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Eye Movements and Visual Abilities Characteristics in Gymnasts, Soccer Players, and Esports Athletes: A Comparative Study

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ABSTRACT

Ramyarangsi P, Bennett SJ, Nanbancha A, Pokaisasawan A, Noppongsakit P, Ajjimaporn A. Eye Movements and Visual Abilities Characteristics in Gymnasts, Soccer Players, and Esports Athletes: A Comparative Study. **JEPonline** 2024;27(5):70-80. This study investigated the differences in eye movements and visual ability among female athletes from gymnastics, soccer, and esports. Forty-two female athletes (14 per Group) participated. Eye movements were recorded using Tobii Pro Glasses 2 while the participants viewed standardized video stimuli. Fixation count, fixation duration, and saccade amplitude were analyzed. Visual abilities were assessed through tasks measuring visual working memory, peripheral vision, and near-far accommodation. Gymnasts exhibited significantly longer fixation duration compared to soccer players for single object stimuli. Gymnasts also showed longer total fixation duration compared to both soccer and esports athletes. Esports athletes demonstrated faster mean reaction times in the near-far accommodation task compared to gymnasts. The findings indicate that sport-specific visual demands influence eye movement patterns and performance. The gymnasts exhibited detailed visual analysis, while the soccer players prioritized rapid scanning. The esports athletes demonstrated superior near-far accommodation. These findings highlight the need for sport-specific visual training.
Key Words: Eyes-Tracking, Ocular Movements, Visual Skills

INTRODUCTION

The eyes play a crucial role in athletic success. Visual skills encompass a range of abilities, such as working memory, peripheral vision, and near-far accommodation that are essential for optimal performance (7). Visual working memory involves the capacity to retain and manipulate visual information over short periods, which is vital for making quick decisions and adjusting strategies in sports (8). Peripheral vision enables athletes to detect and respond to stimuli outside their direct line of sight, which is an important skill for maintaining spatial awareness and anticipating opponents' movements in dynamic sports like soccer (28). Similarly, near-far accommodation, the ability to rapidly and accurately switch focus between objects at different distances, is critical for sports that require quick shifts in visual attention, such as gymnastics and esports (23,27). Previous research has underscored the importance of these visual abilities in enhancing athletic performance. For example, Kruger et al. (17) demonstrated the role of visual attention in expert cricket players, while Gobet and Simon (10) highlighted the significance of visual working memory in high-level chess players.

Recent advancements in eye-tracking technology have enabled researchers to analyze ocular movements and gain insights into gaze patterns and cognitive demands (6). Parameters such as the number of fixations and fixation duration can reveal decision-making processes in sports, particularly in complex situations (6). Studies have shown correlations between fixation patterns and information processing during matches, especially in highly skilled midfield soccer players compared to amateur players. This suggests that sport-specific adaptations in visual processing exist (3).

Different sports demand specific visual skills, which can vary significantly depending on the nature of the sport. For example, gymnastics requires exceptional visual acuity and coordination, soccer emphasizes field awareness and quick decision-making, and esports focuses on rapid visual processing of screen-based information (5,14,18,19). Most existing studies on visual function have compared experts and novices within a single sport, highlighting the vision expertise developed through training [e.g., Abernethy & Wood, 2001] (2). However, there is a need for further examination of whether the specific visual demands of different sports lead to unique visual abilities and functions.

This study hypothesized that athletes from diverse sports exhibit distinct visual processing adaptations due to the specific visual demands of their respective disciplines. By analyzing ocular movements using eye-tracking technology and assessing visual abilities through targeted tests, this study aims to identify these sport-specific adaptations. Additionally, it explores the correlations between ocular movements and visual performance within each sport. By enhancing our understanding of how athletes adapt to the unique visual demands of their respective sports, this study seeks to inform tailored training strategies and interventions aimed at optimizing visual skills and overall performance. The findings could have significant implications for developing sport-specific training protocols that enhance cognitive abilities and decision-making processes in elite athletes.

METHODS

Subjects

Forty-two female professional athletes participated in this study, comprising 14 gymnasts, 14 soccer players, and 14 esports athletes. All participants had over 3 years of competitive experience in their respective sports, were aged between 18 and 25, and had normal or corrected-to-normal vision. Physical attributes (age, weight, height, and BMI) were comparable across groups. Informed consent was obtained from all participants, and the study was approved by the Mahidol University Ethics Committee (MU-CIRB 2021/485.2311), adhering to the principles of the Helsinki Declaration.

Procedures

The participants attended a laboratory session at 9:00 a.m. for an assessment of physical attributes, followed by testing for ocular movement and visual ability.

Assessments

Ocular Movement Recording

Ocular movements from both eyes were recorded using Tobii Pro Glasses 2 while participants watched experimental video stimuli. The participants were seated 60 cm from a 17-inch monitor with a head support to minimize head movement (12). Eye-tracking data were analyzed using Tobii Pro Lab Analyzer for fixation count, average fixation duration, and total fixation duration. The video stimuli included single and multiple-athlete running videos, each lasting 30 sec (Figure 1). Eye-tracking data were collected at 50 Hz with a spatial resolution of 240 x 960 pixels 21. The front-facing scene camera operated at 25 Hz with a spatial resolution of 1920 x 1080 pixels. The fixation circle size was set to 100%, and the raw gaze filter was used to capture all eye movements. Areas of interest (AOIs) were defined within the video stimuli to extract fixation metrics (13).

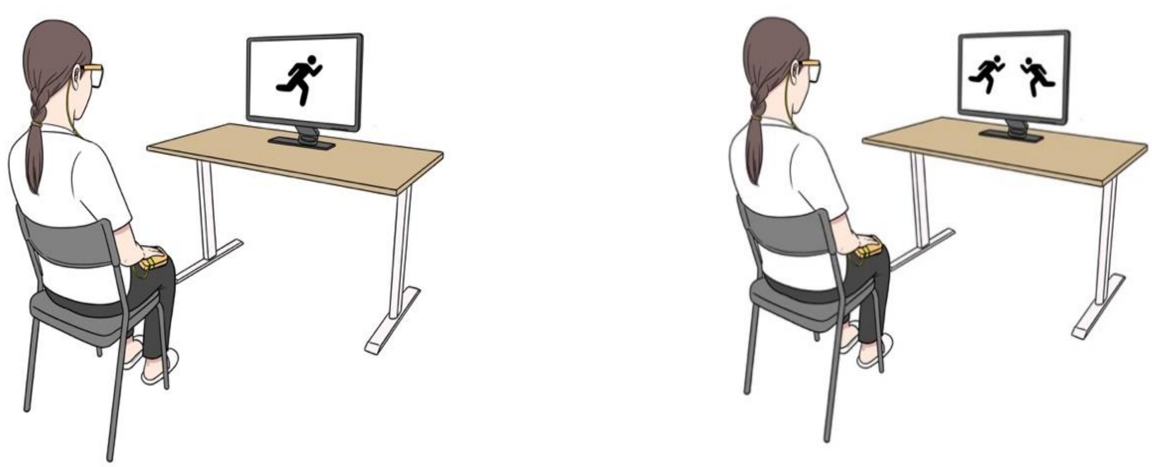

Figure 1. Illustration of Eye-Movement Recording Setting; Left: Eye-Movement Recording During One Object's Video Stimulus; Right: Eye-Movement Recording During Multiple Object's Video Stimulus.

Visual Ability Tests

Near-Far Accommodation Test: The accommodation facility was measured using a Near-Far Quickness Test. A black Landolt ring was presented on far (1 meter) and near (40 cm) screens alternately. The participants pressed the arrow key corresponding to the direction of the gap in the Landolt ring. The first ring was always presented on the far screen, alternating with the near screen following each response (24). There were 20 trials (10 at each distance), recording accuracy (in percentage) and response time (in milliseconds) (Figure 2A).

Visual Working Memory (N-Back Task): The participants completed 1-back and 2-back tasks with continuous image sequences, responding by pressing the space bar for matching stimuli 16. ach task consisted of nine 30-second blocks with 15 stimuli per block (1,500 ms presentation, 105 ms inter-stimulus interval). A 12-second instructional phase preceded each block (25) (Figure 2b).

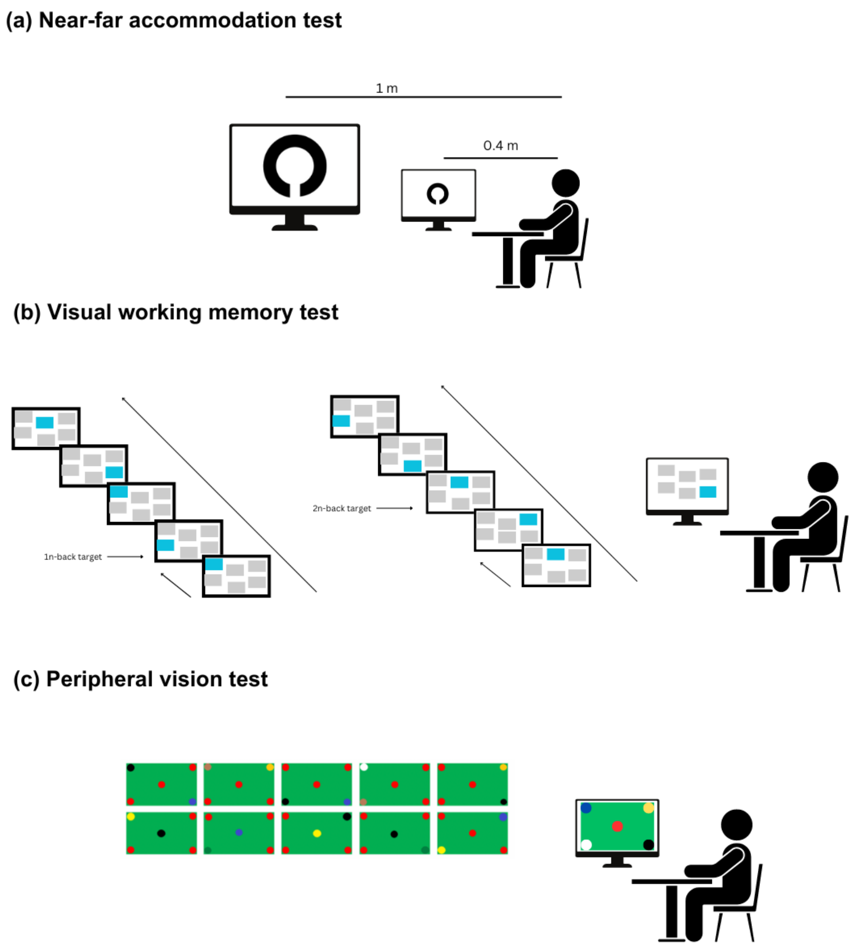

Figure 2. Illustration of Visual Ability Tests (i.e., Near-Far Accommodation, Visual Memory, and Peripheral Vision Tests).

Peripheral Vision Test: Dynamic peripheral visual ability was assessed using a task with 7 colored circles (targets and non-targets). The participants were seated in a comfortable chair with an adjustable height to keep their eyes centered on the screen and were positioned 53 cm away from the screen. During the test, 7 circles, each of a different color (yellow, white, red, green, brown, blue, and black) were assigned as either a target or non-target. Three out of 5 objects must be the same color as were target or otherwise, it was a non-target. The test session had 56 trials comprised of 13 target trials and 43 non-target trials (20). Once the participants perceived the target pattern, they were required to press the space bar as quickly as possible. They were instructed not to move their eyes to scan the display, which was confirmed by observing the eye-tracker. This peripheral visual performance was described by the accuracy. In the test session, the following events were considered: true positive (TP) indicated successfully pressing the target; true negative (TN) referred to correctly ignoring a non-target; false positive (FP) was recorded when a non-target mistaken clicked; false negative (FN) stood for ignoring a target. The events described above were used to compute the accuracy as defined in Equation (1), where "T" represented the total number of targets, and "NT" represented the total number of non-targets (20) (Figure 2C).

$$accurate = \frac{1}{2}\left[\left(\frac{\mathrm{TP}}{\mathrm{T}} - \frac{\mathrm{FP}}{\mathrm{NT}}\right) + \left(\frac{\mathrm{TN}}{\mathrm{NT}} - \frac{\mathrm{FN}}{\mathrm{T}}\right)\right] \times 100\%$$

Statistical Analyses

Sample size calculations, based on Cohen's effect size of 0.5, an alpha level of 0.05, and a power of 0.8 from a previous study (19) by using G Power v3.1, determined a required sample size of 14 participants per Group. The participant demographic characteristics were described using mean ± standard deviation. The normality of dependent measures from the visual oddball paradigm and visual skill tests was assessed using the Shapiro-Wilk Test. One-way ANOVA was employed to compare demographic characteristics, visual skill test results, and AOI data from the multiple object stimulus condition across the 3 Groups of athletes. Given non-normal distributions in the AOI data for the single object stimulus condition, Kruskal-Wallis Tests were used for these comparisons. Pearson correlation coefficients were calculated to examine the relationship between eye-tracking metrics (fixation count, average fixation duration, total fixation duration) and visual performance (visual working memory, peripheral vision, and near-far accommodation scores). The values of the magnitude of the differences, F value and Chi-Square (χ^2), the effect size partial eta-square (η^2), and the P-value were calculated. The level of significance was set at $P < 0.05$ for all analyses. Statistical computations were performed using GraphPad Prism 9 software version 9.5.1.

RESULTS

General Characteristics

Demographic data including age, height, weight, and BMI did not differ significantly between gymnasts (mean age = 20 ± 1 years, height = 1.62 ± 0.02 m, weight = 57.6 ± 4.0 kg, BMI = 22.0 ± 1.5 kg/m²), soccer players (mean age = 21 ± 1 years, height = 1.60 ± 0.06 m, weight = 53.4 ± 7.3 kg, BMI = 20.8 ± 2.5 kg/m²), and esports athletes (mean age = 21 ± 2 years, height = 1.62 ± 0.06 m, weight = 56.8 ± 10.6 kg, BMI = 21.5 ± 3.3 kg/m²). These findings suggest that observed differences in eye movements and visual performance are likely attributable to sport-specific demands rather than demographic factors.

Eye Movement Analysis (Figure 3)

One Object Stimulus

Gymnasts exhibited significantly longer total (Gymnasts = 376.9 ± 85.1 ms, Soccer = 98.38 ± 49.5 ms, Esports= 229.3 ± 76.53 ms, $\chi 2$ (3,42) = 6.897, P = 0.03) and average fixation durations (Gymnasts = 306.6 ± 73.6 ms, Soccer = 85.8 ± 47.6 ms, Esports = 152.4 ± 40.3 ms, χ^2 (3,42) = 8.510, P = 0.01) at the area of interest (AOI) compared to soccer players. No significant differences in fixation count were observed.

Multiple Object Stimuli

Gymnasts demonstrated a significantly longer total fixation duration at the second object's AOI compared to both soccer players and esports athletes (Gymnasts = 1832.0 ± 496.1 ms, Soccer = 280.8 ± 67.6 ms, Esports = 283.9 ± 80.7 ms, $F(2,43) = 10.60$, $P < 0.01$, $\eta^2 = 0.19$). No significant differences were found in average fixation duration or fixation count.

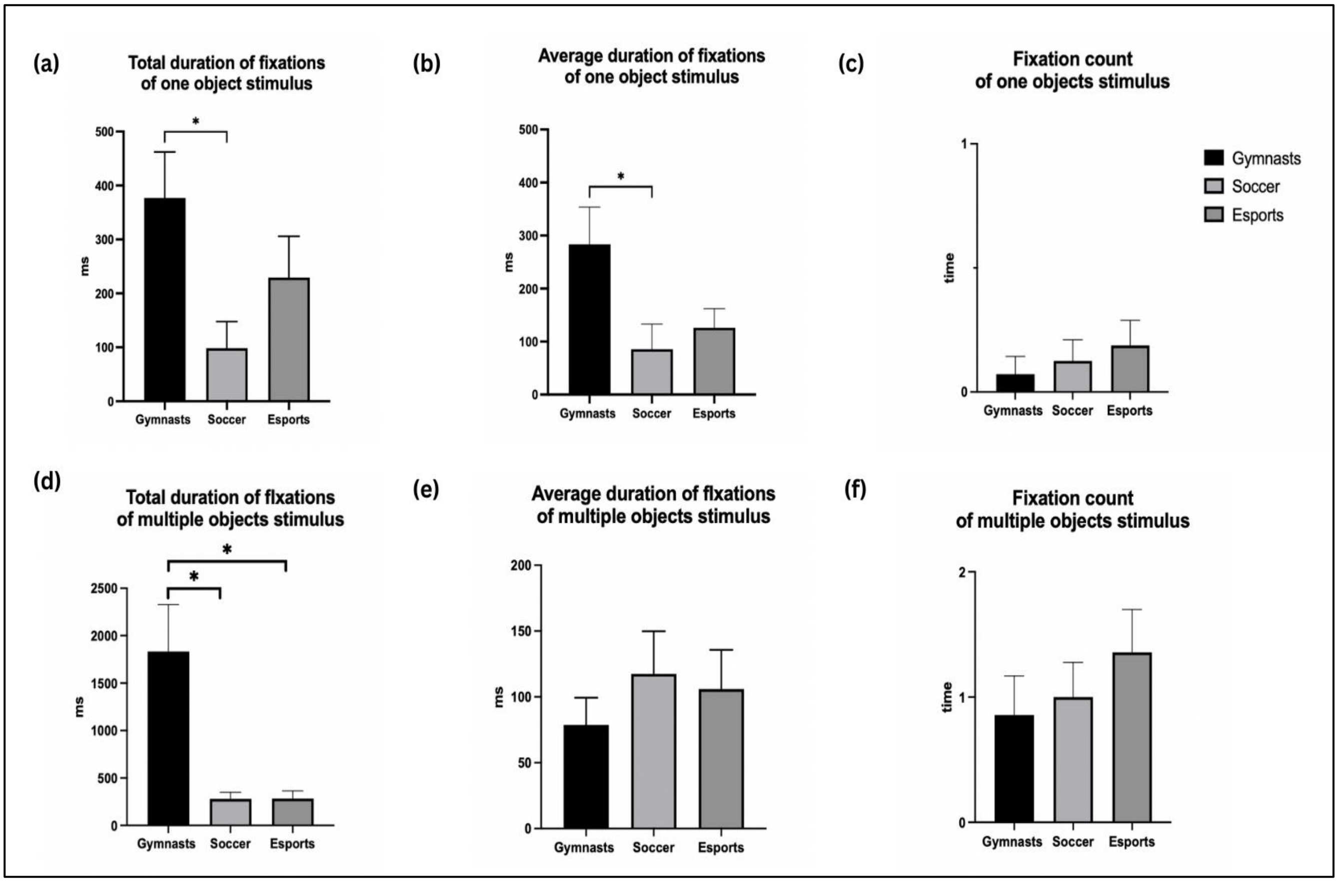

Figure 3. Comparisons of: (a) Total Duration of Fixation AOI of One Object Stimulus; (b) Average Duration of Fixation AOI of One Object Stimulus; (c) Fixation Count of One Object Stimulus; (d) Total Duration of Fixation AOI of Multiple Object Stimulus; (e) Average Duration of Fixation AOI of Multiple Object Stimulus; and (f) Fixation Count of Multiple Object Stimulus for the Gymnasts, the Soccer, and the Esports. The data are shown as means ± SEM. n = 14 for each Group. *P < 0.05.

Visual Ability

Near-Far Accommodation

Esports athletes exhibited significantly faster mean reaction times compared to gymnasts (Gymnasts = 1331.0 ± 58.6 ms, Soccer = 1195.0 ± 87.2 ms, Esports = 1061.0 ± 48.4 ms, F(2,39) = 4.07, P = 0.02, $\eta^2 = 0.17$). No significant differences were observed in accuracy (Gymnasts = 92.9 ± 2.33%, Soccer = 95.0 ± 1.9%, Esports = 97.8 ± 0.9%).

Peripheral Vision and Visual Working Memory

No significant differences were found between Groups in accuracy for either task. (Visual Working Memory (n1-back): Gymnasts = 99.11 ± 0.9%, Soccer = 85.16 ± 3.47%, Esports = 91.41 ± 2.7%, Visual Working Memory (n2-back): Gymnasts = 75.7 ± 4.8%, Soccer = 67.2 ± 4.7%, Esports= 69.2 ± 7.1% and Peripheral Vision Gymnasts = 99.5 ± 0.5%, Soccer = 96.6 ± 1.7%, Esports= 96.6 ± 1.7%). No significant differences were observed between Groups in mean response time for either task. (Visual Working Memory (n1-back): Gymnasts = 475.3 ± 11.27 ms, Soccer = 469.4 ± 17.21 ms, Esports = 472.8 ± 12.12 ms, Visual Working Memory (n2-back): Gymnasts = 539.5 ± 14.53 ms, Soccer = 514.3 ± 28.71 ms, Esports = 498.5 ± 31.05 ms and Peripheral Vision Gymnasts = 602.7 ± 8.7 ms, Soccer = 597.6 ± 14.94 ms, Esports = 616.4 ± 17.2 ms).

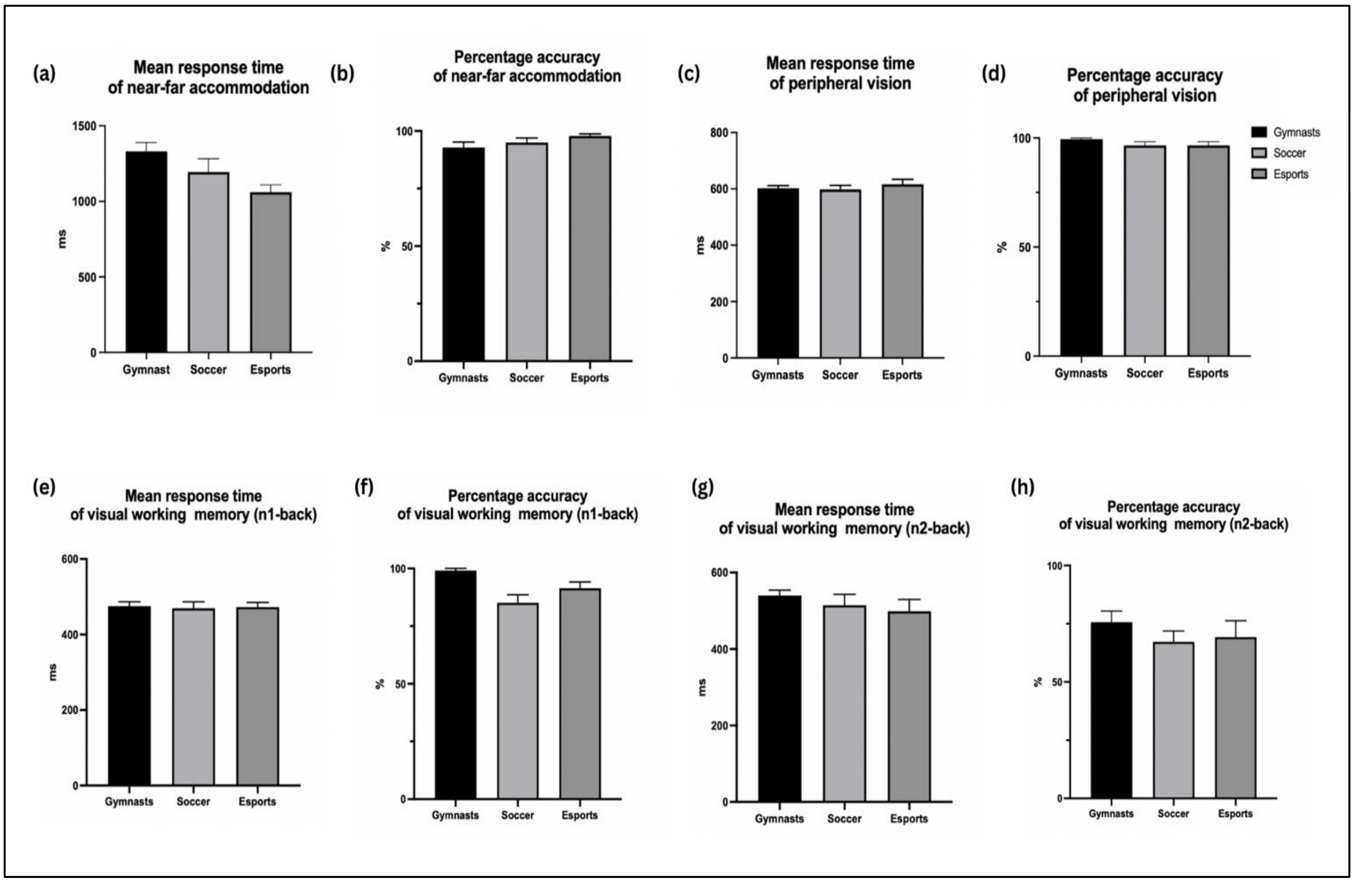

Figure 4. Comparisons of: (a) Mean Response Time of Near-Far Accommodation; (b) Percentage Accuracy of Near-Far Accommodation; (c) Mean Response Time of Peripheral Vision; (d) Percentage Accuracy of Peripheral Vision; (e) Mean Response Time of Visual Working Memory (n1-back); (f) Percentage Accuracy of Visual Working Memory (n1-back); (g) Mean Response Time of Visual Working Memory (n2-back), and Percentage Accuracy of Visual Working Memory (n2-back) for the Gymnasts, the Soccer, and the Esports. The data are shown as means ± SEM. n = 14 for each Group. *P < 0.05.

DISCUSSION

This study examined the differences in eye movements and visual abilities among female athletes from 3 distinct sports: gymnastics, soccer, and esports. The findings indicated sport-specific adaptations in ocular movements, suggesting that the unique demands of each sport shape visual processing. However, no significant differences were found in general visual abilities across the Groups.

The analysis of ocular movements highlighted significant variations in eye movement patterns between the Groups. Gymnasts exhibited significantly longer fixation durations compared to soccer players for both single and multiple object stimuli. This suggests that gymnasts may need more time to process visual information, likely due to the complex visual-motor coordination required in their sport (4). Additionally, the longer fixation durations at the second object's area of interest (AOI) in the multiple-object stimuli condition indicate that gymnasts may prioritize key visual cues during complex visual tasks (1). This behavior could reflect their enhanced ability to anticipate and respond to dynamic environmental cues, which is critical for executing intricate routines (29). Furthermore, the gymnasts' tendency to focus on relevant and necessary information within AOIs could explain the prolonged fixation durations observed (4). The meticulous attention to relevant information within AOIs is characteristic of gymnasts, who typically compete individually and demonstrate high internal focus (22).

Conversely, soccer players exhibited the shortest fixation durations, suggesting a preference for rapid visual scanning. This behavior aligns with the dynamic nature of soccer, where players must continuously monitor their surroundings to track the ball, teammates, and opponents (3). The ability to quickly gather and process visual information is essential for making fast decisions and maintaining situational awareness on the field (26). The shorter fixation durations observed in soccer players may indicate their proficiency in rapidly switching attention between visual targets, a necessary skill for high-level performance in a fast-paced and unpredictable sport (28).

Esports athletes demonstrated superior performance in the near-far accommodation task, as evidenced by their significantly faster reaction times compared to gymnasts. This finding underscores the impact of sport-specific training on visual skills (11). Esports athletes, who are accustomed to rapid visual processing in a fast-paced digital environment, have developed the ability to quickly shift visual focus between different on-screen elements (15). This skill is crucial for success in esports, where players must respond swiftly to in-game events (9). The near-far accommodation task results highlight the visual adaptations esports athletes undergo, emphasizing their capacity for quick and accurate visual adjustments (27).

Despite these differences in eye movements, no significant variation was found between gymnastics, soccer, and esports athletes in visual abilities, such as visual working memory and peripheral vision. This suggests that these skills may be less influenced by the specific demands of each sport and more generalized across different athletic domains (11). For example, gymnasts rely heavily on precise visual-motor coordination but may not need heightened peripheral vision, as their routines are performed in controlled environments with focused visual targets. Soccer players, on the other hand, depend on peripheral vision to monitor their surroundings and maintain situational awareness on the field, yet this study did not show superior peripheral vision compared to the other Groups. Similarly, esports athletes, who are accustomed to rapidly processing in-game stimuli, did not exhibit significant differences in visual working memory despite the fast-paced nature of their tasks.

While certain visual skills, such as fixation duration and near-far accommodation, appear highly specialized, our findings indicate that visual working memory and peripheral vision may not vary as much between these sports as initially expected. This might be due to the generalized importance of these abilities across multiple sports, where the need to retain and manipulate visual information or detect changes outside the central field of vision is essential, regardless of specific sporting contexts. Future research should explore the role of visual memory in sports like chess and solitaire that depend heavily on cognitive processing, to further understand how these visual skills are developed and whether they can be further specialized in different athletic or cognitive contexts.

Limitations in this Study

This study has several limitations. Controlling for confounding variables, such as cognitive abilities and training intensity, would provide a more comprehensive understanding of the observed differences. Furthermore, the assessment tools used to measure visual abilities in this study may not fully reflect the real-world demands encountered in actual sports situations. The controlled laboratory conditions, while useful for isolating specific variables, may not capture the complexity and dynamic nature of visual processing required during competition. As a result, this could have affected the ecological validity of the findings. Future research should incorporate more sport-specific assessment tools or simulations to better replicate the visual challenges athletes face in their respective sports.

CONCLUSIONS

This study highlights the influence of sport-specific demands on visual processing and performance. Tailored training programs that target specific visual skills could enhance athletic performance. Future research should explore the neural mechanisms underlying these adaptations and develop interventions to improve visual abilities across a variety of sports.

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