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The Effect of Fatigue on Visuospatial Perception Accuracy of Basketball Athletes

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Abstract. This study aims to analyze the impact of fatigue on the accuracy of visuospatial perception of basketball athletes. A total of 23 athletes from BKMF Basketball FIKK UNM participated in this study, using a pre-test and post-test quasi-experiment design. Visuospatial perception was measured with the Mental Rotation Test (MRT) before and after a high-intensity exercise program designed to induce physical fatigue. The results showed a significant decrease in perceptual accuracy (pre-test: 82.09%; post-test: 68.43%) as well as an increase in response time (pre-test: 6.81 minutes; post-test: 7.78 minutes) ($p < 0.001$). These findings indicate that physical fatigue can impair athletes' ability to process, interpret and make decisions based on visual information. This impact could potentially reduce technical and tactical performance during matches. The implications of this study highlight the importance of integrating cognitive training alongside physical training to maintain athletes' cognitive performance under fatigue conditions.

Keywords: Visuospatial Perception, Physical Fatigue, Mental Rotation Test, Basketball Athletes.

1 Introduction

Basketball is a sport that requires a combination of high-level physical and cognitive skills (Trunić & Mladenović, 2014). The success of a basketball athlete in a match depends on decision-making speed, perceptual accuracy, and precise motor coordination (Gou & Li, 2023). One of the cognitive abilities that is very instrumental in the dynamics of the match is visuospatial perception, which is the ability to recognize the position of oneself, teammates, opponents, and the ball in three-dimensional space (Komarudin et al., 2024). This ability allows athletes to read the game situation, predict the opponent's movements, and respond appropriately to changes in the situation. Sharp visuospatial perception allows basketball players to perform accurate passing, strategic positioning, and effective penetration and finishing (Fu & Stasko, 2023). Thus, visuospatial perception is not just a supporting skill, but one of the important foundations of athletic performance in the sport of basketball.

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However, athletes' performance on the field is not always in optimal condition. The fatigue factor is one of the main challenges faced by athletes, especially in basketball games that are high intensity and intermittent. Fatigue can generally be defined as a condition of decreased physical and mental capacity due to repetitive activities that cause accumulation of muscle fatigue, decreased central nervous system function, and metabolic disturbances (Ament & Verkerke, 2009; Finsterer & Mahjoub, 2014; Parwata, 2015). In the context of sport, fatigue not only affects physical abilities such as strength, speed, and endurance, but also has a significant impact on cognitive abilities, including attention, reaction, decision-making, and visuospatial perception (Connell et al., 2016; Palmer, 2013; Van Cutsem et al., 2017). As fatigue levels increase, athletes' ability to interpret visual and spatial information quickly and accurately may decrease. This has serious implications in competition situations, where decisions must be made within seconds under high physical and emotional stress.

Numerous studies have revealed that fatigue can cause changes in brain activity, especially in the prefrontal cortex area which plays an important role in executive function and cognitive information processing (Petruo et al., 2018). Prolonged physical fatigue can slow reaction speed, decrease perceptual accuracy, and inhibit decision-making in competitive situations (Aini et al., 2025; Gantois et al., 2020). In basketball, this condition can lead to passing errors, misreading the opponent's movements, losing awareness of teammates' positions, and delays in responding to changes in game situations. Therefore, understanding the relationship between fatigue and decreased visuospatial perception accuracy is crucial to developing more effective training, recovery and performance management strategies in competitive sports.

Although the relationship between fatigue and cognitive decline has been widely investigated in various sports, research that specifically examines the effect of fatigue on visuospatial perception accuracy in basketball athletes is still relatively limited, especially at the national level. Most previous studies have focused more on physical aspects such as running speed, shooting accuracy, or muscle fatigue levels, without exploring in depth how fatigue affects spatial cognitive abilities that are vital in the game of basketball. Thus, there is a need to fill this gap with more focused and specific research. Through this research, it is hoped that a more comprehensive understanding of the impact of fatigue on the visuospatial perception abilities of basketball athletes can be obtained, as well as the implications for performance on the court.

Furthermore, the results of this study are expected to provide a basis for coaches, athletes and sports practitioners in designing exercise programs that not only increase physical capacity, but also maintain and even improve cognitive function under fatigue conditions. For example, game-based cognitive training under high physical load or the use of active recovery strategies aimed at maintaining perceptual acuity. In addition, this research may also encourage the development of a more holistic training approach, which integrates physical and cognitive aspects as one in building athlete performance. Thus, the contribution of this research is not only theoretical in the development of science, but also applicable in the world of sports practice.

2 Method

2.1 Research Design

This study uses a quantitative approach with a quasi-experimental pre-test and post-test one group design. This design allows researchers to compare the results of visuospatial perception measurements before and after treatment in the form of fatigue induction. By comparing pre-test and post-test scores in the same group, it can be analyzed to what extent fatigue affects visuospatial perception accuracy without the need to involve a control group. This design was chosen because it is effective for evaluating changes that occur due to certain treatments in a short period of time and with sufficient internal control.

2.2 Population and Sample

The population in this study were all active athletes who were members of the Basketball BKMF of the Faculty of Sport and Health Sciences, Makassar State University (FIKK UNM). The sample was taken by total sampling, considering the number of athletes available according to research needs. A total of 23 male athletes who joined the BKMF Basketball FIKK UNM team became subjects in this study. All subjects have followed a routine training program for at least the last six months, are in good health, and have no injuries or visual disturbances during the study.

2.3 Instrument

The main instrument in this study to measure visuospatial perception is the Mental Rotation Test (MRT). The Mental Rotation Test (MRT) is one of the cognitive psychology measuring instruments used to assess a person's ability to manipulate mental representations of two- or three-dimensional objects (Lochhead et al., 2022).

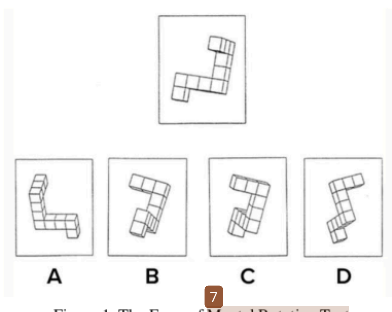

Figure 1. The Form of Mental Rotation Test

MRT is a standardized test used to measure the ability to mentally manipulate objects in two or three-dimensional space. The test requires participants to distinguish pairs of images whether they are identical (simply rotated) or different, within a limited time. Response time and accuracy level are the two main indicators in the assessment. The faster and more accurate the response, the better the mental rotation ability.

2.4 Research Procedure

The research was conducted in several stages as follows:

Table 1. Research Implementation Procedure

Phase	Description

Preparation phase	The researcher provided a briefing on the study procedures, including the completion of informed consent from the participants.
Initial Test	Participants underwent the Mental Rotation Test (MRT) in a fully resting condition to measure basic visuospatial perception accuracy.
Practice	Participants followed a high-intensity basketball training program designed to induce physical fatigue, including sprinting, dribbling, shooting, and defensive drills continuously for 20-30 minutes.
Final Test	Immediately after the high-intensity training was completed, participants underwent MRT again under fatigue conditions.
Analysis	All pre-test and post-test results were collected and analyzed using statistical methods. The data obtained from the MRT pre-test and post-test results were analyzed using the paired sample t-test statistical test. This test is used to determine significant differences between two conditions (before and after fatigue) in the same group.

3 Result

3.1 Descriptive Statistics

Before conducting further analysis, descriptive analysis was carried out to see an overview of the data obtained. These descriptive statistics include measures of central tendency (mean) and measures of data distribution (standard deviation, minimum, and maximum) from the Mental Rotation Test (MRT) test results both before (pre) and after fatigue (post).

Data Group		n	mean	Std.dev	min	max
Accuracy Score (%)	Pre	23	82.09	6.26	71	90
	Post	23	68.43	5.69	60	80
Response Time (Menit)	Pre	23	6.81	0.40	6.0	7.4
	post	23	7.78	0.43	7.1	8.5

From the results of descriptive statistics, it can be seen that in general there is a decrease in accuracy from pre (82.09%) to post-test (68.43%). The processing time also increased from an average of 6.81 minutes in the pre to 7.78 minutes in the post. The distribution of data is relatively homogeneous because the standard deviation is not too large. The minimum and maximum scores showed that almost all participants experienced a decrease in performance after fatigue.

3.2 Test of Normality (Shapiro-Wilk)

The normality test is carried out to determine whether the data is normally distributed. Data normality is important to determine the appropriate statistical analysis technique. If the data is normally distributed, parametric tests such as paired t-test can be used.

Data Group		n	Statistik	p-value	Description
Accuracy Score (%)	Pre	23	0.917	0.056	Normal
	Post	23	0.965	0.562	Normal
Response Time (Menit)	Pre	23	0.958	0.430	Normal
	post	23	0.954	0.362	Normal

All variables show a p-value greater than 0.05, so it can be concluded that the data is normally distributed. This fulfills the basic assumption for using the parametric t-test. The normal distribution of this data strengthens the validity of the results to be obtained from further analysis.

3.3 Test of Homogeneity (Levene's Test)

The homogeneity test was conducted to determine whether the variance of the data between the pre-test and post-test groups was the same.Homogeneity of variance is important in two-group comparison analysis.

Data Group	Statistik F	p-value	Description
Accuracy Score (%) Pre-Post	0.680	0.414	Homogen
Response Time (Menit) Pre-Post	0.143	0.707	Homogen

Based on the Levene test results, the p-value in both comparisons (accuracy and time) is greater than 0.05. This means that the variance between the pre-test and post-test data is homogeneous. This condition again fulfills one of the important assumptions for using the paired t-test, so that subsequent analysis can be performed more accurately.

3.4 Paired sample t-Test

This test is used to determine whether there is a significant difference between the results before and after fatigue.

Group Data	Mean Difference	Std. Dev Difference	T-Statistik	Df	P-Value	95% Ci	
						Lower	Upper
Accuracy Score (%)	13.65	5.13	8.251	22	<0.001	10.22	17.08
Response Time (Menit)	-0.97	0.39	-6.814	22	<0.001	-1.26	-0.67

Based on the results of the paired sample t-test analysis, it is known that there is a significant difference between the results of the visuospatial ability test before and after fatigue.The average decrease in MRT test accuracy was 13.65 points (from mean pre 82.09% to post 68.43%), with $t(22) = 8.251$, $p < 0.001$, and this difference was within the 95% confidence interval range of 10.22 to 17.08. This indicates that physical fatigue had a marked negative impact on participants' accuracy in mentally identifying object rotation, which is a key component in visuospatial ability. Meanwhile, the completion time of the MRT test also experienced significant changes. The average completion time increased by 0.97 minutes, from 6.81 minutes (pre) to 7.78 minutes (post). The test results showed $t(22) = -6.814$, $p < 0.001$, with a 95% confidence interval between -1.26 to -0.67. The negative values in the mean difference and t-statistic indicate an increase in time (longer duration), which suggests that fatigue made participants slower in processing information and completing the mental rotation task.

Both results show that fatigue significantly affects the spatial cognitive performance of basketball players, both in terms of accuracy and speed. This has important implications in the context of competitive sports, where the ability to read space, body position orientation and visual decision-making are crucial in fast and dynamic game situations.Such cognitive impairment can impair a player's technical and strategic performance during intense games or training sessions..

3.5 Data Visualizations

To support the results of statistical analysis that has been done, data visualization is presented in several forms of graphs. These graphs aim to clarify the difference between the visual spatial test results in the pre-test and post-test conditions of the fatigue intervention.

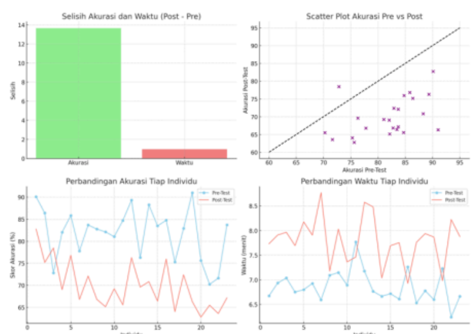

Figure 2. Visuospatial Difference Chart Data

The Accuracy and Time Difference (Post - Pre) graph shows that there was a decrease in accuracy by about 13 percentage points after the subjects experienced fatigue. In contrast, the processing time increased by almost 1 minute. This indicates that fatigue has a negative impact on accuracy and speed of task completion in visual-spatial aspects. The Scatter plot graph illustrates the relationship between the accuracy scores on the pre-test and post-test for each participant. Most of the points are below the diagonal line (y=x), indicating that the post-test scores were lower than the pre-test. This corroborates the finding that fatigue causes a decline in cognitive performance, particularly in visual-spatial ability tested using the Mental Rotation Test (MRT). The Individual Accuracy Comparison Chart shows the changes in each individual's accuracy score before and after fatigue. Almost all individuals experienced a decrease in accuracy scores, characterized by the post-test line being lower than the pre-test. This shows the consistency of the negative effect of fatigue on accuracy across individuals, although there is variation in the magnitude of the decrease between participants. The fourth graph illustrates the difference in pre-test and post-test completion times for each individual. There is a trend towards longer completion times after fatigue. This pattern supports the hypothesis that a fatigued physical or mental state slows down the processing of visual-spatial information, thus extending the time needed to complete the task.

4 Discussion

This study aims to determine the effect of fatigue due to high-intensity training on the accuracy of visuospatial perception of basketball athletes. Based on the results of measurements using the Mental Rotation Test (MRT), it was found that there was a decrease in visuospatial perception performance after participants experienced physical fatigue. Before participating in the high-intensity training program, the majority of athletes showed optimal mental rotation ability, with a high level of answer accuracy. However, after undergoing training sessions that induced severe fatigue, there was a trend towards decreased accuracy in completing the MRT task.

The observed decrease in visuospatial perception accuracy indicates that physical fatigue affects athletes' cognitive function, particularly in the domain of spatial processing. Physiologically, fatigue due to strenuous physical activity can disrupt the work of the central nervous system, particularly in areas of the brain such as the parietal and prefrontal cortex responsible for spatial processing, decision-making, and mental rotation (Canepa, 2021; Wang et al., 2023). When the body experiences fatigue, blood flow, oxygenation, and the efficiency of neurotransmitters in the brain can be impaired, which ultimately results in decreased cognitive performance (Amar et al., 2023; Noakes, 2012). These results are in line with previous studies showing that physical fatigue can reduce cognitive function, especially in tasks that require attention, information processing speed, and spatial ability (Dong et al., 2024; Gavelin et al., 2023). In the context of basketball, this impairment in visuospatial perception can have implications for the quality of decision-making on the court, such as delays in reading the opponent's movement, inaccuracies in passing, or errors in determining defensive positions. Therefore, understanding the impact of fatigue on cognitive function is important in developing training and recovery strategies for athletes.

Theoretically, the concept of mental fatigue suggests that fatigue not only affects physical abilities, but also the cognitive aspects of individuals (Alam, 2022; Behrens et al., 2023). Persistent mental load during strenuous physical activity can result in limited cognitive resources, making it difficult for individuals to perform tasks that require complex information processing (Balk & de Jonge, 2021). This phenomenon was evident in the results of this study, where athletes who had experienced fatigue showed a significant decrease in their mental rotation accuracy. Psychological factors may also play a role in this phenomenon. After a high-intensity training session, athletes' motivation and focus may decrease, resulting in less attention to detail in the completion of MRT tasks (Cece et al., 2022). In addition, increased perception of bodily fatigue may divert some of the athlete's cognitive capacity from the task at hand, resulting in decreased effectiveness of visual-spatial information processing. This suggests that physical and psychological fatigue interact to influence cognitive performance (Behrens et al., 2023; Komarudin et al., 2024).

The study also showed that individual variation in the ability to manage fatigue plays an important role. Some athletes were able to maintain relatively more stable MRT accuracy than others, despite being under fatigue conditions. This could be influenced by factors such as aerobic fitness level, competition experience, mental adaptive capacity to physical stress, and coping strategies used by athletes during physical and mental stress. Athletes with better cardiovascular fitness tend to have higher fatigue tolerance, so that their cognitive function remains more stable even under conditions of physical stress (Graziano et al., 2022; Wu et al., 2024).

From an applicative standpoint, the results of this study imply the importance of incorporating cognitive training under fatigue conditions as part of an athlete development program. Coaches can design simulation games that combine intense physical training with spatially-based cognitive tasks to train quick decision-making skills in fatigue situations. Thus, athletes are not only trained in terms of physical endurance, but also in terms of cognitive toughness that is needed in real competition situations. Furthermore, these results support the importance of effective fatigue management in competition preparation. Strategies such as recovery optimization, implementation of nutrition that supports brain recovery, training load management, and mindfulness training may be relevant interventions to maintain the quality of athletes' cognitive function during competitive periods (Clemente-Suárez et al., 2025). Awareness of the importance of maintaining cognitive function, especially visuospatial perception under fatigue conditions, is a key factor in improving the consistency of athletes' performance on the field.

Although this study has provided relevant findings, it is necessary to recognize the limitations of its conduct. The study sample being limited to one university basketball club may limit the generalizability of the results to a wider population of athletes. In addition, the measurement of fatigue focused more on physiological indicators and subjective perceptions, without direct examination of more specific neurophysiological parameters. Therefore, future research is recommended to utilize neuroimaging techniques or other biomarkers to deepen the understanding of the biological mechanisms underlying the influence of fatigue on mental rotation. Overall, this study confirms that fatigue due to high-intensity training negatively impacts the visuospatial perception accuracy of basketball athletes. These findings enrich the literature on the relationship between physical fatigue and cognitive function in the context of sport, and open up opportunities to develop more comprehensive training programs that take into account the cognitive aspects of athletes. Efforts to maintain spatial perception acuity even when fatigued are one of the strategic elements in supporting athletic performance at high levels of competition.

5 Conclusion

Based on the results of the research that has been conducted, it can be concluded that fatigue due to high-intensity training has a negative effect on the accuracy of visuospatial perception of basketball athletes. The condition of physical fatigue that occurs after training causes a decrease in mental rotation ability, which is reflected in the decreased accuracy of answers in the Mental

Rotation Test (MRT) given to athletes. This decline suggests that cognitive function, particularly in the domain of spatial perception, becomes more susceptible to disruption when the body is fatigued. Physiological factors such as decreased oxygen supply to the brain, changes in the work of neurotransmitters, as well as interactions with psychological factors such as decreased focus and motivation, are thought to be the main causes of decreased cognitive performance under conditions of fatigue.

In addition, the results of this study confirm the importance of fatigue management in training programs, not only to maintain physical performance but also to maintain the acuity of cognitive functions that are essential in the game of basketball. The integration of cognitive training under fatigue conditions and the implementation of effective recovery strategies are important recommendations in order to improve the consistency of athletes' performance on the field. Thus, this study contributes to enriching the understanding of the relationship between fatigue and cognitive function in the context of sport, and provides a basis for the development of more holistic training interventions for basketball athletes.

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