Relationship between Maximum Oxygen Consumption (VO2) and the Occurrence of Musculoskeletal Injuries

Alexandre Pedro Nicolini[1] Vitor Viana Costa[1] Elizabeth Biruel[1] Alberto de Castro Pochini[1] Carlos Vicente Andreoli[1]

[1] Department of Sports Medicine, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Exerc Sport Med 2025;01(1):s00451812845.

Address for correspondence Alexandre Pedro Nicolini, MD, MSc, Universidade Federal de São Paulo (UNIFESP), Estado de Israel street, 713, Zip Code: 04022-001, São Paulo, SP, Brazil (e-mail: apnicolini@uol.com.br).

Abstract

Musculoskeletal injuries are extremely common in sports and have a multifactorial etiology, involving both intrinsic and extrinsic risk factors, as well as modifiable and non-modifiable factors. Among the modifiable intrinsic factors, aerobic capacity stands out, which is believed to be inversely proportional to the occurrence of such injuries. The present study is a systematic review examining the correlation between aerobic capacity and the occurrence of musculoskeletal injuries. The diagnostic hypothesis proposed is that athletes with greater aerobic capacity have a lower rate of musculoskeletal injuries. Method: search for the terms designated on the platforms: PUBMED-Central, PUBMED-Medline, EMBASE, LILACS, and SportDiscus. The PRISMA checklist was used for analysis and evaluation performed by 3 independent examiners. Results: 632 articles were found initially, and, after selection, 7 final articles were included. The following variables were analyzed: type of study, population studied, way in which aerobic capacity was measured, and the outcome. Of the 7 articles analyzed, 4 articles found significance between a greater aerobic capacity and a lower occurrence of musculoskeletal injuries. Discussion: few studies were found in the literature with varied methodology, population, and measurement of aerobic capacity. Conclusion: a greater aerobic capacity has, apparently, a protective effect for musculoskeletal injuries. More studies with better methodological quality are needed.

Keywords
- ► oxygen consumption
- ► aerobic training
- ► musculoskeletal injuries
- ► aerobic capacity

Introduction

Musculoskeletal injuries are the most common in sports, corresponding to 80%, and are responsible for periods of absence or even interruption of practice permanently. In addition to periods of absence and even permanent career interruption, musculoskeletal injuries also lead to economic and financial damage in the short and long term.[1–3]

Injuries can be classified according to the time away from activities as: non-reportable, in which the athlete does not interrupt activities; minor, interrupts activities for a period of 1 to 7 days; moderate, for a period of 8 to 21 days; greater, more than 21 days of loss, and, finally, severe, with permanent disability. Another way of classification divides musculoskeletal injuries into acute (or traumatic), which includes bruises, sprains, strains, dislocations, and fractures and chronic (or overload), which include tendinopathies and stress fractures. The first group is the most frequent, with bruises, muscle injuries, and minor sprains making up about 54% of the total amount.[1–4]

They have a multifactorial etiology for their occurrence, and the risk factors can also be divided into two categories, intrinsic and extrinsic. Among the intrinsic factors, we can mention age greater than 25 years, female gender, history of previous injury, body composition (weight / height / BMI), biomechanics, muscle strength and muscle imbalance,

received September 7, 2025
accepted after revision September 12, 2025

DOI https://doi.org/10.1055/s-0045-1812845.
ISSN XXXX-XXXX.

Thieme Revinter Publicações Ltda., Rua Rego Freitas, 175, loja 1, República, São Paulo, SP, CEP 01220-010, Brazil

ligament hyperlaxity, psychosocial factors, habits (such as smoking), and aerobic capacity. As for extrinsic factors: footwear and clothing, climate, environment, and rules of the sport. Both intrinsic and extrinsic factors can be subdivided into modifiable and non-modifiable factors.[1–4]

Modified factors are extremely important to reduce the incidence of such injuries. Through specific training plans, with a focus on physical conditioning, skills development, and an increase in aerobic capacity, attempts have been made to prevent and/or minimize all the undesirable effects related to these injuries previously reported.

Among the modifiable intrinsic factors reported in the literature, aerobic capacity stands out. It is believed that athletes with greater aerobic capacity have less fatigue; Fatigue would be responsible for an alteration in muscle recruitment, alteration in the pattern of force distribution and proprioception, and finally, it would generate musculoskeletal injuries. Despite being frequently reported as an important risk factor, there are few conclusive studies in literature, and, for the most part, they are carried out with the military population or professionals with high physical demands, such as police and firefighters; studies involving athletes are rare. The present study is a systematic review aimed at establishing a relationship between aerobic capacity and the occurrence of musculoskeletal injuries.[3,5–7]

Main Objective

Establish a relationship between aerobic capacity and the occurrence of musculoskeletal injuries in athletes. Protective effect?

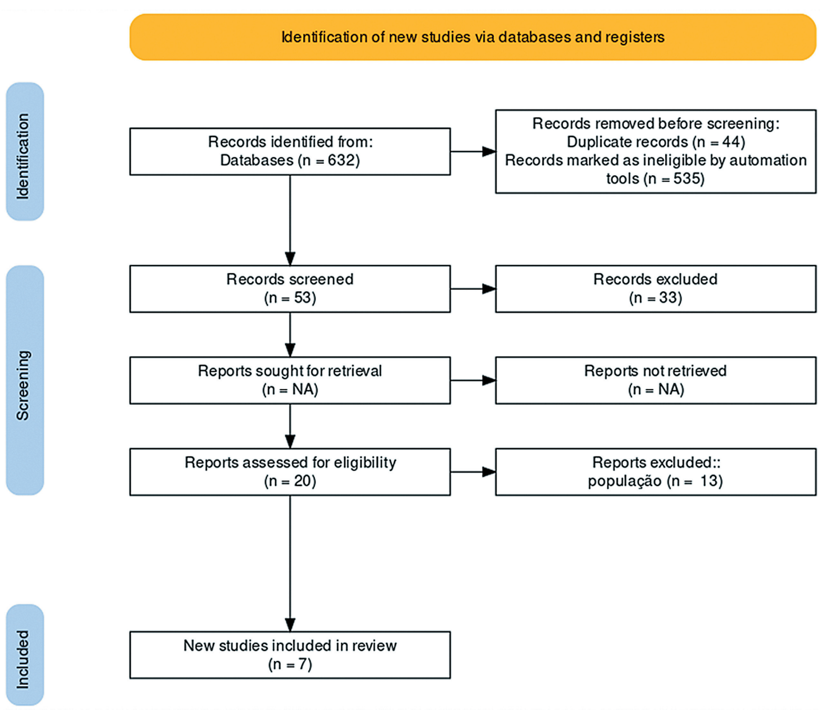
Hypothesis

Athletes with higher aerobic capacity have a lower rate of musculoskeletal injuries.

Methods

After registering on the Prospero platform, a search was carried out with the following terms: "Aerobic training" AND "musculoskeletal injuries" "Aerobic capacity" AND "musculoskeletal injuries" "Oxygen consumption" AND "musculoskeletal injuries" (“Aerobic fitness” OR “Physical fitness”) AND “musculoskeletal injuries” (“Oxygen consumption” OR “Aerobic training”) AND (“musculoskeletal injury” OR “musculoskeletal injuries”) “Cardiorespiratory endurance” AND (musculoskeletal AND lesion*) ("musculoskeletal injuries" OR (musculoskeletal AND injury*) OR "musculoskeletal lesions" OR (musculoskeletal AND lesion*) OR "Musculoskeletal diseases" OR "Musculoskeletal diseases") AND ("Aerobic training" OR "Aerobic training" OR "Endurance Training" OR "Aerobic training" OR "Training OR "Running Training" OR "Endurance Training" OR "Oxygen Consumption" OR "Oxygen Consumption" OR "Oxygen Consumption" OR "Oxygen Requirements" OR mh:G03.680 OR mh:SP4.031.100 .200,247,458.00 3) (’oxygen consumption’/exp OR ’oxygen consumption’ OR ’aerobic training’/exp OR ’aerobic training’) AND (’musculoskeletal diseases’/exp OR ’musculoskeletal diseases’ OR ’musculoskeletal injury’ OR ’musculoskeletal injuries’) AND (’athlete’/exp OR athlete) AND ’randomized controlled trial’/de ("Oxygen consumption" OR "Aerobic training" OR "Aerobic training") AND ("Musculoskeletal Diseases" OR "musculoskeletal injury" OR "musculoskeletal injuries") on search platforms: PUBMED-Central, PUBMED-Medline, EMBASE, LILACS and SportDiscus.

The results found were placed in the Rayyan application, and all results were then analyzed by 3 independent examiners in a blinded manner. To analyze the results found, the PRISMA checklist was used. A total of 632 articles were found, and the result was that 7 articles were included. The PRISMA flowchart follows:



Authors	Year	Journal	Study type	Population	VO2 measurement	Results
Ostenberg et al	2000	Scandinavian Journal of Medicine and Science in Sport	Prospective Cohort	123 women – soccer players (14-39)	Indirect measure – 20-m shuttle run test of increasing velocity	- No difference – aerobic condition - Injury group x no-injury group
Frisch et al	2011	Scandinavian Journal of Medicine and Science in Sport	Prospective Cohort	67 men – soccer players, young (15-19)	Indirect measure – 20-m shuttle run test of increasing velocity	- Tendency -protective effect VO2 - No significant difference VO2 max (mL/min/kg) Hazard ratio = 1.03 CI = 0.96/1.11 p = 0.461
Chalmers et al	2013	Journal of Science and Medicine in Sport	Prospective Cohort	382 men, soccer players / junior categories (14-19)	Indirect measure – 20-m shuttle run test of increasing velocity	- < speed – 20m (<VO2) ↑ risk - injuries (leg / foot) (p = 0.045)
Grant el al	2014	Sports Health	Prospective Cohort	79 men, hockey players / high school and college (17-24)	300-m shuttle run (6 laps - 25m)	- For every 1 second improvement in the test (>VO2), the probability of injury decreased by 28% (p = 0.014)
Gastin et al	2015	International Journal of Sports Physiology and Performance	Prospective Cohort	69 men, Australian football players – elite (17-32)	Indirect measure – 6-min run + 40-m sprint + 6 × 40-m sprints	- 6 min run: every 1 meter further run - risk of injury ↓ 0,6% (OR= 0.994 / p = 0.051)
Watson et al	2016	Clinical Journal of Sports Medicine	Prospective Cohort	23 men / 20 women Soccer player High school age (mean 20)	Direct measure	- VO2 max lesion x VO2 max non-lesion p= 0.010 - VO2 max - significantly related to injury - univariate / multivariate analysis - OR 0.97: increase of 1 unit relative VO2 max - ↓ 3% risk of injury
Watson et al	2017	The Orthopaedic Journal of Sports Medicine	Case-control	54 women / young athletes (13-18)	Direct measure	- Subject with injury < VO2 (54.9 ± 7.3 vs 58.3 ± 8.5 mL/kg/min) p= 0.13 Tendency

Results

Included 7 final studies. The following variables were analyzed: type of study, population studied, how aerobic capacity was measured (directly or indirectly), and the outcome found. ►**Table 1** shows the studies included and the variables mentioned.

Discussion

Musculoskeletal injuries are very prevalent in sports and cause several damages to practitioners. Of multifactorial etiology, aerobic capacity stands out as a modifiable risk factor that, if increased, could generate a lower occurrence of such injuries. There is common sense in the medical/sporting environment about this relationship between aerobic capacity and the occurrence of injuries, and that athletes with a lower volume of oxygen consumed during physical activity develop fatigue earlier, which would be responsible for the greater number of injuries suffered. Despite this common sense, literature is scarce in relation to studies conducted with good methodology involving athletes.[4,5]

This lack of studies is confirmed in this systematic review, in which only 7 studies were included.[1,3,5,8–11] Six prospective cohorts[1,5,8–11] with similar study design in which the studied population was analyzed in terms of aerobic capacity subsequently followed up for a specific period of time, and observed the occurrence of musculoskeletal injuries. The remaining work is a retrospective case-control study 3 comparing two groups: athletes who presented injury and athletes who did not present injury, and, retrospectively, the initial aerobic capacity of the groups was seen.

Regarding the main objective of the study, four studies showed significant results on the protective effect of greater aerobic capacity: Chalmers S,[10] Gastin PB,[11] Grant JA.[1] and Watson A. (2016).[5] That is, an inversely proportional relationship between maximum oxygen consumption and risk of injury, corroborating the instinctive consensus already mentioned.

Two studies found a tendency towards a protective effect, but without significance: Frisch A.[9] and Watson A. (2017).[3] And finally, one last study found no relationship, Östenberg A.[8]

Another variable analyzed was how aerobic capacity was measured, that is, whether it was performed directly through an ergospirometric test or indirectly through running tests. What can bring bias to the analysis? Five studies were used to run tests to obtain the results: Chalmers S,[10] Gastin PB,[11] Grant JA,[1] Frisch A,[9] Östenberg A.[8] Only two used direct measurement: Watson A (2016)[5] and Watson A (2017).[3]

The studies also differ greatly regarding the population studied, in relation to sex, age, and modalities. Bedno et al[12] in 2018, reported in their study that women are more susceptible to injuries, which makes the analyzed gender an important bias in the comparison between the studies found. The age of the population is also another very predominant bias in the analysis; Lisman PJ et al[4] in 2017 carried out a systematic review on the risk factors for the occurrence of orthopedic injuries in sports and reported that the greater the age, the greater the occurrence. Watson A et al[5] in their 2016 study noted an increase in lesions in patients aged over 25 years.

As previously mentioned, most studies in the world literature analyze the military population or professional activities with high physical demand. These studies also report an inversely proportional relationship between aerobic capacity and the prevalence of injuries. Anderson MK (2016)[13],; Knapik JJ (2001),[6] Heller R (2019),[14] Bedno AS (2018),[12] Sharma J (2019),[15] Grier TL (2017),[16] Heebner NR (2017),[17] Molloy JM (2012),[18] Lentz L (2019)[19] and Shaffer RA (2006)[20] are some of the most important studies conducted in this population profile. These studies also fail in relation to the standardization of the population and the measurement of oxygen consumption.

There is a need for more studies involving athletes with good methodology, with a better definition of the population (gender / age / modality) that allows a better comparison, with measurement performed directly with an ergospirometric test, and, preferably, the risk factors researched are analyzed individually and jointly. However, these studies are difficult to perform because they require many individuals to be studied, with a high cost and a long follow-up.

Conclusion

Few studies suggest an inversely proportional relationship between maximal oxygen consumption and the occurrence of musculoskeletal injuries, with the need for more studies with greater uniformity and better methodological quality.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1 Grant JA, Bedi A, Kurz J, Bancroft R, Gagnier JJ, Miller BS. Ability of preseason body composition and physical fitness to predict the risk of injury in male collegiate hockey players. Sports Health. 2015;7(01):45–51
2 Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. Sports Med. 1990;9(04):205–215
3 Watson A, Brindle J, Brickson S, Allee T, Sanfilippo J. Preseason Aerobic Capacity Is an Independent Predictor of In-Season Injury in Collegiate Soccer Players. Clin J Sport Med. 2017;27(03):302–307
4 Lisman PJ, de la Motte SJ, Gribbin TC, Jaffin DP, Murphy K, Deuster PA. A systematic review of the association between physical fitness and musculoskeletal injury risk: Part 1–Cardiorespiratory Endurance. J Strength Cond Res. 2017;31(06):1744–1757
5 Watson A, Brickson S, Brooks MA, Dunn W. Preseason Aerobic Fitness Predicts In-Season Injury and Illness in Female Youth Athletes. Orthop J Sports Med. 2017;5(09):2325967117726976
6 Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH. Risk factors for training-related injuries among men and women in basic combat training. Med Sci Sports Exerc. 2001;33 (06):946–954
7 Drain JR, Reilly TJ. Physical employment standards, physical training and musculoskeletal injury in physically demanding occupations. Work. 2019;63(04):495–508
8 Östenberg A, Roos H. Injury risk factors in female European football. A prospective study of 123 players during one season. Scand J Med Sci Sports. 2000;10(05):279–285

9 Frisch A, Urhausen A, Seil R, Croisier JL, Windal T, Theisen D. Association between preseason functional tests and injuries in youth football: a prospective follow-up. Scand J Med Sci Sports. 2011;21(06):e468–e476

10 Chalmers S, Magarey ME, Esterman A, Speechley M, Scase E, Heynen M. The relationship between pre-season fitness testing and injury in elite junior Australian football players. J Sci Med Sport. 2013;16(04):307–311

11 Gastin PB, Meyer D, Huntsman E, Cook J. Increase in injury risk with low body mass and aerobic-running fitness in elite Australian football. Int J Sports Physiol Perform. 2015;10(04):458–463

12 Bedno SA, Nelson DA, Kurina LM, Choi YS. Gender differences in the associations of body mass index, physical fitness and tobacco use with lower extremity musculoskeletal injuries among new US Army soldiers. Inj Prev. 2018;0:1–6

13 Anderson MK, Grier T, Dada EO, Canham-Chervak M, Jones BH. The Role of Gender and Physical Performance on Injuries: An Army Study. Am J Prev Med. 2017;52(05):e131–e138

14 Heller R, Stammers H. Running to breaking point? The relationship between 1.5-mile run time and injury risk in female recruits during British Army basic training. J R Army Med Corps. 2019; 0:1–5

15 Sharma J, Heagerty R, Dalal S, Banerjee B, Booker T. Risk Factors Associated With Musculoskeletal Injury: A Prospective Study of British Infantry Recruits. Curr Rheumatol Rev. 2019;15(01): 50–58

16 Grier TL, Canham-Chervak M, Anderson MK, Bushman TT, Jones BH. Effects of physical training and fitness on running injuries in physically active young men. J Strength Cond Res. 2017;31(01): 207–216

17 Heebner NR, Abt JP, Lovalekar M, et al. Physical and Performance Characteristics Related to Unintentional Musculoskeletal Injury in Special Forces Operators: A Prospective Analysis. J Athl Train. 2017;52(12):1153–1160

18 Molloy JM, Feltwell DN, Scott SJ, Niebuhr DW. Physical training injuries and interventions for military recruits. Mil Med. 2012; 177(05):553–558

19 Lentz L, Randall JR, Guptill CA, Gross DP, Senthilselvan A, Voaklander D. The Association Between Fitness Test Scores and Musculoskeletal Injury in Police Officers. Int J Environ Res Public Health. 2019;16(23):4667

20 Shaffer RA, Rauh MJ, Brodine SK, Trone DW, Macera CA. Predictors of stress fracture susceptibility in young female recruits. Am J Sports Med. 2006;34(01):108–115

