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The Influence of Mindfulness Practices and Music Training on Fatigue Management in Professional Basketball: A Comprehensive Study

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ABSTRACT

Objective: Basketball is a sport characterized by open skills, where actions are unpredictable and dynamics are constantly shifting, leading professional players to experience varying levels of physical and mental fatigue. This study aimed to explore and compare how mindfulness and music training affect physical and mental fatigue in elite basketball players.

Method: In this quasi-experimental research, 27 elite basketball players were randomly assigned to either a mindfulness-based training group, a music-based training group, or a control group. Blood samples were taken under fasting conditions to assess the study variables before and after the intervention. Data analysis involved one-way analysis of variance (ACNOVA), paired t-tests with a significance threshold ($P \leq 0.05$), and the Bonferroni post hoc test to identify intra-group and inter-group differences. SPSS version 27 was utilized for these analyses.

Results: When comparing the groups, there was no significant difference in the impact of mindfulness and music on physical fatigue at a significance level ($P \leq 0.05$). Similarly, the effect of mindfulness and music on changes in inflammatory markers such as lactate dehydrogenase, creatine kinase, and C-reactive protein was not significantly different at the same significance level. However, the effect of mindfulness and music on mental fatigue showed a significant difference at a significance level ($P \leq 0.05$), indicating that mindfulness significantly reduces psychological fatigue.

Conclusions: The findings of this study revealed no significant difference between the effectiveness of mindfulness-based training and music in terms of physical fatigue and changes in serum levels of lactate dehydrogenase, creatine kinase, and C-reactive protein. However, in the area of mental fatigue, mindfulness-based training demonstrated a significant reduction in mental fatigue in the post-test.

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Introduction

Basketball is a team sport that demands both physical and mental fitness, leading to heightened physical and mental fatigue during competitions. The sport is marked by short bursts of high-intensity activity, followed by brief recovery periods, which occur repeatedly in both training and competition. This continuous exertion, requiring strength and agility, results in significant physical fatigue post-training [1]. Fatigue is linked to a subjective sensation of physical, emotional, and cognitive exhaustion that is disproportionate to recent activities, impairs overall performance, and is not alleviated by sufficient rest and sleep [2]. The origins of fatigue related to chronic pain are complex and multifaceted, likely involving the physiological, biochemical, and psychological systems of the individual. Exercise-induced fatigue is described as a physiological process where the body's capacity to exercise or perform diminishes and cannot be sustained at a certain level [3]. Prolonged exercise under fatigue conditions can lead to sports injuries and significantly hinder the enhancement of athletic ability. Physical fatigue is considered a strong predictor of role limitation due to physical issues [4]. Another type of fatigue that has gained attention in exercise and performance research is mental fatigue. Mental fatigue is defined as a psychological state resulting from extended cognitive activity, negatively impacting physical performance [5]. It is characterized by an increased sense of internal mental fatigue, often accompanied by reduced cognitive performance, following long and demanding cognitive tasks [4]. Some research suggests that elite athletes might be more resilient to mental fatigue due to superior inhibitory control [6]. However, the unique environmental stressors, combined with the high-level training and competition demands faced by athletes, create a significant potential for mental fatigue. Given that success in elite-level competition is determined by very small margins, it seems reasonable that mental fatigue could influence elite sports. A study by Van Katsum, Makura, Depa et al. indicated that mental fatigue was linked to decreased endurance performance and, conversely, increased effort and exertion. They also found that maximal strength, power, and anaerobic activity were not consistently impacted by mental fatigue [1]. In the realm of physical fatigue, various factors can be explored. Factors such as physiological, biomechanical, nutritional, and psychological aspects influence an athlete's ability to achieve peak performance [7]. Studies have noted changes in three factors—creatine kinase, lactate dehydrogenase, and C-reactive protein—in athletes' blood [8]. Intense and exhausting exercise damages cellular structures, particularly muscle and contractile tissues, leading to the breakdown of the sarcomere cellular structure in active muscle cells. The stress from these exercises causes muscle tissue damage and initiates the inflammatory process.

The inflammation triggers the generation of reactive oxygen species, which are linked to the enzymes CK, LDH, and CRP [9]. An increase in C-reactive protein in seemingly healthy individuals is linked to a heightened risk of cardiovascular diseases (Franca et al., 2010). Matosch et al. investigated how regular endurance training affects resting CRP levels in twelve participants. Their findings indicated that even with a steady rise in training intensity, CRP levels post-training decreased in ten runners [10]. Lactate, a byproduct of carbohydrate metabolism, is produced in muscles and erythrocytes and eliminated by the liver. An increase in lactate leads to the accumulation of H+ ions, causing metabolic acidosis in the muscle, which hinders contractile reactions and is a primary cause of muscle fatigue [11]. In a study on elite male swimmers, lactate dehydrogenase levels significantly dropped 15 minutes after a full training session, and lactate levels significantly decreased after 30 minutes [9]. The third factor of interest is creatine kinase. Total creatine kinase levels are influenced by age, sex, race, muscle mass, physical activity, and weather conditions. Elevated creatine kinase levels in seemingly healthy individuals are likely related to physical training status and sarcomeric damage. In fact, intense exercise that damages skeletal muscle cells result in increased serum creatine kinase, with the highest increase occurring when exercises are of longer duration and involve abnormal muscle contractions [12]. Recent research has shown that elite-level competitive volleyball players endure a high training load during both preparatory and competitive periods, which also increases psychological demands [1]. To alleviate the psychological stress caused by fatigue, studies like the one by Depuy et al. have suggested relaxation techniques, with mindfulness gaining significant attention [13]. Mindfulness is defined as non-judgmental, moment-to-moment awareness of the present experience; it is a clinical method developed to treat psychological disturbances such as anxiety and depression [14]. In Miall's research (2023), awareness is described as the private experience of one's existence in relation to the surrounding social environment. According to Frith, awareness has three main social roles: 1) awareness of one's "actions," which fosters a sense of responsibility towards oneself and others; 2) awareness of one's "choices," which allows for the justification of decisions and motivations; and 3) awareness of one's "feelings," which leads to a shared reality [15]. The significance of music and rhythm on motor behavior dates back to the early twentieth century when music was recognized as a therapeutic method. Music therapy, an interdisciplinary field combining psychology, music, and therapy, has garnered considerable attention. Music enhances the excitability, activity, and mood of neurons in the cerebral cortex [7]. Bentotti (2023) reported that listening to music can induce pleasure in the brain, enhance neural network function, and boost the immune system [16]. Combining music with exercise might heighten cognitive stimulation by increasing motivation [17]. Music could also enhance activity efficiency by substituting the sensory input from physical activity that reaches the central nervous system, thereby elevating the emotional response to the activity [18]. Additionally, music can improve speed and endurance during training [7]. In this context, Orgei et al. investigated how music-induced arousal affects the performance of national-level adolescent taekwondo athletes during warm-ups, finding that their performance improved when music was played during these exercises [19]. So far, no research in Iran has specifically focused on the impact of mindfulness-based exercises on fatigue and physical and mental recovery. Traditionally, methods like active recovery, massage, compression garments, immersion, contrast water therapy, and cryotherapy have been the primary means to address physical fatigue from exercise [20]. Conversely, psychological strategies and mental training techniques are more often recommended for alleviating mental and emotional fatigue from exercise and competition [21]. Understanding the role of mindfulness or music-based exercises in mitigating the effects of high-performance sports during competition is crucial [22]. Moreover, a review of existing domestic studies reveals that no research has compared these two interventions during a competitive period or evaluated their long-term effects in a follow-up period, nor have they examined their impact on LDH, CK, and CRP factors. This study aims to evaluate and compare the effectiveness of mindfulness-based mental exercises versus music-based exercises on physical and mental fatigue in elite male basketball athletes.

Materials and methods

Research design

This research is a quasi-experimental study carried out in two phases, namely pre-test and post-test, with a control group. Data for the study was gathered during both the pre-test and post-test phases. The quasi-experimental approach was selected due to the inability to control all variables influencing the measurement, such as sleep patterns and natural circadian rhythms.

Participants

The study's statistical population consists of approximately 50 young basketball players residing in Qom. From this group, a sample of 27 individuals was chosen through convenience sampling and joined the research project after voluntarily expressing their willingness to participate. Those who volunteered were asked to fill out a medical history questionnaire, and only those meeting the study's criteria were selected. Participants then signed a personal consent form, providing written agreement to partake in the research. Ethical considerations were observed, including thoroughly explaining the study's objectives to each participant, ensuring the confidentiality of their information, and allowing them to withdraw from the study at any time. Participants were randomly assigned to one of three groups: mindfulness-based mental training, music-based training, or a control group.

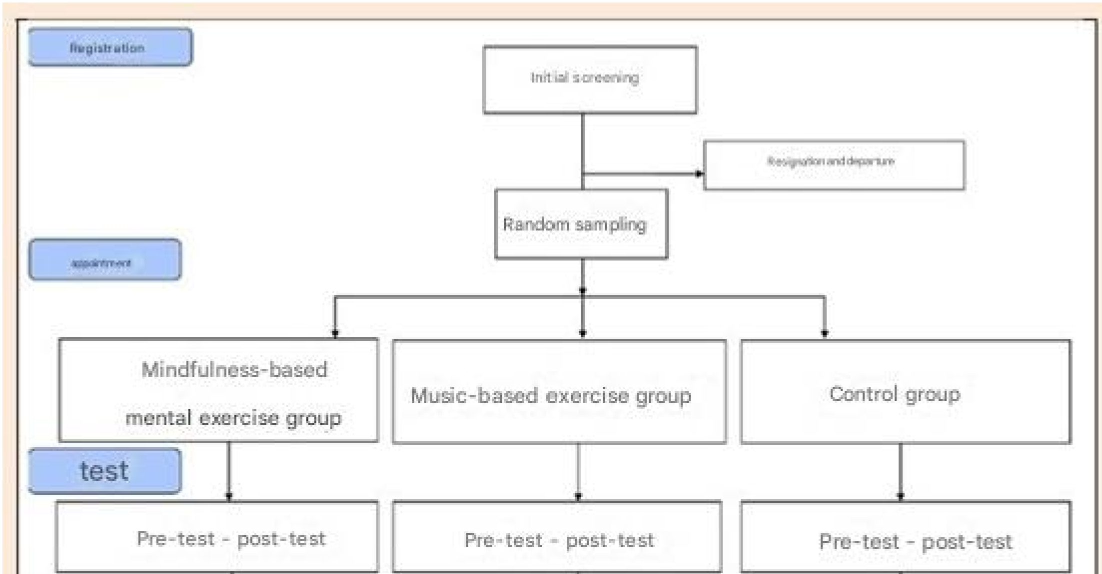

Figure 1. Overview of the sampling process and research practice protocol

T ools

Mindfulness Inventory for Sport(MIS)

The initial version of this questionnaire was created in Australia by Dinath et al. (2014) and is in English. It comprises 15 questions that athletes might face before or during a competition. The Sports Mindfulness Inventory is divided into three subscales: awareness (e.g., I notice the thoughts passing through my mind), nonjudgment (e.g., When I realize I'm not concentrating on my performance, I criticize myself for this lapse), and refocusing (e.g., When I become aware that I'm thinking about my fatigue, I promptly shift my focus back to the task at hand). Each subscale is evaluated with 5 questions, with questions 1 to 5 assessing awareness, questions 6 to 10 evaluating non-judgment, and questions 11 to 15 measuring refocusing. The inventory is scored using a 6-point Likert scale, ranging from not at all to 6. Scores for each subscale are calculated by summing the scores of the relevant questions. The minimum score for each factor is 5, while the maximum is 35. In the original version validated by Dinath et al. (2014), the Cronbach's alpha coefficient was 0.77 for awareness, 0.78 for non-judgment, and 0.77 for refocusing. In the Persian adaptation of this inventory, validated among the Iranian population by Hayattalab, Khabiri, and Zare (2016), the Cronbach's alpha coefficient was 0.79 for awareness, 0.86 for non-judgment, and 0.83 for refocusing.

Mental Fatigue Scale (MFS)

The scale, developed by Johnson, Starmark, Berglund, Rodham, and Ronbak (2010) in Gothenburg, Sweden, was created through research involving stroke patients, individuals with multiple sclerosis, those with a history of brain injuries, people under stress, and individuals experiencing burnout. This mental fatigue scale comprises 15 elements: fatigue, inability to perform tasks, mental fatigue, recovery from mental fatigue, concentration difficulties, memory issues, slow thinking, stress sensitivity, emotional irritability, sensitivity to light and sound, variations in sleep patterns, and 24-hour changes. Scores typically range from 0 to 44, with scores below 7.49 indicating no problems, scores between 7.5 and 49.22 suggesting minor issues, scores from 5.22 to 45.37 indicating relatively minor issues, and scores from 5.37 to 44 representing serious problems. For each element, a score of zero signifies "no problem," a score of 1 denotes a "minor problem," a score of 2 indicates a "fairly serious problem," and a score of 3 represents a "serious problem." In the original study by Johnson et al. (2010), the internal consistency of the components was measured with a Cronbach's alpha coefficient of 0.944. The Persian version of this scale, validated by Bakhshi, Mazloumi, and Hosseini (2019), showed a Cronbach's alpha coefficient of 0.893.

Method for measuring physical fatigue

Draper and Whyte (1997) introduced an anaerobic running assessment derived from the Running-based Anaerobic Sprint Test (RAST) to evaluate a runner's performance. This assessment calculates maximum and minimum power, average power, and a fatigue index. The test's accuracy relies heavily on the precision with which the administrative team conducts it. Test procedure: The test involves six sprints of 35 meters each, with a 10-second pause between sprints. Initially, an assistant records the athlete's weight. Each participant begins with a 10-minute warm-up. Assistants then set up a straight 35-meter track using cones. The athlete must complete all six sprints at full speed, with a 10-second break between each, after which the assistant signals the start again. Assistants use a stopwatch to time and document each sprint. Ethical considerations, including attention to child participation, obtaining informed consent, establishing open and honest communication, maintaining confidentiality, and ensuring the sensitive dissemination of information and justice, were adhered to in this study. This research project is registered with the ethics code number IRQOM.REC.1401.029.

Experimental protocol: Figure 1 presents a summary of the sampling flow chart and the training protocol. Following the initial contact with the team and the screening assessment of entry and exit criteria, athletes were randomly chosen, assigned to various groups, and informed about the research conditions. Measurements were taken at Time 1 (pre-test) and Time 2 (post-test). Approval for this research was obtained from the Qom City Volleyball Board through a letter, and by attending several volleyball classes in the city, participants were recruited based on the desired age range and a minimum of two years of volleyball experience. After volunteers expressed their willingness and completed a consent form, a number of available participants were selected. These individuals participated in at least three volleyball training sessions per week. The average height of the participants was 184.44 cm, and their average weight was 72.62 kg. Inclusion criteria included athletes under federation supervision without injuries or health issues that could impact the research. None of the subjects had prior experience with weight training before the sessions. The participants were male volleyball players aged 16 to 22, and exclusion criteria included missing more than half of the training sessions or interventions and the use of dietary supplements by the subjects. After the initial study, participants were randomly divided into three groups: the mindfulness-based mental training group (G1), the music-based training group (G2), and the control group (CG). The control group only took part in the initial and final tests and was advised to maintain their usual activities during this period. Fasting blood tests were conducted twice, before and after the protocol, to measure creatine kinase, lactate dehydrogenase, and CRP levels, assessing the impact of the music-based and mental training program on these factors. The Rast test was employed to perform this test and measure the mentioned factors. Blood samples were collected immediately after the athletes completed six runs according to the Rast test during both the pre-test and post-test stages and sent to the laboratory for analysis. For the other two groups, a specialized program was developed in line with the principles of mental training and music. The program details are as follows. Additionally, all three groups continued their volleyball training with at least three sessions per week. The implementation spanned eight weeks, with three 60-minute training sessions per week, adhering to the training principles in both experimental groups. Before commencing the training, a session on mental training based on mindfulness and music was conducted for the volunteers.

Table 1. Audio transcription of the body scan technique

Subject	Timing(seconds)
Introduction	00:00- 00:21
Instructions for Position, Posture, and Feelings	00:22- 01:38
Notice the feeling in your feet and ankles.	01:39- 02:36
Notice the feeling in your calves and ankles.	02:37- 02:46
Notice the feeling in your knees and thighs.	02:47- 03:10
Notice the feeling in your hips and buttocks.	03:11- 03:19
Notice the feeling in your lower back and abdomen.	03:20-03:28
Notice the feeling in your chest and ribcage.	03:29- 03:39
Notice the feeling in your shoulders.	03:40- 04:07
Notice the feeling in your left and right arms.	04:08- 04-30
Notice the feeling in your neck, face, and head.	04:31- 04-47
Notice the feeling in your body as a whole, as it is, without control or change.	04:48- 05-29
Notice the center of your body, in your belly, as you breathe.	05:30- 05:43
Notice the physical reactions of your body locally and momentarily. Feel the increase and decrease.	05:44-06:00
Notice the reactions of your breathing with each inhale and exhale.	06:01- 06:12
Notice that your breathing is natural and uncontrollable.	06:13-06:30
Notice that if your mind wanders, note it and return to the breathing phase.	06:31-06:59

The intervention was carried out by a researcher alongside a member of the monitoring team. It was implemented before bedtime for each individual. Participants were randomly assigned through a lottery and grouping method, resulting in a total of 14 MBMT or MBT sessions. These music sessions, lasting about 10 minutes each, were conducted three times a week during the training week, after games, and before bedtime. A frequency control worksheet was utilized to track the number of sessions each athlete completed. The intervention required a smartphone and headphones. The mindfulness group listened to a recorded file based on the body scan technique from Coomba et al.'s research, while the music group listened to a wordless track from the album Spring Rain by international musician Henny Becker [1]. Control group: The control group included other athletes from the same team. These athletes followed the same routine of three sessions per week for 60 minutes, with no competitions scheduled during the data collection period.

Data Analysis Method: To analyze the study's data, descriptive statistics such as mean and standard deviation were employed, while inferential statistics involved repeated analysis of variance to compare groups in the pre-test and post-test phases. ANOVA was used for intra-group evaluation, followed by the Bonferroni post-test to identify intra-group and inter-group differences. Data analysis was conducted at a significance level of p>0.05 using SPSS version 27.

Findings

The table below presents data concerning descriptive statistics, including the mean and criterion, for the research variables. It provides descriptive details for the research variables during the pre-test and post-test phases, categorized by groups.

Table 2. Descriptive values of variables inPre and Post Test

Status		N	Min	Max	SD	Average
Pre Test Fatigue Physical	Mindfulness	9	4/93	21/83	5/06937	9/8856
	Music	9	6/61	22/72	4/98906	11/4478
	Control	9	5/93	18/94	4/24524	13/4078
Post Test Fatigue Physical	Mindfulness	9	2/40	8/84	1/86649	5/9400
	Music	9	4/61	20/63	4/59919	9/9578
	Control	9	5/02	10/19	4/59113	12/9478
Pre LDH test	Mindfulness	9	297/00	793/00	159/88312	425/8889
	Music	9	106/00	414/00	102/73604	321/7778
	Control	9	228/00	396/00	60/08628	328/1111
Post LDH test	Mindfulness	9	113/00	552/00	144/50096	234/4444
	Music	9	99/00	399/00	101/03465	295/0000
	Control	9	220/00	390/00	60/41684	328/2222
Pre CPK test	Mindfulness	9	113/00	1600/00	530/74806	454/6667
	Music	9	90/00	377/00	89/95060	203/8889
	Control	9	130/00	309/00	53/90269	201/6667
Post CPK test	Mindfulness	9	75/00	600/00	205/45323	196/4444
	Music	9	80/00	310/00	76/42771	169/7778
	Control	9	130/00	315/00	56/90587	204/5556
Pre CRP test	Mindfulness	9	/40	3/60	/83815	2/3333
	Music	9	1/10	9/20	2/79841	4/3889
	Control	9	/50	8/00	2/23762	3/7222
Post CRP test	Mindfulness	9	/20	2/50	/66729	1/3444
	Music	9	/75	8/60	2/58348	3/7333
	Control	9	/20	7/50	2/17120	3/5322
Pre Test Fatigue Mental	Mindfulness	9	9/00	13/00	1/33306	10/8100
	Music	9	10/00	14/00	1/51673	12/2744
	Control	9	9/14	13/51	1/41674	11/4078
Post Test Fatigue Mental	Mindfulness	9	4/25	10/00	1/83271	6/6644
	Music	9	6/00	9/64	1/05199	8/1644
	Control	9	9/21	13/97	1/52261	11/3933

Descriptive statistics and central indices, such as the mean and standard deviation, are presented. It is evident that in the variables of physical fatigue, mental fatigue, factor (LDH), factor (CPK), and factor (CRP), participants in both the mindfulness intervention group and the music intervention group exhibited a downward trend in the post-test compared to the control group. In other words, after the intervention, the scores for physical fatigue, mental fatigue, factor (LDH), factor (CPK), and factor (CRP) decreased for those in the mindfulness and music intervention groups. This change, however, was not observed in the control group.

Table 3. Mindfulness and Music intervention on physical and mental fatigue, LDH, CPK, CRP.

		Source	Mean squares	df	Sum of squares	F	Sig/
Physical Fatigue	Mindfulness	Group	93/741	1	93/741	19/259	0/001
	Music	Group	6/060	1	6/060	1/891	0/189
Mental Fatigue	Mindfulness	Group	73/237	1	73/237	68/514	0/000
	Music	Group	59/638	1	59/638	76/789	0/000
LDH	Mindfulness	Group	121256/204	1	121256/204	89/000	0/000
	Music	Group	3280/093	1	3280/093	22/549	0/000
CPK	Mindfulness	Group	40304/952	1	40304/952	10/022	0/006
	Music	Group	6080/880	1	6080/880	39/623	0/000
CRP	Mindfulness	Group	3/024	1	3/024	27/321	0/000
	Music	Group	0/776	1	0/776	5/341	0/035

The f value of the effect of the mindfulness intervention group on physical fatigue, mental fatigue, lactate dehydrogenase, creatine kinase, and CRP is significant. This means that after removing the effect of the pre-test, there is a significant difference between the means of the two experimental and control groups in the post-test.

The f value of the effect of the music intervention group on physical fatigue is not significant. This means that after removing the effect of the pre-test, there is no significant difference between the means of the two experimental and control groups in the post-test. However, the effect of the music intervention group on mental fatigue, lactate dehydrogenase, creatine kinase, and CRP is significant. This means that after removing the effect of the pre-test, there is a significant difference between the means of the two experimental and control groups in the post-test.

Table 3. Bonferroni comparative test to investigate the mean difference in physical fatigue status between two mindfulness and music interventions

Variable	(I) Group	Average difference(IJ)	Estimation error	Sig
Physical fatigue	Mindfulness	-2/968	1/079	0/034
		-4/642	1/121	0/001
	Music	2/968	1/079	0/034
		-1/673	1/085	0/410
	Control	4/642	1/121	0/001
		1/673	1/085	0/410
Mental fatigue	Mindfulness	-0/359	0/535	1/000
		-4/263	0/497	0/000
	Music	0/359	0/535	1/000
		-3/904	0/505	0/000
	Control	4/263	0/497	0/000
		3/904	0/505	0/000
LDH	Mindfulness	-153/841	15/923	0/000
		-181/388	15/798	0/000
	Music	153/841	15/923	0/000
		-27/547	14/830	0/228
	Control	181/388	15/798	0/000
		27/547	14/830	0/228
CPK	Mindfulness	-68/153	28/609	0/078
		-103/771	28/636	0/004
	Music	68/153	28/609	0/078
		-35/618	27/023	0/601
	Control	103/771	28/636	0/004
		35/618	27/023	0/601
CRP	Mindfulness	-0/502	0/197	0/054
		-0/913	0/189	0/000
	Music	0/502	0/197	0/054
		-0/411	0/184	0/106
	Control	0/913	0/189	0/000
		0/411	0/184	0/106

The results of the post hoc test presented above illustrate the differences in the average physical fatigue, lactate dehydrogenase between groups. There is a notable distinction in the impact of mindfulness versus music interventions on physical fatigue, lactate dehydrogenase. Specifically, the mean difference between the two groups is significant at the level of ($P < 0.05$). Consequently, it can be concluded that the mindfulness intervention had a more pronounced effect on reducing physical fatigue, lactate dehydrogenase.

The findings from the post hoc analysis, aimed at identifying differences in mental fatigue means between groups, indicate that there is no significant disparity in the impact of mindfulness versus music interventions on mental fatigue, creatine kinase, C-reactive protein factor. Consequently, the mean difference between the two groups is not statistically significant at the ($P < 0.05$) level. Thus, it can be concluded that both interventions were effective for this variabled, with no observed difference in the degree of their effectiveness.

Discussion

The purpose of this research was to explore how a mindfulness and music training program affects physical and mental fatigue in basketball players from Qom. The findings revealed that mindfulness training significantly benefits athletes' mental fatigue, but it does not significantly improve their physical fatigue. Additionally, the group that underwent music-based training showed no notable impact on either mental or physical fatigue. When comparing mindfulness and music training, the results highlighted the effectiveness of mindfulness in reducing mental fatigue, with no significant difference between the two in terms of physical fatigue. Physical pain and fatigue are not merely physical issues [20]. Athletes who believe that fatigue will diminish their physical strength may find this belief becomes a reality, leading them to exert less effort [26]. Consequently, their training efficiency declines, and they feel more exhausted. This study examined the impact of mindfulness and music-based exercises on physical fatigue. In the mindfulness group, no significant effect on physical fatigue was observed, which contrasts with the findings of Yi et al. [17], Kaufman et al. [21], and Daya et al. [3]. Recent studies have produced different results, likely due to variations in implementation conditions, methods of measuring physical fatigue, and existing limitations. In the music-based exercise group, no significant effect on physical fatigue was found, aligning with the study by Coimbra et al. [1]. However, Terry et al.'s meta-analysis [22] presents results that differ from this study. Overall, these findings suggest that athlete fatigue results from multiple factors, and improvement cannot be achieved solely through these exercises without considering other physical conditions and potential injuries during competitions. Recovery and fatigue are influenced by factors such as nutrition, sleep, training and competition conditions, and psychological aspects, all of which must be addressed for complete recovery [3]. The study's results indicate that mindfulness exercises significantly impact athletes' mental fatigue, whereas music-based exercises do not. Thus, the difference between the groups is significant. This finding, specifically the significant effect of mindfulness on mental fatigue, aligns with the research of Coimbra et al. [1], Mial et al. [15], and Mehrsfar et al. [27]. Mental fatigue negatively affects athletes' performance, with research showing that this decline is more evident in activities and exercises requiring high technical skill and decision-making [14].

In this model of common fatigue, which encompasses more than just feeling tired and lacking energy, mindfulness can play a significant role in reducing its intensity [4]. The distinction between elite and non-elite athletes lies in their extensive skills, particularly in psychological abilities [28]. Mindfulness, or being mentally present, is one psychological factor that influences sports performance. When an athlete experiences mental fatigue, it impacts their attention span and significantly diminishes their ability to disregard distractions and irrelevant factors. Mindfulness involves concentrating on the present, accepting both external and internal experiences, and embracing the process of action without judgment [29]. This approach aids athletes in first acknowledging their limitations during competitions when negative thoughts arise, and then differentiating between limiting thoughts and actual problems [30]. Numerous studies have explored the impact of music-based training. In this area, various factors, including individual differences, have been deemed influential in interpreting physiological symptoms [31]. During high-intensity exercise, findings indicate that fatigue symptoms improve and emotional capacity scores increase, which contradicts the results of the current study. In interpreting these findings, factors such as a person's emotional capacities, the type and rhythm of music selected, and the frequency of use should be considered [19]. Even without the moderating effect of emotional capacity, studies suggest that music likely has a positive impact on individual performance during exercise, regardless of personal, situational, and musical characteristics [26]. However, more precise findings can be achieved by controlling the type of music chosen and the individual's emotional characteristics. When training volume is high and competition is intense, especially with limited recovery time, symptoms of fatigue and general body weakening emerge [21]. Additionally, intense training and heavy competition lead to muscle damage. Muscle damage and the breakdown of muscle fibers result in post-exercise pain, associated with the release of enzymes such as creatine kinase, lactate dehydrogenase, aspartate aminotransferase, and alanine aminotransferase [32], which can be measured in the blood. Creatine kinase is a crucial enzyme involved in muscle cell metabolism. Since muscle fatigue and pain are influenced by blood levels of CPK and LDH, the rapid removal of these metabolites is vital for recovery from fatigue. In the present study, this enzyme was measured in athletes' blood during pre-test and post-test phases, and after analyzing the blood samples and examining the results of all three groups, no significant decrease in the enzyme level was observed in the post-test, indicating no significant difference between mindfulness-based and music-based exercises in this study. In contrast, the study by Mousavi et al. [12] found that the serum creatine kinase level in wrestlers who underwent mindfulness-based intervention significantly decreased, which is inconsistent with the results of this hypothesis.

It appears that the outcomes were influenced by changes in sleep and nutrition schedules, conducting the study under non-competitive conditions, and assessing their levels of depression and stress. In general, the study by Mousavi et al. took into account the limiting factors in a more controlled way [12]. Furthermore, in the current study, elite volleyball players are likely to experience high-stress levels due to their ongoing involvement in professional competitions, which often results in shorter recovery periods. Another element that prolongs muscle inflammation in the blood is lactate dehydrogenase. This enzyme's role is to convert lactate to pyruvate by reducing NAD+ to NADH and vice versa [8]. In both the pre-test and post-test, the variations in this factor were consistent across all three groups, showing no significant differences. The findings of this study aligned with those of Mousavi et al. [9]. C-reactive protein (CRP) is synthesized in liver cells in response to infection or tissue damage, triggered by interleukin-6, tumor necrosis factor-alpha, and IL-1β. During athlete fatigue, inflammatory markers like creatine kinase, lactate dehydrogenase, and CRP rise in serum blood levels [10]. Data from all three mindfulness-based training groups, music, and the control group in both the pre-test and post-test showed no significant difference in the rate of change in this factor. However, some studies, including one by Mir et al. [33], contradicted this conclusion, noting a reduction in CRP levels in the group that underwent mindfulness-based training. It is also important to note that in this study, the effect of mindfulness was reported to be delayed, suggesting that mindfulness exercises should be consistently practiced during training and competitions.

Paying attention to research limitations and planning future research directions

The study faced several limitations, including the inability to control the stressful conditions and situations of the subjects outside of training, the lack of control over environmental factors such as sleep patterns and jobs, individual differences in perceived fatigue levels and recovery time, and the withdrawal of two subjects due to training injuries. Additionally, a significant limitation was the use of the same music for all participants, rather than each player's preferred music, which might have influenced the results. Therefore, it is recommended that future research incorporate each participant's favorite music.

Conclusion

Overall, the study's findings indicate that mindfulness-based training had a notable and beneficial impact on the mental fatigue of elite athletes. However, it did not significantly influence physical fatigue or the serum levels of inflammatory markers related to fatigue, such as creatine kinase, lactate dehydrogenase, and C-reactive protein. Similarly, music-based training did not show a significant effect on either physical or mental fatigue, nor did it alter the serum levels of the three inflammatory markers examined. When comparing the two groups, a significant difference was found only in mental fatigue, with mindfulness-based training proving more effective than music-based training, consistent with previous studies. In terms of changes in serum levels of creatine kinase, lactate dehydrogenase, and C-reactive protein, as well as physical fatigue, no significant differences were observed between the mindfulness-based and music-based training groups. An elite athlete may possess the physical attributes and professional skills necessary for success in competitive sports, but these alone do not guarantee success. Psychological factors, such as mental fatigue, which this study also explored, play a crucial role. The study's results suggest that mindfulness-based training, supported by a strong research foundation, can be employed to shorten recovery time, enhance mental readiness, and improve an athlete's focus on their current state. To obtain more precise results, further research should be conducted with better control over limiting factors, as previous intervention-based studies have not simultaneously examined inflammatory markers and psychological factors affecting fatigue. Therefore, addressing both physical and mental fatigue factors in elite athletes and implementing interventions like mindfulness training by experts can enhance their performance.

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Ethical considerations

Ethical considerations were taken into account in conducting the research in accordance with the guidelines of the Ethics Committee of Qom University, and the ethics code isIRQOM.REC.1401.029.

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Authors' contribution

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Conflict of interest

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