PHYSICAL PERFORMANCE AND INJURY OCCURRENCE IN MALE BASKETBALL PLAYERS: IS THERE A RELATIONSHIP?

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Abstract:

Although evidence suggests that physical fitness level may play a contributing role in injury development in athletes, available literature yields conflicting results with positive, null or even negative associations between them. Therefore, the main purpose of the study was to examine cross-sectional associations between baseline physical fitness and injury occurrence. In this study, participants were 60 male 1st Division basketball players (mean age: 22.1 ± 1.4 years, height: 193.3 ± 6.2, body mass: 89.3 ± 12.1 kg). Physical fitness was assessed through musculoskeletal (squat jump, countermovement jump, and countermovement jump with the arm swing) and cardiorespiratory fitness (maximal oxygen uptake). Injury registration included a question regarding any musculoskeletal complaint or injuries during the previous seven days with 'yes' and 'no' answers. The least fit group of participants in squat jump (OR = 1.25, 95% CI 1.10 to 2.55, p<.001), countermovement jump (OR = 1.14, 95% CI 1.02 to 1.96, p=.036), and maximal oxygen uptake (OR = 1.32, 95% CI 1.10 to 2.10, p<.001) exhibited the highest likelihood of injury occurrence, compared with the high fit group. The medium fit group in squat jump (OR = 1.05, 95% CI 1.01 to 4.05, p=.045) was at the significant and increased risk for injury occurrence comparing with the high fit group. This study indicates that lower levels of musculoskeletal and cardiorespiratory physical fitness may lead to higher likelihood of injury occurrence in male basketball players. Thus, physical fitness may be considered as a protective factor against injuries incurred.

Keywords: *injury, musculoskeletal fitness, cardiorespiratory fitness, associations, basketball*

Introduction

Basketball is a complex invasion sport with high physical demands, involving high-intensity activities such as accelerations, decelerations, changes of direction, and sprinting (Stojanović, et al., 2018). These activities are typically performed in a short period of time and are interspersed with active or passive recovery phases (Scanlan, Tucker, & Dalbo, 2014). Research over the last two decades has shown a significant increase in the intensity of basketball games, particularly in the time spent covering distances at high-speed running (>19.5 km/h – 25.1 km/h) or sprinting (>25.1 km/h) (Scanlan, Dascombe, & Reaburn, 2012). As a result, the development of high-intensity movement patterns should be a fundamental aspect of planning and evaluating training protocols in professional basketball (Wen, Dalbo, Burgos, Pyne, & Scanlan, 2018).

Basketball players who engage in more physically demanding activities during a match face an increased risk of injuries, even when striving to maintain high performance levels (Lewis, 2018). International basketball organizations such as the National Basketball Association (NBA) (Mack, et al., 2025) and the Fédération Internationale de Basketball (FIBA) (Aksović, et al., 2024) have expressed concerns about the heightened physical demands during preparatory and competition periods, which can contribute to significant injury issues. Research indicates that professional basketball players experience a range of 3-6 injuries per 1000 hours of exposure, underscoring the importance of finding the right balance between training, competitive matches, and recovery (Kataria, et al., 2025; Milić, et al., 2025). As a result, elite basketball players who frequently sustain injuries often encounter challenges in reaching their maximum skill potential, impacting their ability to develop exceptional abilities (Sarlis, Papageorgiou, & Tjortjis, 2025).

In order to achieve successful game-related outcomes, basketball players must maintain high levels of physical fitness (Mancha-Triguero, García-Rubio, Calleja-González, & Ibáñez, 2019). Physical fitness is defined as 'a set of attributes linked to the ability to carry out daily tasks with vigor and alertness' (Caspersen, Powell, & Christenson, 1985) and is a crucial component for basketball players to

endure the demands of the game (Calle, Mancha-Triguero, Recio, & Ibáñez, 2025). It is somewhat expected that more elite basketball players would have higher levels of physical fitness (Ostojic, Mazic, & Dikic, 2006). However, evidence regarding the associations between physical fitness and injury occurrence is scarce. To date, most studies have come from soccer which revealed that higher levels of muscular and cardiorespiratory physical fitness, calculated as z-score values, are associated with a higher risk of all injuries in cadet (Verstappen, van Rijn, Cost, & Stubbe, 2021) and junior players (Le Gall, et al., 2006). However, one study found that high-skilled players had an injury incidence ranging from 4.4 to 4.9 injuries per 1000 hours as compared to the range of 2.8 to 4.0 injuries per 1000 player hours of low-skilled players (Soligard, Grindem, Bahr, & Andersen, 2010). The same study also confirmed that more technically and tactically proficient players were at higher risk of sustaining any injury than their low-skilled peers (Soligard, et al., 2010). However, some studies reported null associations between physical fitness and injury rate (Leppänen, et al., 2022). On the other hand, a 2-year prospective cohort study showed only a weak association between musculoskeletal fitness assessed by the quadriceps concentric peak torque of 300 °/s and the incidence of injury (O'Kane, et al., 2017). Similar observations were noted in a study by Powers, Ghoddosi, Straub, and Khayambashi (2017), where impaired hip-adductor strength increased the future injury risk. In basketball, general findings have reported that ankle sprains or knee ligament injuries account for a significant time loss and reduced physical performance (Aksović, et al., 2024; Rubio-Martin, González Sánchez, Manuel-Garcia, & Cabezón Manchado, 2026).

Research efforts to evaluate the relationship between physical fitness and injury risk in sports have produced inconclusive findings. Physical fitness is considered a powerful marker of health (Ortega, Ruiz, Castillo, & Sjöström, 2008) and requires continuous development over time to enhance performance. However, athletes who train frequently may experience accumulated chronic fatigue, which increases the risk of sports-related injuries (Bakken, et al., 2018). Experts have recommended that athletes focus on smarter training methods and allow sufficient time for recovery to mitigate the risk of injuries (Bakken, et al., 2018). Therefore, it is important to investigate the interplay between physical fitness and injury risk for the benefit of coaches, team members, and athletes, as these risk factors are modifiable, easy to administer, and can be tracked over time at both individual and team levels. Given the relative lack of knowledge about these associations in basketball, it is crucial to examine whether physical fitness acts as a protective or a risk factor for injury development.

Therefore, the main purpose of the present study was to examine the associations between physical fitness and injury occurrence in male basketball players.

Materials and methods

Study participants

In this cross-sectional study, participants were male basketball players from the 1st division league (mean age: 22.1 ± 1.4 years, height: 193.3 ± 6.2, body mass: 89.3 ± 12.1 kg), who had over 10 years of experience in basketball. They trained five times per week for two hours (equals 10 hours weekly) and played basketball matches during weekends. At baseline, we included seventy-three basketball players. Based on a low Cohen's D effect size (<0.20) reported in previous studies (Leppänen, et al., 2022), a statistical power of 0.90 (1-β), an α level set at 0.05, one group with three measurements, and a hypothetical correlation of $r = 0.50$ between them, the G*power calculator determined that the appropriate sample size should be n = 55. The inclusion criteria were the following: basketball players without injuries that could hinder their full participation in the study who completed both cardiorespiratory and musculoskeletal physical fitness tests as well as reported their injury status. The exclusion criteria eliminated basketball players with pre-existing injuries or injury-related problems that impeded them from continuing with the testing. All data related to the inclusion and exclusion criteria were collected through a questionnaire. The final sample consisted of 60 basketball players, who were tested for both musculoskeletal and cardiorespiratory physical fitness and completed injury-related questionnaire. Their common training protocol consisted of a 5-day, 2-hour per day training regimen, which included warm-up exercises, technical and tactical preparation components, and testing of different match-related formations. Before providing written consent, all participants were informed about the experimental protocol and potential risks. The procedures were carried out anonymously and in accordance with the Declaration of Helsinki. The study was approved by the Ethical Committee of the Faculty of Sports Science and Technology (Ethical code number 5443-2271/53). Furthermore, all examinees signed a statement expressing their willingness to proceed with the testing for the research. Measures were taken to ensure participants' confidentiality. Participants could withdraw from the study at any time without facing any repercussions.

Injury registration

By following the recommendations of Fuller et al. (2006), injury definition and registration was defined as a contact injury of lower extremities reported as physical complaint resulting from

basketball training or a match that diverted a player from participating in regular training or match schedule. The reason for including only injuries of lower extremities came from previous findings, which stated that lower extremity injuries were more common in basketball players, accounting from approximately 54% to 62% of all injuries (Aksović, et al., 2024). Basketball players reporting any kind of injury related to ankle sprains, knee and hip injuries were classified as having an injury *vs.* those who were injury-free. The presence of injury was determined by a single question: Have you had any musculoskeletal complaint or injury of lower extremities during the previous seven days (yes/no)?.

Musculoskeletal physical fitness

To evaluate musculoskeletal physical fitness, we utilized two different jump tests: squat jump and countermovement jump. Both jumps were conducted using the Optojump photocell system from Microgate in Bolzano, Italy, which estimated vertical jump height. The squat jump involved starting from an upright position with the hands on the hips, then transitioning to a flexed, semi-squat position (90°) after a 3-second pause, and finally initiating the upward, concentric phase without any countermovement throughout the test (Glatthorn, et al., 2011). For the countermovement jump, participants began from an upright position with their hands on the hips, quickly flexed their knees to 90°, and then forcefully pushed off in the vertical position to achieve maximal concentric contraction (Glatthorn, et al., 2011). The same protocol was conducted for the countermovement jump with the arm swing. Previous verification of the test-retest reliability and concurrent validity of the Optojump photocell system for evaluating these tests has shown high intraclass correlation coefficients (ICC > 0.95) (Glatthorn, et al., 2011).

Cardiorespiratory physical fitness

Cardiorespiratory physical fitness was assessed using a ramp protocol on a motorized treadmill and determined through a breath-by-breath pulmonary gas exchange system called Quark b2, manufactured by COSMED in Italy. The protocol began at a speed of 7 km/h and was incrementally increased by one $km*h^{-1}$ every minute until the participant volitionally stopped running due to exhaustion. The exhaustion criteria included: i) a VO_2 of less than 1.0 $ml*kg^{-1}*min^{-1}$ after the speed increase; ii) an exchange ratio greater than 1.1; and iii) a peak lactate level exceeding 6 $mmol*L^{-1}$ after the exercise (Düking, et al., 2024). If the participant experienced any bodily pain or discomfort, the test was halted. Following the exercise, a 5-minute recovery period involved walking at 4.5 $km*h^{-1}$. Aerobic data related to maximal oxygen uptake were averaged on a 5-second basis and utilized as a measure of cardiorespiratory capacity in subsequent analyses.

Anthropometric data

Body height and mass were objectively measured with a Seca stadiometer and digital scale with the precision of 0.1 cm and 0.1 kg, respectively, calibrated before the measurements. Body mass index was calculated as the ratio of body weight in kg and body height in m^2 using the following formula: (weight/height^2). Age was self-reported.

Testing protocol

A total of 60 male basketball players who were uninjured participated in musculoskeletal and cardiorespiratory physical fitness assessments. The first day of assessment included tests for the squat jump and countermovement jumps, with each jump being performed three times and the average value was used for analysis. A 30-second resting period was observed between each jump, and a 5-minute break was taken between different jumping tests to minimize the impact of fatigue. On the following day, the focus shifted to evaluating the players' cardiorespiratory physical fitness. Testing commenced at 9:00 a.m. on both days, with the average air temperature and humidity recorded at 23°C and 60%, respectively. Furthermore, all basketball players were advised to have a light breakfast and maintain regular hydration during the testing. On the final day, the occurrence of injuries among the players was documented.

Data analysis

Basic descriptive statistics of musculoskeletal and cardiorespiratory fitness tests are presented as mean and standard deviation (SD). The presence of injury was recorded as frequency (n) and percentage (%). Cross-sectional associations between musculoskeletal and cardiorespiratory physical fitness with injury occurrence were determined using odds ratios (ORs) and 95% confidence intervals (95% CI). First, we transformed numerical physical fitness values into tertiles and categorized basketball players into low (1st tertile; <33.3%), moderate (2nd tertile; 33.3% – 66.6%) and high (3rd tertile; >66.6%) musculoskeletal and cardiorespiratory physical fitness groups. We analysed separate associations between each musculoskeletal and cardiorespiratory physical fitness test with the injury occurrence. Finally, physical fitness index derived from *z*-scores of all physical fitness tests and categorized into tertiles was applied, to examine overall physical fitness level and injury occurrence. In addition, we adjusted for the average time spent playing in official matches and created tertile categories of ≤15 min, 16-29 min, and ≥30 min. All statistical analyses were performed using SPSS v27.0 software

(IBM, Armonk, NY, USA) with an alpha level set *a priori* at p<.05 to denote statistical significance.

Results

Basic descriptive statistics of physical fitness at baseline are presented in Table 1. In the total sample, 15 basketball players reported injuries (25.0%).

For the squat jump, basketball players categorized in the lowest and medium groups were 1.25 (OR = 1.25, 95% CI 1.10 to 2.55, p<.001) and 1.05 (OR = 1.05, 95% CI 1.01 to 4.05, p=.045) more likely to experience injury, compared with the most fit group. For the countermovement jumps, basketball players categorized in the lowest group exhibited statistically higher likelihood of injury occurrence (OR = 1.14, 95% CI 1.02 to 1.96, p=.036), while the medium group was 1.02 times more likely for the same outcome, yet the association was non-significant (OR = 1.02, 95% CI 0.87 to 1.23, p=.544). Compared to the high fit group in cardiorespiratory physical fitness, the lowest group was 1.32 times more likely to incur injury (OR = 1.32, 95% CI 1.10 to 2.10, p<.001). For the medium fit group, no significant association with injury occurrence was observed (OR = 0.99, 95% CI 0.87 to 2.10, p=.655). Physical fitness index factor indicated that the lowest and medium fit groups were 1.45 (OR =

Table 1. Basic descriptive statistics of the study participants (n = 60)

Study variables	Mean ± SD	Minimum	Maximum
Age	22.1 ± 1.4	21.3	22.9
Height (cm)	**193.3 ± 6.2**	187.9	199.8
Weight (kg)	89.9 ± 12.1	83.5	96.7
Body mass index (kg/m^2)	24.6 ± 2.1	23.1	25.1
Squat jump (cm)	39.1 ± 4.1	36.2	42.8
Countermovement jump (cm)	44.8 ± 4.8	40.1	50.6
Maximal oxygen uptake (ml*kg^{-1}*min^{-1})	60.2 ± 5.2	57.4	65.2

Table 2. Associations between musculoskeletal and cardiorespiratory physical fitness with injury occurrence in basketball players

Study variables	Model 1	Model 2	Model 3	Model 4
Squat jump				
Tertile 3 (the highest)	Ref.			
Tertile 2 (medium)	1.05 (1.01 – 4.05)			
Tertile 1 (the lowest)	1.25 (1.10 – 2.55)			
Countermovement jump				
Tertile 3 (the highest)		Ref.		
Tertile 2 (medium)		1.02 (0.87 -1.23)		
Tertile 1 (the lowest)		1.14 (1.02 – 1.96)		
Maximal oxygen uptake				
Tertile 3 (the highest)			Ref.	
Tertile 2 (medium)			0.99 (0.87 – 2.10)	
Tertile 1 (the lowest)			1.32 (1.10 – 2.10)	
Physical fitness index				
Tertile 3 (the highest)				Ref.
Tertile 2 (medium)				1.23 (1.02 – 5.44)
Tertile 1 (the lowest)				1.45 (1.18 – 1.99)
Average playing time				
≤15 min	Ref.	Ref.	Ref.	Ref.
16-29 min	1.03 (0.87 – 1.23)	1.01 (0.83 – 1.54)	0.98 (0.76 – 2.01)	1.04 (0.93 – 1.32)
≥30 min	1.08 (0.97 – 1.64)	1.04 (0.92 – 1.77)	1.01 (0.89 – 1.96)	1.10 (1.00 – 2.15)

Note. **Model 1:** Examines the associations between musculoskeletal physical fitness (squat jump) and injury occurrence. **Model 2:** Examines the associations between musculoskeletal physical fitness (countermovement jump) and injury occurrence. **Model 3:** Examines the associations between cardiorespiratory physical fitness and injury occurrence. **Model 4:** Examines the associations between physical fitness index (z – score of all tests) and injury occurrence. p<.05.

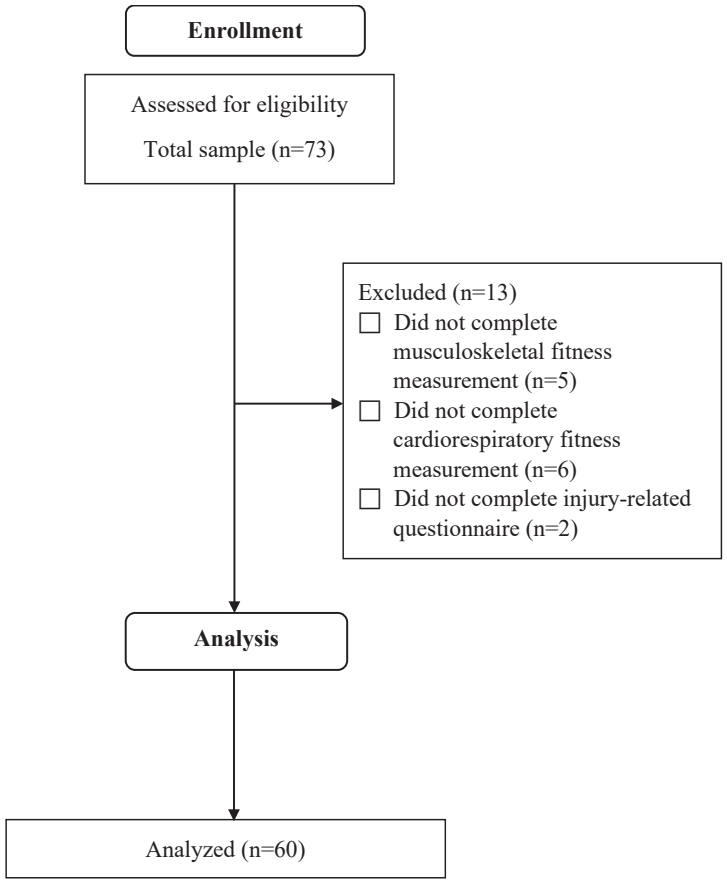


Figure 1. Flow chart diagram of participants' enrolment and final analysis.

1.45, 95% CI 1.18 to 1.99, p<.001) and 1.23 (HR = 1.02 to 5.44, p=.032) more likely for injury occurrence, compared to the high fit group.

Discussion and conclusion

The primary objective of the current study was to investigate the potential association between cardiorespiratory and musculoskeletal physical fitness and injury occurrence in male basketball players. The results indicate that lower levels of both musculoskeletal and cardiorespiratory fitness are linked to a higher probability of experiencing injuries. The analysis of the relationship between the physical fitness index and injury rate reveals a clear linear negative trend, demonstrating that the medium and low fit groups have an increased likelihood of injury occurrence compared to the high fit group.

To be successful, it is crucial for basketball players to maintain high levels of physical fitness (Mancha-Triguero, et al., 2019). Various theories have indicated that a high level of physical fitness can enhance an athlete's ability to withstand high training loads, meet the demands of sports, and it acts as a protective factor against injury development (Kataria, et al., 2025; Milić, et al. 2025). Given the demanding nature of basketball, it is expected that better athletic performance can lead to a reduced risk of injury (Aksović, et al., 2024). Our findings align with previous studies conducted with soccer players, showing that both musculoskeletal and cardiorespiratory fitness are associated with lower injury incidence at follow-up (Verstappen, et al., 2021). A 2-year prospective cohort study revealed a minimal link between musculoskeletal fitness, measured by the quadriceps concentric peak torque at 300 °/s, and injury occurrence (O'Kane, et al., 2017). However, the same research indicated that increased quadriceps concentric peak torque at 60 °/s correlated with the likelihood of overuse injuries, with low predictive power of the important strength variables (O'Kane, et al., 2017). Similarly, a study by Powers et al. (2017) found that weakened hip-adductor strength heightened the risk of future injuries. Another study by Malone et al. (2017) observed that soccer players with higher functional capacities during high-speed running and sprinting had a significant reduction in injury risk, as opposed to those engaged in lower high-speed running and sprinting activities.

However, some epidemiological studies have revealed that increased muscular and cardiorespiratory fitness, measured as z-scores, correlates with a greater risk of all injuries in soccer players aged 9-14 years (Verstappen, et al., 2021). A study conducted by Soligard et al. (2010) determined that the rate

of injuries in high-skilled players was between 4.4 and 4.9 injuries per 1000 hours, while low-skilled players experienced between 2.8 and 4.0 injuries per 1000 player hours. Additionally, players with more technical and tactical skills faced a greater likelihood of suffering any injury compared to their less skilled counterparts (Soligard, et al., 2010).

The mixed findings regarding the relationship between weekly training and match exposure, physiological and psychological demands, and maturity can be explained by various internal and external mechanisms (Lewis, 2018). It has been reported that more physically fit athletes tend to be more involved in training and match-related schedules, leading to higher physical loading and insufficient recovery time (Lewis, 2018). However, in this study, the sample consisted of mature basketball players who performed better in musculoskeletal and cardiorespiratory physical fitness tests compared to younger athletes from previous studies. Research has shown that individuals with higher fitness levels tend to play more strategically, rather than relying solely on physical prowess to avoid potential injury development. A systematic review by Cardoso-Marinho et al. (2022) highlighted low muscle strength, lack of physical fitness, fatigue, excessive training, and the type and condition of surfaces as the most frequent perceived injury risk factors. Our data supported these findings, indicating that individuals with lower fitness levels exhibited a higher probability of injury development.

Similar to musculoskeletal fitness, we found a graded inverse association between maximal oxygen uptake and injury occurrence, where the least fit group were at increased risk for injury, while the tendency of higher likelihood (although not significant) was observed for the medium fit group. Interestingly, studies that used cardiorespiratory physical fitness found that more fit individuals had higher probability rates of all injuries (Le Gall, et al., 2006; Verstappen, et al., 2021). The discrepancy between the findings could be explained by different chronological age of the study participants, where the aforementioned studies predominantly used players <18 years, while we included seniors in this study. As we speculated that more advanced players played more intellectually and had better understanding of the game, it is possible that they used different playing tactics to keep them from being injured. This has been supported by previous evidence, where poor cardiorespiratory physical fitness measured with on-field tests has been regarded as a risk factor for musculoskeletal injuries in adults (Lindman, Ryman Augustsson, Baranto, Sansone & Abrahamson , 2024). Thus, it is not surprising that interplays between physical fitness and injury risk are age-dependent, as different biological and environmental factors may influence the outcome.

To understand the significance of physical fitness in basketball performance, researchers have sought to determine its potential role in preventing injuries. This study represents one of the initial efforts to investigate both musculoskeletal and cardiorespiratory fitness as factors influencing the risk of injury. The findings indicate that basketball players with moderate to low levels of fitness may face an elevated risk of injury. Given the conflicting evidence in existing literature, this study contributes to the understanding by demonstrating that higher levels of physical fitness are linked to a reduced incidence of injury in senior male basketball players. As a result, it is advisable for strength and conditioning coaches to closely monitor and assess physical fitness of players, particularly those with lower musculoskeletal and cardiorespiratory fitness, as they may be more susceptible to injuries.

This study has several limitations that should be considered. Firstly, we did not collect individual or team loading exposure to examine the intensity and duration in conditions of training and matches. Secondly, some other physical fitness components, such as body composition, flexibility, and speed/agility/coordination, were not measured. Additionally, we did not examine basketball-specific skills including passing and dribbling. Thirdly, we did not examine the associations between injury and physical fitness according to playing positions, as centers and forwards are more prone to injuries, due to frequent jumping and physical contact. Finally, the evaluation of injury was based on only a single-item question, and more detailed information regarding the consequences of overuse problems on sports participation, training volume, performance, and perceived pain was not examined (Clarsen, et al., 2020).

To conclude, this study reveals strong connections between musculoskeletal and cardiorespiratory physical fitness and injury occurrence in male basketball players. Both aspects of physical fitness showed similar probability scores, with the low and medium fit groups from the physical fitness index demonstrating a higher likelihood of injury. Despite acknowledging the limitations of the study, higher levels of physical fitness act as a protective factor against the occurrence of injury. Therefore, it is recommended that strength and conditioning coaches, along with other team members, should prioritize the monitoring and tracking of physical fitness, as its development could play a crucial role in reducing injury rates throughout an athlete's career.

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