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Comparing visio-spatial intelligence in amateur rugby and netball players using hand-eye coordination tests

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Background: Research investigating the differences in visio-spatial skills (VSS) between athletes and non-athletes, as well as variations across sports, presents conflicting findings.

Aim: The objective of this study was to determine if there exist significant differences in visio-spatial intelligence (VSI) skills between rugby players and netball players, and whether such disparities are present when comparing both groups to non-athletes.

Setting: All participants, including the control group (non-athletes), rugby players and netball players, were recruited from the Zululand region of South Africa's KwaZulu-Natal province, specifically from all premier league rugby and netball teams in the area.

Methods: Participants underwent an optometric assessment, followed by an evaluation of VSS using six established tests: The Hart Near Far Rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests.

Results: The results revealed that rugby players significantly outperformed netball players in speed of recognition, peripheral awareness and hand-eye coordination ($P = 0.000$). Moreover, both rugby players and netball players performed significantly better than non-athletes in five of the six tests ($P = 0.000$), with the exception being the visual memory test ($P = 0.809$).

Conclusion: This discrepancy in performance suggests that certain VSS are superior in athletes compared to non-athletes, highlighting potential implications for theories of vision, test selection and the development of sport-specific VSS testing batteries. Furthermore, the use of a hand-eye coordination-specific VSS test battery effectively differentiated between different sports.

Contribution: The identified pattern was not consistent across all VSS tests, indicating that further research should explore the training methods employed by both sports, as these factors may contribute to the observed differences.

Keywords: visio-spatial intelligence (VSI); Rugby vision; netball vision; visual skills; sport.

Introduction

One of the most sophisticated and essential sensory systems for receiving information from the environment is vision.[1] Sports vision refers to an individual's ability to effectively and efficiently utilise the three phases of visual processing – perception, integration and response – to react to a stimulus.[2] This is a growing area of research in sport physiology and optometry, requiring a wide range of physical and mental skills for competitive sports.[2] Vision is a crucial factor in sports execution,[3,4] and high-level sports performance is achieved only when both visual information and cognitive abilities are adequate.[5,6] Sports training programmes often emphasise visual and visual-motor skills because sports are perceptually demanding, and athletes, coaches and trainers constantly seek ways to enhance these skills.[7] Phrases such as 'the eyes guide the body', 'keep your eye on the ball', and 'you can't strike what you can't see' highlight the critical role that vision plays in athletics.[8,9] The notion that expert athletes possess superior visual-perceptual and visual-cognitive abilities is supported by empirical evidence across various sports disciplines.[8,9]

Rugby necessitates visual skills that enable players to perform tasks such as target identification, scanning the opponent's playing style, positioning, reacting to audio-visual signals, and most importantly, hand-eye and foot-eye coordination.[10,11] For instance, during a line-out, players require excellent hand-eye coordination with the ball, precise timing for throwing and catching, and the use of both central and peripheral vision to successfully complete the catch, often using opponents' eye gazes as cues.[11] Research conducted by Du Toit et al.[12] on 20 female rugby players aged 19 to 24 years confirmed the positive impact of a sports vision training programme on visual skills and hand-eye coordination.

Netball is categorised as a non-static sport, requiring continuous processing of visual information for over an hour. This necessitates visual attention and dynamism from the player to consistently process game-related information.[13,14] Coaches should recognise that optimal performance in competitive sports such as netball involves the entire body, including the visual system.[15] Netball performance depends on making precise decisions based on visual input,[15] and the effectiveness of a player's visual system in interpreting information determines their ability to perform quickly and accurately.[16] According to Wilson and Falkel,[17] hand-eye coordination, balance and visual skills (such as accommodation, visual tracking of teammates and opponents, and peripheral awareness) are among the most essential skills in netball.

Research on gender disparities in cognitive capacity is contradictory; however, it is generally acknowledged by social and psychological scientists that men and women have different spatial abilities.[18,19] Studies have shown that males exhibit stronger spatial skills on average than females in various sports categories.[20] However, when comparing tennis and volleyball athletes (both hand-eye coordination sports) with similar performance and training experiences, no significant differences in spatial ability were found between males and females, suggesting that sport activity may influence spatial abilities.[21] In other high-impact sports such as basketball, female athletes have been found to outperform male athletes, with evidence suggesting that androgens might enhance spatial abilities in women while impairing them in men.[22]

These findings indicate that the physical impact level and associated hormonal variations may explain the differences in capacities between male and female athletes.[22] The contradictory findings on visio-spatial intelligence (VSI) between male and female athletes may be because of the use of standard testing methods rather than sport-specific test batteries. There is a knowledge gap regarding the VSI of male and female athletes because of the lack of sport-specific research. This study was conducted to compare VSI between male rugby players and female netball players using a hand-eye coordination-specific visual test battery.

Aims and hypothesis

The aim of this study was to compare the VSI of amateur rugby and netball players using a hand-eye coordination specific visual test battery. Six visio-spatial skills (VSS) components were compared between amateur rugby players and netball players in this study: accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, hand-eye coordination and visual memory. The study hypothesises that rugby and netball players will exhibit superior VSS compared to non-athletes.

Research methods and design

Participants

The study sampled male amateur rugby players (*n* = 35), female netball players (*n* = 35), and a sedentary control group (*n* = 35), all participants were aged 18 to 34 years. All participants, including the control group (non-athletes), rugby players and netball players, were recruited from the Zululand region of South Africa's KwaZulu-Natal province, specifically from all premier league rugby and netball teams in the area. A non-probability sampling technique was employed. Rugby and netball players were required to have completed 30 h of training and played at least one competitive game per week in the Premier League in the previous three months. To ensure group equivalence, participants in each group were age-matched. The non-athletes participating were required to not participate in any form of sport for the past 6 months.

Optometric assessment

Each participant underwent a general optometric assessment using the Spectrum Eyecare program (Version 6.0.0, Digital Optometry, Republic of South Africa) to determine whether any visual impairments prevented them from taking part in the study. Every participant claimed to have normal or corrected-to-normal vision, characterised 20/20 or greater vision. All of them had previously undergone a VSS test.

Visio-spatial skill test battery

Testing was conducted on weekday mornings between 07:00 am and 12:00 pm in the post-absorptive state following a 9 to 12-h fast to minimise the influence of any meal or supplement influences. To minimise any physical and psychological effects, participants were assessed at least 48 h after partaking in any physical activity. Both groups received the same VSS test battery, which was administered in the following order to prevent the impact of earlier tests on later tests: accommodation facility, saccadic eye movements, speed of recognition, hand-eye coordination, peripheral awareness and visual memory. Five minutes of rest was taken between each session to ensure adequate recovery.

Accommodation facility

The ability of an eye to locate and recognise an object at a specific distance, as well as its position, orientation and refractive errors, was evaluated using a Hart Chart.[23,24] The test is valid and reliable to use, with a reliability score of 0.724.[25,26] The Hart Chart was placed at each participant's head height on a wall 3 m away. Each participant was required to hold a second chart at arm's length, the font size of the letters was standardised according to the set up used by previous authors. The participants were then requested to read aloud the first letter of the first line of the chart from 3 m, and they were then told to read aloud the first letter of the chart from an arm's length away.[26,27] The participants were instructed to continue in this manner for 30 s, at the end of which the errors and their final score (i.e. the number of letters properly read) were recorded. The final score was calculated by deducting the participant's total number of errors from the overall score. Various charts were used to demonstrate that letters cannot be memorised.[23,26] After a 5-min intersession break, the highest score from the two trials was recorded and used in the analysis.

Saccadic eye movements

The participant's eyes were monitored using a saccadic eye movement chart to determine how rapidly they moved to a new location in the visual field.[17,28,29] The reliability of this test is 0.703.[26] This chart has movable letters running vertically downward on both sides of the page. Various charts were used to prevent letters from being memorised.[26] Two saccadic eye movement charts fixed on a wall and separated by 1 m were placed 3 m apart from the participant. The participant was then required to quickly turn to the right chart and read the first letter aloud on the lateral side before doing the same on the left side of the chart. The participants were instructed to shift their eyes while maintaining a constant head position. The test lasted for 30 s, and both the final score and the number of errors (i.e. number of letters were read) were recorded by deducting the number of errors from the total number of letters read. The highest score from the two trials was recorded and used in the analysis at the end, with a 5-min rest period in between.[26]

Speed of recognition

The Batak Pro (Quotronics, Surrey, United Kingdom),[30] which has a reliability of 0.946 and requires the subject to react to a mobile stimulus,[26] was used to evaluate the participants' speed of recognition. The Batak Pro equipment stands out for its capacity to emit light with a one-second lifespan, which is used to prompt a neurological speed of response in test subjects in sports including tennis, basketball, rugby and netball.[25] This software allowed 100 timed targets to glow randomly, with Batak's 'time' light-emitting diode (LED) panel counting the targets down from 100 to zero, and the 'score' LED screen showing each successful attack. The targets were maintained to provide a potential attack window of one second. If the wrong target was struck, or it was hit 'out of time', the entire procedure was accelerated. The participant was instructed to perform this exercise without striking any flashing targets. In addition to losing five points for striking the target, the athlete also received a verbal 'foul' from the equipment. The infrared beam was immediately released, and the participant had to dodge it or lose five points if all targets in the middle lit up simultaneously. The system recorded all errors, automatically deducted them from the final score, and computed the score.[30] After a 5-min intersession break, the highest score from the two trials was recorded and used in the analysis.

Peripheral awareness

The ability of participants to perceive objects and motion that are not directly in front of them was assessed using the Accumulator Program of the Batak Pro.[30] The reliability of this test is 0.885.[25] As part of the Accumulator Program, random targets on the Batak Pro remained lit for 60 s before the participant touched them.[30] Two trials were conducted with a 5-min break in between, and the system recorded the targets that were successfully touched in 60 s. The top score was recorded and used in the concluding stage of the analysis.

Hand-eye coordination

To assess hand-eye coordination, a tennis ball wall throw was used in this study.[25] The reliability rating of this test was 0.708.[26] Each player had to throw the ball from a designated location two meters away from the wall and catch it using their opposite hands, the participant was allowed to pick up the ball from the ground if it falls. The participants performed this for 30 s.[26] For each ball that the participant successfully caught, points were scored. The competitors had 30 s to complete as many catches as they could. A 5-min break was taken between each session and the highest score from the two trials was recorded and used in the analysis.

Visual memory

The Batak Pro Flash Program, which entailed the illumination of six randomly selected targets for 0.5 s, was utilised to evaluate the memory where the stored information was collected by the visual system.[26] This test has a reliability of 0.735.[26] Following the sound of the 'double beep' instruction, participants had to reliably recall the specific targets and the sequence in which they were activated and strike the illuminated targets (which lit up in a certain order). The 'score b' LED panel displayed the maximum score, while the 'score a' LED screen displayed the points received for each successful strike.[30] The highest scores from the two trials were recorded and used in the final data analysis. Between trials, there was a 5-min rest period.

Ethical considerations

The study followed the tenets of the declaration of Helsinki and approval was obtained from the ethical board committee (UZREC 171110-030 PGD 2019/24 and UZREC 171110-030 PGM 2022/55) of the University of Zululand in the form of certificates. Informed consent was obtained from all subjects prior to participating in the study after indications and potential consequences of the study had been explained in detail. All data collected were kept safe in a password protected excel document that was saved on the laptop of the first author.

Results

The findings showed that there was a significant difference ($P \leq 0.05$) between rugby players and netball players in three of the six tests (Table 1). In terms of speed of recognition (P = 0.000), peripheral awareness (P = 0.000) and hand-eye coordination (P = 0.000), rugby players significantly outperformed netball players, but not in terms of accommodation facility (P = 0.070), saccadic eye movement (P = 0.156) and visual memory (P = 0.163). The findings showed that there was a significant difference ($P \leq 0.05$) between rugby players and the sedentary control group in five of the six tests (Table 2). In terms of accommodation facility (P = 0.000), saccadic eye movement (P = 0.000), speed of recognition (P = 0.000), peripheral awareness (P = 0.000) and hand-eye coordination (P = 0.000), rugby players significantly outperformed the sedentary group, but not in terms of visual memory (P = 0.809). Furthermore, the findings showed that there was a significant difference ($P \leq 0.05$) between netball players and the sedentary control group in five of the six tests (Table 3). In terms of accommodation facility (P = 0.000), saccadic eye movement (P = 0.000), speed of recognition (P = 0.000), peripheral awareness (P = 0.000) and hand-eye coordination (P = 0.000), netball players significantly outperformed the sedentary group, but not in terms of visual memory (P = 0.195).

According to a rank-ordered analysis, rugby players performed 46% faster at the speed of recognition than netball players, followed by 19% for hand-eye coordination and 16% for peripheral awareness (Table 1).

TABLE 1: Visio-motor expertise comparison in rugby players and netball players.

Visio-spatial skill	Rugby players (n = 35)	Netball players (n = 35)	Difference (%)	Significance (P-value)
Accommodation facility	38.66 ± 4.58	36.23 ± 6.34	6.3	0.070
Saccadic eye movement	48.69 ± 6.40	45.94 ± 9.32	5.7	0.156
Speed of recognition	51.03 ± 14.67	27.49 ± 15.22	46.2	0.000*
Peripheral awareness	76.34 ± 4.34	63.97 ± 6.43	16.2	0.000*
Hand-eye coordination	29.91 ± 3.67	24.23 ± 3.73	19.0	0.000*
Visual memory	46.37 ± 5.96	44.60 ± 4.43	3.8	0.163

Note: Mean ± s.d.
*, Statistically significant ($P \leq 0.05$).

TABLE 2: Visio-motor expertise comparison in rugby players and sedentary control group.

Visio-spatial skill	Rugby players (n = 35)	Sedentary control group (n = 35)	Difference (%)	Significance (P-value)
Accommodation facility	38.66 ± 4.58	29.17 ± 2.75	24.6	0.000*
Saccadic eye movement	48.69 ± 6.40	33.11 ± 4.86	32.0	0.000*
Speed of recognition	51.03 ± 14.67	12.00 ± 5.92	76.5	0.000*
Peripheral awareness	76.34 ± 4.34	56.34 ± 3.58	26.2	0.000*
Hand-eye coordination	29.91 ± 3.67	20.66 ± 3.15	31.0	0.000*
Visual memory	46.37 ± 5.96	46.06 ± 4.87	0.7	0.809

Note: Mean ± s.d.
*, Statistically significant ($P \leq 0.05$).

TABLE 3: Visio-motor expertise comparison in netball players and sedentary control group.

Visio-spatial skill	Netball players (n = 35)	Sedentary control group (n = 35)	Difference (%)	Significance (P-value)
Accommodation facility	36.23 ± 6.34	29.17 ± 2.75	19.5	0.000*
Saccadic eye movement	45.94 ± 9.32	33.11 ± 4.86	28.0	0.000*
Speed of recognition	27.49 ± 15.22	12.00 ± 5.92	56.4	0.000*
Peripheral awareness	63.97 ± 6.43	56.34 ± 3.58	12.0	0.000*
Hand-eye coordination	24.23 ± 3.73	20.66 ± 3.15	14.8	0.000*
Visual memory	44.60 ± 4.43	46.06 ± 4.87	3.2	0.195

Note: Mean ± s.d.
*, Statistically significant ($P \leq 0.05$).

Rugby players performed 77% faster at the speed of recognition than the sedentary group, according to a rank-ordered analysis, followed by 32% for saccadic eye movement, 31% for hand-eye coordination, 26% for peripheral awareness and 25% for accommodation facilities (Table 2).

Netball players performed 56% faster at the speed of recognition than the sedentary group, according to a rank-ordered analysis, followed by 28% for saccadic eye movements, 20% for accommodation facilities, 15% for hand-eye coordination and 12% for peripheral awareness (Table 3).

Discussion

This study compared the VSI of male rugby players and female netball players using a battery of hand-eye coordination-specific visual tests. The six components of VSI assessed were accommodation facilities, saccadic eye movements, speed of recognition, peripheral awareness, hand-eye coordination and visual memory.

A statistical difference was found in accommodation facilities between rugby and netball players, with netball players demonstrating superior performance. This finding aligns with Agostini et al.,[31] who also observed better accommodation facilities in female players compared to male players. However, Muzaliha et al.[32] found no discernible relationship between gender and accommodation facilities. Factors contributing to these results may include the consistent engagement of women in visual tasks, which can enhance visual processing capacity, as suggested by Feng et al.[33] In addition, a positive correlation exists between prenatal testosterone and women's visuo-spatial abilities.[34] Women displaying high levels of androgyny – fewer feminine traits and more masculine behaviours – may perform better in visual tasks.[35] Research suggests that females may have more interhemispheric brain connections, enhancing their ability to integrate visual information and perceive patterns.[36,37] Both rugby and netball players outperformed a sedentary control group in accommodation facilities, consistent with findings by Mathe et al.[14] and Millard et al.[25] Conversely, Omar et al.[38] reported superior accommodation facilities in non-athletes compared to athletes, potentially because of the intense focus and rapid adaptability required in athletic training.[38]

Rugby players also exhibited superior saccadic eye movements compared to netball players, this is controversial to the findings by Sargezeh et al.,[39] who observed longer scan paths and larger saccade amplitudes in females. Wilson et al.[40] reported no gender differences in saccadic eye movements. Gender-specific processing strategies could account for the differences in performance observed,[41,42] with high scores among females possibly because of effective instruction-following and extensive training.[43] Variations in retinal wiring, including photoreceptor and retinal ganglion cell distribution, may contribute to female superiority in this area.[44] Rugby and netball players also surpassed the sedentary control group in saccadic eye movements, echoing findings by Nakamoto and Mori[45] regarding improved saccadic movements in baseball and basketball players. However, shooters showed no differences from non-athletes in saccadic eye movements.[46] Visual training, physical conditioning, mental focus and strategic skills likely contribute to superior athletic performance.[47]

Rugby players demonstrated a 46% faster speed of recognition than netball players, showing the greatest disparity. This finding supports McGivern et al.,[48] who found men outperforming women in speed recognition tasks favouring movement processing. Conversely, Camarata and Woodcock[49] observed higher scores in females for speed of recognition. Men's faster route learning and accurate distance estimation, linked to superior visual abilities and mental rotation strategies, may explain these differences.[21] Gender differences in small-scale spatial ability may arise from the cognitive strategies employed,[50] with women often using less effective egocentric strategies.[51] Rugby and netball players both outperformed sedentary controls, consistent with Nakamoto and Mori[45] regarding speed of recognition in baseball and basketball players. Conversely, Mori et al.[52] found no significant differences in recognition speed between karate athletes and non-athletes. Athletes' need to quickly scan the field and process information for decision-making likely enhances their speed of recognition.[6]

Peripheral awareness also showed significant differences between rugby and netball players. This aligns with David et al.,[53] who found males superior in peripheral vision when assessing children's sensitivity to traffic hazards. However, Adhilakshmi et al.[54] found no gender differences in peripheral field vision. Women may use route-imagining and reference place strategies more effectively,[21] and hormonal effects during adolescence could influence spatial experiences and preferences, leading to gender disparities.[55,56] Experienced soccer players also showed differences in peripheral vision compared to novices,[57] although Ward et al.[58] found little difference in peripheral awareness among football players of varying experience. The enhanced peripheral awareness in athletes may stem from visual training, physical conditioning and mental focus.[47]

Rugby players demonstrated superior hand-eye coordination compared to netball players, aligning with Swathi et al.,[59] who found men had an advantage in hand kinematics and tracking accuracy. However, Orhan et al.[60] found no gender differences in overall eye coordination. Evolutionary pressures may have led to sex-specific spatial abilities, giving males an edge in such tasks.[61] Sex hormones, such as estrogens and androgens, along with differences in hemispheric language processing differences in women may also contribute these findings.[19,62] Both rugby and netball players showed superior hand-eye coordination compared to the control group, supporting findings by Mathe et al.[14] and contrasting with results for badminton players.[63] Athletic training likely enhances VSI and eye-hand reaction time.[64]

Finally, rugby players exhibited superior visual memory compared to netball players, which was controversial to other studies showing females have better visual memory post-concussion.[65] Other studies, however, found no gender differences in visual memory among adolescent soccer players.[66] Superior visual memory in females may result from analytical, detail-oriented approaches,[67] while males typically use holistic strategies.[68] There was no significant difference in visual memory between rugby players and the sedentary control group, consistent with findings by Tomczyk et al.[69] and Mathe et al.[14] Athletes' need to memorise and retain pertinent information likely enhances cognitive functions and motor skills, contributing to overall athletic performance.[70]

Conclusion

The identified superiority of certain VSS within this study carries broad implications for theories of vision, test selection and the development of sport-specific VSS testing batteries. While confirming the hypothesis that athletes, particularly rugby and netball players, exhibit superior VSS compared to non-athletes, the study also revealed that this superiority does not extend to all aspects of VSS, such as visual memory. In addition, utilising a hand-eye coordination specific VSS test battery effectively differentiated between different sports, showing significant differences in three out of six VSS tests, with rugby players outperforming the netball players. However, this trend was not consistent across all VSS tests, suggesting that future research should explore the training methods employed by both sports, as these may account for the observed differences.

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Competing interests

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Authors' contributions

L.M., G.J.B. and N.M. contributed to the article equally and approved the submitted version.

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Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

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