreational, university, professional, etc. sports), their participants had a history of lower or upper extremity injuries and at least one of the risk factors consisted of body composition or related components. Exclusion criteria covered research that failed to state the main idea, including review studies, expert opinions, and studies that were under currently review such as annual meetings, master's theses, and animal studies. The articles excluded from the research were discussed by two researchers and any dispute was settled by the head of group. After

reviewing the abstracts, the full text of the articles was studied and categorized independently by two researchers for eligibility.

### Search strategy:

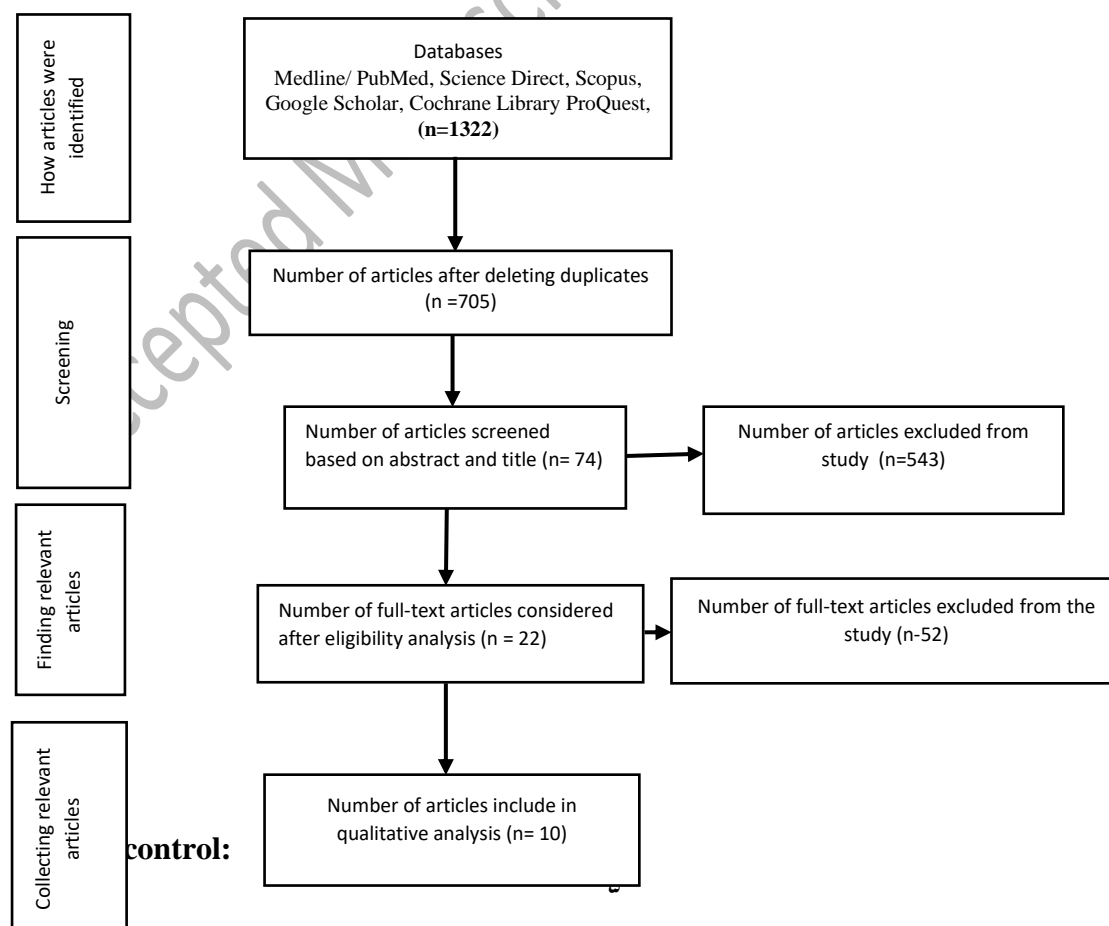
Articles in English were searched in databases of Google Scholar, Science direct and PubMed, WOS, Scopus, ProQuest, Cochrane Library without time limit until 2020 using keywords such as body composition, waist circumference, body mass index, air-plethysmography chamber, dual-energy x-ray, DXA, skinfold, caliper, fat free mass, total body fat, lean body mass, fat-free bone, fat-free adipose tissue, fat-free muscle, waist-to-hip ratio, lower extremity injuries, upper extremity injuries, sport injury, risk factors, predication, sport, prospective studies

Many studies tend to use BMI to assess body composition. Other assessments of body compositions such as waist-to-hip ratio and waist circumference are also employed to determine body composition. Modalities such as imaging and DXA are scantily used in research due to their high cost. In light of the above, we utilized the above-discussed methods in this study without considering any restrictions in terms of time and language for studies. Articles not written in English or Persian were translated via Google Translate.

### Data extraction

In the present study, the problem under study was studied in several stages, and the findings were collected, analyzed and interpreted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) [10] (Figure 1). Results pertained to body composition and injury were extracted from relevant studies.

Figure (1): Search results during the review process



To evaluate the quality of the selected studies, the adjusted checklist of the Cochrane Screening and Diagnostic Tests Methods Group (Cochrane methods) was used [11]. Two researchers evaluated the quality of articles and 11 items were reviewed[12].

The 11 items assessed in this paper were as follows: “study design” (1 for prospective and 0 for retrospective); “level of evidence” (5 for level 1, 4 points for level 2; 3 points for level 3; 2 points for level 4; 1 point for level 5); “selection criteria” (1 point for clear explanation of inclusion and exclusion criteria); “setting” (1 point for presenting sufficient information to pinpoint setting); “demographic information” (1 point for assessing mean, median and standard deviation, and reporting age and gender); “screening tool” (1 point for details of screening tool that enable duplication of the test as well as details of test device or instruments, and protocols of screening); “statistical analysis” (1 point if there are details on mean, median, standard deviation, confidence intervals and predictive value); “screening test’s reliability” (1 point if reliability has been reported); “percentage missing” (1 point if all subjects have been measured or missing data or withdrawals have been reported) ; “outcome” (1 point for a clear definition of methods used for discussing outcomes) ; “confounders” (1 point for identifying and considering key confounders and prognostic factors in the design study). Hence, ideally, a total score of 16 could be attained. Given the absence of any guidelines on rating scores, we considered four categories: excellent quality (16 points), good quality (15–14 points), fair quality (13–10 points) and poor quality (< 10 points).

## Results

A total of 1322 articles were identified after searching the above keywords in different databases. Then, after removing duplicates (705), 74 articles were opted for abstract review. Based on the inclusion and exclusion criteria, 22 full-text articles were obtained. Twelve articles were omitted from the review process because they did not meet our criteria. [12] Finally, 10 articles were selected for comprehensive review (Figure 1).

The body composition components commonly used to predict injury in these articles was BMI, with other components such as waist circumference, waist-to-hip ratio, imaging and DXA scanty used in these studies. The BMI classification is primarily based on the recommendations made by the World Health Organization.

In articles examined in our review, a wide array of sports had been considered. As far as the demographics is concerned, research had chiefly focused on male athletes. Besides, studies often investigated team sports with individual sports receiving little attention. The bulk of research dealt with professional athletes and scant attention had been dedicated to amateur or non-professional athletes.

In most research, a valid definition of injury had been presented, which usually describes an accident during sports and exercises that caused an athlete stay away from training and competitions. The time frame of the research covered the entire of a competition season.

## Quality assessment results

The results related to the quality assessment are illustrated in Table (1). All studies were evaluated based on the adjusted quality index[11] . For most articles, the quality index score was higher than 14, indicating that the selected articles had desirable quality. The predictive role of body composition in sports injuries had been investigated in 10 articles, as reported in Table 1 (Table 1).

Table 1. Methodological quality of studies

Study	Design <sup>1</sup>	Level of Evidence <sup>2</sup>	Selection Criteria <sup>3</sup>	Setting <sup>4</sup>	Demographic Information <sup>5</sup>	Screening Tool <sup>6</sup>	Statistical Analysis <sup>7</sup>	Reliability of screening test <sup>8</sup>	Percentage Missing <sup>9</sup>	Outcome <sup>10</sup>	Confounders <sup>11</sup>	Total score (max = 16)
Grant et al.[1]	1	4	1	1	1	2	1	1	1	1	0	14
Gabbe et al.[2]	1	4	1	1	1	2	1	1	1	1	0	14
Benneil et al.[3]	1	4	1	1	1	2	1	1	1	1	1	15
Hadala et al.[4]	1	4	0	1	1	2	1	1	1	1	1	14
Twitchett et al.[4]	1	4	0	1	1	2	1	1	1	1	0	14
Gaida et al [5]	0	2	1	1	1	2	1	1	1	1	0	11
Kemper et al.[6]	1	4	1	1	1	2	1	1	1	1	1	15
Jesper sen et al.[7]	1	4	1	1	1	2	1	1	1	1	1	15
Henderson et al.[8]	1	4	1	1	1	2	1	1	1	1	1	15
Fousekis et al.[9]	1	4	1	1	1	2	1	1	1	1	1	15

Table 2. Characteristics of the included studies

Study	Subject characteristics Population	No. of subjects	Sex (M:F)	Age (year) ; mean (SD)	Outcome measure	Injury definition  Criteria for definition of injury	Study results
Grant et al.[1]	Division I university hockey player	79	79:0	20.2 : 1.6	Body fat percentage was measured based on the bioelectrical body composition	They defined injury as any events that can directly hamper the participation of an athlete in on-ice activity for at least one day.	The possibility of injury for a player with BMI $\geq 25$ kg/m <sup>2</sup> was 2.1 times (95% CI, 1.1-3.8) more than that of a player with a BMI $< 25$ kg/m <sup>2</sup>
Gabbe et al.[2]	Australian football clubs players	174	174:0	N/A	body mass index	Injury of an elite player that leads to the missing of least one game	Body weight was an independent predictor of hamstring injury in players $\geq 25$ years of age. Risk ratio=1.07 (1.01—1.15)
Bennell et al.[3]	track and field athletes	101	58:53	20.4 : 2.1	Total bone mineral content, soft tissue composition and regional bone density were measured by dual-energy X-ray absorptiometry and anthropometric methods.	The diagnosis of stress fractures were based on positive results on clinical examination, CT scan and triple-phase isotope bone scan.	None of the risk factors assessed were able to predict the stress fractures incidence in men. In female athletes, nonetheless, there were significant risk factors such as low lean mass in their lower limb, low bone density, leg



							length discrepancy, and a low-fat diet.
Hadala et al[4]	America's Cup yachting crew	61	61:0	29.5: 8.17	BMI, body weight, skinfold thickness, fat, muscle and limb body	An injury during a scheduled sailing or training that leads to pain, tissue damage or disability, and requires treatment from the medical staff	Crew members with overuse injuries showed significantly lower skinfold thickness and also lower muscle mass percentage. Athletes suffering more than one injury had lower weight in both. Athletes with injuries at the upper extremity had the lowest weight, the lowest skinfold thickness, the lowest muscles mass also, and the lowest body fat weight.
Twitchett et al.[10]	elite dancers	30	0:30	19 : 0.7	Body density, body weight, fat percentage were measured using caliper, standard weighing scales and related formula	They defined dance-related injury as a physical disorder caused by stress or other factors related to	Body fat percentage was linked to the time a dancer was obliged to adjust activity as a result of injury ( $r = -.614$ , $p = 0.026$ ).

						performance, training, rehearsal, touring or other conditions of dance life, which influences ability to fully engage in ordinary dance training, or physical activities	
Gaida et al [5]	National Basketball League and The Australian Basketball Association clubs	39	0:39	21:3	They measured body composition by a dual energy X-ray. Also, the lean body mass and total regional fat were measured by a body scan.	Ultrasound examination of the both patellar tendons. Tendons were treated as pathological if both longitudinal and transverse scans revealed a hypoechoic lesion.	The waist to hip ratio was higher in athletes with unilateral patellar tendinopathy. Also, the tibia length was longer relative to stature in these athletes.
Kemper et al.[6]	Elite soccer players	101	101:0	N/A	fat percentage, body mass index, fat free mass index Growth in height were measured	Any physical complaint originating from the football match or training, whether it needs medical attention or leads to absence from football activities	$\geq 0.6$ cm growth in a month ( $p=0.03$ ; 95% CI: 1.06–2.52; OR=1.63), $\geq 0.3\text{kg/m}^2$ increase in BMI over a month ( $p=0.03$ ; 95% CI: 1.04–2.49; OR=1.61) and the low fat percentage
Jespersen	Preschool to	632	311:32	9.6 :	Weight and	Injuries	Children

et al.[7]	fourth-grade schools attending the CHAMPS Study-DK		1	0.9	height and total body fat were measured by dual energy X-ray	were recorded using the International Classification of Diseases (ICD-10), WHO.	that were considered overweight in terms of BMI and TBF% were most susceptible to the lower extremity injuries (IRR 1.38; 95% CI: 1.05 to 1.81). Children who were assumed to be overweight according to BMI and TBF% were highly susceptible to lower extremity injuries (IRR 1.38; 95% CI 1.05 to 1.81).
Henderson et al.[8]	English Premier League soccer players	36	36:0	22.6 : 5.2	lean mass	Hamstring injury described any injury that hampered the player from participating in general training for 48 h or more	Lean mass had no significant effect on the overall model (p = 0.068). At the practical scale, 95% CI for its inclusion were on the verge of unity (0.71–1.01), showing that athletes with lower lean mass are more prone to injury.

Fousekis et al.[9]	professional soccer teams	100	100:0	N/A	body mass index, body weight	An ankle sprain that leads to the missing of at least 1 practice session or game by the player was registered by medical staffs of each club's	In players with elevated body mass index (95% CI, 1.42-46.63; OR = 8.16; P=.018), and body weight (95% CI, 1.37-23.95; OR = 5.72; P = .017) the risk of a noncontact ankle sprain was significantly higher.
BMI = body mass index N/A= not available OR = odd ratio RR= risk ratio TBF = total body fat							

## Discussion

Weight gain and BMI are associated with an augmented risk of injury. In heavy-weighted players, body fat is potentially higher and they are less fit, which makes them more prone to injury. Given that lean muscle mass of athletes has relatively increased compared to the general population, it is worth noting that BMI in the former group is a general yardstick of body mass to height ratio and does not provide a measure of body fat or body composition in particular[13].

In the study of Gabbe et al. [14], since 78% of the elite group under study were Australian professional football players, the elevated weight and BMI are likely to be pertained to the higher lean muscle mass. One clear limitation of this study is its failure to consider the body composition[14].

A study by Fousekis et al. [15] revealed that players with elevated BMI (OR=8.16; 95% CI, 1.42-46.63, P=.018) and elevated body weight (OR=5.72; 95% CI, 1.37-23.95, P=.017) had a considerably higher risk of non-contact ankle sprains.

In a study by Bennell et al. [16], none of the risk factors investigated could predict stress fracture in men. Nonetheless, in female athletes, significant risk factors were low bone density, lower adipose tissue in the lower extremities, and unequal leg length. Multiple logistic regression indicated that menstrual age and leg circumference are the best independent predictors of stress fracture in women. This bivariate model accurately assigned 80% of female athletes to groups with/without stress fracture. These results suggest the possibility of identifying female athletes who are more prone to this bone injury. Women

experiencing stress fractures had a lower bone density and significant defects in the axial and appendicular skeleton. Low axial bone density could be an measure of risk factors for stress fractures, such as ovarian dysfunction or poor diet. On the contrary, bone density was unable to predict the occurrence of stress fractures in men. This could be ascribed to higher regional bone density in males compared to females. Female athletes suffering from stress fractures were less muscular than female athletes who did not have any fractures. Thus, this defect seems to be a regional phenomenon, because the total lean mass and hip circumference were not distinct between the two groups. The muscle mass and stress fracture correlation can be explained by decreased regional bone density, because both leg circumference and dual-energy X-ray absorptiometry of the lower limb lean mass were positively associated with tibial and fibula bone density ( $r$ , 0.37 to 0.41). The second possible justification is that the ability to absorb muscle shock is a major factor to reduce forces applied to the bone [17]. The in vivo animal models have exhibited that muscle contraction increases bone strength and protects against fractures [18-20].

In the study of Hadala et al.[21], low-weight athletes were more likely to suffer chronic and recurrent injuries in lower extremities. Lack of weight loss during competition was observed to be linked to the occurrence of injury. The thickness of subcutaneous fat is commonly analyzed to assess nutritional status and physical changes associated with the conditioning. This data illustrate that the nutritional behavior of athletes engaged in severe physical activity has been inappropriate, or at least underestimated. Low levels of subcutaneous fat are retained in other aerobic exercises for many years [22, 23]. This attributes were not applied to the America's Cup sailors. In addition, these athletes are busy with heavy training courses for several years. One of the noticeable findings of the study [21] was that a thicker skinfold during competition leads to traumatic injuries and higher chance of lower extremity injuries. Elevated BMI was observed in sailors with acute injuries. Constant high body fat mass indicates that this parameter has not been properly oriented or at least underestimated in the team. The appropriate body fat assigned for elite athletes was previously estimated at 15%. For instance, Rico Sanz [24] expressed that the percentage of football players' body fat should be about 10%. The adverse effect of body fat on motor performance observed in these athletes has been reported in other sports methods [24, 25] Maximizing the ratio of functional muscle mass to fat mass is a key factor in the recruitment of crew [26]. Between 2004 and 2007 seasons, there was a statistically significant difference in muscle mass [21]. Physiologically, this represents a positive change because muscle strength is proportional to muscle size[27]. Larger muscle mass can be beneficial, especially in sailors in the high-intensity group. In fact, a large muscle mass will generate more power[26, 28]. An increase in muscle mass suggests a higher muscle cross-sectional area, and consequently higher strength and power in those limbs. The data on muscle mass of different groups of athletes in this study confirms this hypothesis. The total muscle mass is associated with the type and site of the injury. A lower increase in muscle mass appears to contribute to injuries caused by the over-use of the upper extremities.

The study by Kemper et al.[29] indicates the relative risk for a monthly increase in BMI. The results of this study showed that a 0.3 increase in this index is associated with a 1.61 higher possibility of injuries in adolescent athletes. In previous studies, a large increase in BMI was also observed in adolescent athletes [30]. When interpreting the association between higher

BMI and injury in adolescent athletes, it is important to note whether this improvement is greater than expected of normal growth and maturity[31]. The link between diminished BMI and injury occurrence was not significant in this study, but BMI reduction could be significant. Trainers and medical staff need to keep an eye for high BMI reduction in youth football players [32]. Players with a low fat percentage are subjected to a greater risk for injury (odds ratio score: 1.81).

Twitchett et al. [33] found that the time a ballet dancer needs to reduce or adjust her level of activity for injury is significantly longer in individuals with lower body fat percentages. Another study on this group of athletes reported that other criteria such as lower BMI prolongs the time required to return from an injury [34]. The low body fat may be associated with several factors, but it is clearly known that dancers tend to limit their diets, especially calorie intake [35]. Factors such as energy, fatty acids, proteins and vitamins influence collagen synthesis and wound healing [36, 37]. Hence, a limited diet may partly explain the association between longer recovery time and lower body fat percentage.

In a study by Gaida et al.,[38] individuals with unilateral tendinopathy had a higher waist-to-pelvic ratio than that of controls, indicating a larger distribution of abdominal fat than gluteus femoral fat [39]. The distribution of human fat is controlled by a complex interaction of hormones, which is particularly affected by the female sex hormones (estrogen and progesterone)[40]. This study suggests hormonal changes due to gender disparity in the incidence of injuries such as patellar tendinopathy.

In a study by Jespersen et al. [41], a comparison can be drawn between the criteria that determine body composition in relation to injury. The results revealed that the risk of injury in lower extremities in overweight children is higher. In comparison of the two different measures of obesity, the percentage of total body fat (TBF%) is a higher risk factor than obesity identified by BMI. This shows that a high ratio of adipose is a good predictor of lower extremity injuries, which could be attributed to a lower ratio of lean muscle mass. On the contrary, Kaplan et al. [42] stated that body weight is a stronger risk factor than adiposity for injury.

This has been demonstrated in a study that compared different body composition criteria (BMI, body fat, height and weight) to injury risk in a group of 98 high school players suffering from 28 injuries recorded by trainers. Another study on American football has reported the rate of injury by weight, body fat, lean body mass and BMI in high school football [43]. The results of this research revealed that obesity expressed as a percentage of total body fat (TBF) provides a solid prediction of BMI with regard to the extent and type (overuse / traumatic injury) of musculoskeletal injuries in military staff[44]. A direct comparison may not be possible due to disparity in TBF measurement techniques, injury recording methods, study values, age and specific exercise in diverse settings.

Still, in some sports, the impact of elevated mechanical load during weight bearing or impact may be more noticeable than in other sports. Injury patterns may also vary relative to different types of injury. It can be argued that traumatic injuries caused by severe impact due to overweight of muscle / fat distribution are stronger than over-use injuries, where tissue quality (e.g., endurance and muscle strength) is of paramount importance.

## Conclusion

In general, it can be concluded that abnormal body composition may be associated with the prediction of injury and strength of prediction for body composition criteria are variable. Hence, trainers are recommended to use body composition factors in pre-participation assessment to prevent injury.

## Ethical considerations

Compliance with the principles of research ethics: Since this is a systematic review, there are no ethical principles to be observed.

**Contribution of authors:** All authors have contributed equally to this article.

**Conflict of interest:** There is no conflict of interest to declare.

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