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Original Article

Visio-spatial intelligence in athletes: comparison of field hockey players and non-athletes

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ABSTRACT

Background: Visio-spatial intelligence (VSI) plays an important role in athletic performance and may vary according to sport-specific training exposure. However, there is limited research comparing VSI between field hockey players and non-athletes using a comprehensive test battery that assesses accommodation facility, saccadic eye movements, speed of recognition, visual memory, hand-eye coordination, and peripheral awareness. Most studies have focused on mixed sports or recreational activities, leaving sport-specific VSI profiles in field hockey insufficiently characterized. This study aimed to compare VSI between field hockey players and non-athletes.

Methods: A comparative analytical cross-sectional study used a convenience sampling approach, and recruited 80 adults aged 18–34 years from the Zululand District, KwaZulu-Natal, South Africa, including 40 field hockey athletes and 40 non-athlete controls. VSI was assessed across six domains: accommodation facility, saccadic eye movements, speed of recognition, visual memory, hand-eye coordination, and peripheral awareness. All participants underwent a comprehensive ocular examination performed by a registered optometrist to assess their ocular status. Visual assessments were conducted using Spectrum Eyecare software to identify any visual abnormalities or limitations in either eye.

Results: Eighty participants completed the study, with an equal distribution of field hockey athletes and non-athlete controls ($n = 40$ each) and an equal sex distribution (20 men and 20 women per group). Mean (SD) age was 20.4 (2.3) and 21.8 (2.8) years for men and women field hockey players, respectively, and 22.1 (2.2) and 21.3 (1.8) years for men and women non-athletes, respectively. Field hockey athletes demonstrated significantly superior VSI in accommodation facility, saccadic eye movements, speed of recognition, peripheral awareness, and hand-eye coordination than non-athletes (all $P < 0.001$), with performance differences ranging from 22% to 66%. In contrast, visual memory did not differ significantly between groups (45.9 [5.2] vs. 44.8 [5.5]; $P > 0.05$), representing only a 2% difference. Overall, field hockey athletes demonstrated significantly better VSI than non-athletes in all assessed domains except visual memory.

Conclusions: Field hockey players demonstrated superior performance across five of the six VSI domains evaluated, including accommodative facility, speed of recognition, peripheral awareness, hand-eye coordination, and saccadic eye movements, whereas visual memory did not differ significantly from that of non-athletes. These findings suggest that participation in field hockey is associated with higher performance in selected visuomotor and perceptual tasks. Nevertheless, the comparable visual memory performance observed between groups indicates that the association between field hockey participation and performance may differ across VSI domains. Visuo-spatial assessment may therefore warrant further evaluation as a potential adjunct to talent identification and athlete development programmes.

KEYWORDS

field hockey, saccadic eye movements, saccade, vision test, sport, athletic, athletic performances, sport medicine, visual feedback, motor skill, sensory feedback, visual spatial processing, optometrist, ophthalmologist

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INTRODUCTION

Vision is a fundamental aspect of human existence, enabling the perception of colours, pattern recognition, and visual memories through the visual cortex, an integrative centre responsible for processing visual information [1–3]. Visual information is processed through two parallel pathways, the ON and OFF pathways, which encode luminance increments and decrements, respectively. These pathways remain functionally distinct throughout the visual system and contribute to the temporal and spatial processing of visual stimuli [4]. Additionally, visual processing is mediated by two functionally distinct cortical streams. The dorsal stream supports the real-time visual control of action by transforming visual information into goal-directed movements. In contrast, the ventral stream is responsible for object perception and recognition, generating detailed representations of object identity, characteristics, and contextual significance that facilitate interpretation of the surrounding environment [5].

Visio-spatial intelligence (VSI) is a fundamental cognitive ability that enables individuals to perceive, process, and respond to visual-spatial information. It encompasses the recognition and interpretation of objects, their spatial relationships, and the integration of visual information with cognitive and motor processes to guide visually directed behavior [1, 4, 5]. In sports, VSI is essential for athletes because it facilitates anticipation of the movements of the ball and opponents, rapid decision-making, and accurate motor responses in dynamic environments [6–9]. Similarly, in everyday life VSI supports object recognition, spatial orientation, navigation, and visually guided interaction with the environment [1, 4, 5].

Field hockey is a tactically demanding team sport characterized by high levels of visual concentration while tracking the ball and opponents, requiring coordinated team performance. The sport is played by two teams of 11 players, including one goalkeeper per team, on a hard rectangular pitch measuring 91.4 × 55 m. Successful performance places high demands on VSI, including efficient gaze behavior, hand-eye coordination, ball speed judgement, and peripheral vision [7, 8, 10–14]. In order for players to score and excel in their playing positions, such as attacking midfielders, fullbacks, wingers, or strikers, effective spatial awareness and familiarity with key pitch landmarks are important attributes. We propose that these abilities involve the development of visual memory for critical pitch areas (“red zones”), facilitating tactical decision-making, spatial orientation, and efficient positioning during play [15–17].

Hand-eye coordination plays a significant role in ensuring that the desired stroke is executed by perceiving the opponent’s position and determining the appropriate amount of force required to strike the ball, allowing it to reach the intended recipient [18–21].Furthermore, opponents must predict the speed of the ball in order to intercept it and potentially prevent the intended recipient from receiving the pass through rapid speed of recognition, which is among the key elements of VSI [22, 23]. Despite the considerable visual demands of field hockey [10], no previous study has directly compared VSI between field hockey players and non-athletes. Therefore, this study aimed to evaluate differences in VSI between these two groups.

METHODS

This comparative analytical cross-sectional study was conducted in March 2024 at the Department of Human Movement Science Visual Laboratory, University of Zululand, Richards Bay Campus, KwaZulu-Natal, South Africa. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, ensuring that all research procedures respected the rights, safety, and well-being of the participants. Ethical approval was obtained from the University of Zululand Research Ethics Committee (UZREC; approval code: UZREC 171110-030 PGM 2022/70). Written informed consent was obtained from all participants prior to enrolment. Before participation, all participants received a detailed explanation of the study objectives, procedures, potential risks, and their right to withdraw from the study at any time without penalty. Participants were given ample opportunity to ask questions before providing written informed consent. To ensure confidentiality, all study data were stored in a password-protected Microsoft Excel file on the first author’s password-protected laptop, with access restricted to authorized personnel only.

Participants were recruited using convenience sampling from the Zululand District through electronic media and poster advertisements. Recruitment was conducted throughout the study period until 80 eligible participants were enrolled, comprised of 40 field hockey players and 40 non-athlete controls.

Participants aged 18–34 years were classified as field hockey players or non-athlete controls based on their athletic history. Field hockey players were defined as individuals who had actively participated in field hockey for at least six months and trained more than three times per week. Non-athlete controls were defined as individuals who were not currently engaged in any form of organized sport, including field hockey. Participants in both groups were further stratified by sex (male and female). All evaluations were conducted at the Department of Human Movement Science, Richards Bay Campus, University of Zululand. Non-athletes were assessed before field hockey players. Before formal testing, all participants completed a practice trial to familiarize themselves with the equipment and allow any necessary positional adjustments. A five-minute interval was scheduled between successive assessments to allow adequate time for data recording and preparation for the next participant.

All participants underwent a comprehensive ocular examination performed by a registered optometrist to assess their ocular status. Visual assessments were conducted using Spectrum Eyecare software (Version 6.0.0; Digital Optometry, South Africa) [24] to identify any visual abnormalities or limitations in either eye. To minimize the potential influence of exercise-induced physiological changes on visual performance [25], participants were instructed to refrain from vigorous physical activity for 48 hours before their optometric assessment.

VSI was evaluated across six domains relevant to field hockey performance: accommodation facility, saccadic eye movements, speed of recognition, hand-eye coordination, peripheral awareness, and visual memory. These domains were assessed using a six-component test battery previously employed to compare first-division rugby players with non-athletes controls [28]; its application in the present study extends the use of the same visuoperceptual and visuomotor measures to the comparison of field hockey players and non-athlete controls.

Accommodative facility: Assessed with the Hart Chart Accommodative Rock Chart Set, which is commonly used to assess accommodative facility by requiring repeated shifts in fixation between distant and near targets, and has also been used in accommodative and oculomotor training. The Hart Chart was positioned on a wall at eye level, 3 m from the participant, while a second chart was held at arm's length. Participants were instructed to read the first letter of the first line on the distant chart, followed by the corresponding letter on the near chart, continuing sequentially for 30 seconds. Two trials were performed, and the number of incorrectly read letters was subtracted from the total number of letters read to obtain the final score [10, 26–28].

Saccadic Eye Movements: Voluntary saccadic eye movements are important components of oculomotor function and visual attention [10]. These were assessed using a standardized saccadic eye movement chart. During the 30-second test, participants rapidly shifted their gaze between two charts positioned 3 m away while reading letters aloud without moving their heads.

Speed of Recognition: Assessed using the Batak Pro (Quotronics, Surrey, UK), which requires participants to react rapidly to randomly illuminated visual stimuli. The Batak Pro emits illuminated targets with a 1-second response window, designed to assess reaction speed and hand-eye coordination through progressively demanding visual tasks [29, 30]. During the test, randomly illuminated targets appeared sequentially and participants were instructed to strike only the illuminated target. Incorrect responses or strikes made out of time caused the task to accelerate, thereby increasing its level of difficulty [29]. The Batak Pro automatically recorded participants' responses and generated the final score. Before testing, participants were familiarized with the testing procedure to ensure they understood the operation of the equipment and the testing protocol.

Hand-eye coordination: reflects the integration of visual perception and upper-limb motor control, enabling accurate and coordinated movements [31]. Hand-eye coordination was assessed using a standardized tennis-ball throw-and-catch test. Participants stood 2 m from a wall and repeatedly threw a tennis ball against it while catching it with alternate hands over a 30-second period. The total number of successful catches completed within the 30-second test period was recorded as the final score [31–34].

Peripheral awareness: enables an individual to be aware of their surroundings without having to turn the entire body to face the stimulus [10, 35]. In the study, a Batak Pro accumulator program was used to test whether athletes and non-athletes could identify targets beyond their tunnel vision by stimulating peripheral awareness. Before the test began, participants were given two free attempts to familiarize themselves with the machine operation. Once the test started, multiple targets appeared at random. The highest obtained score with minimal errors was recorded as the final score using the Batak Pro [24, 30, 36].

Visual Memory: Assessed using the Flash Program on the Batak Pro [29, 30]. Six randomly selected targets were illuminated for approximately 0.5 seconds, after which participants were required to recall the illuminated targets (and their order of presentation). The highest score achieved across the trials was recorded as the final score [24, 37, 38].

All statistical analyses were performed with IBM SPSS Statistics for Windows (version 23.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables. Continuous variables are presented as mean (standard deviation [SD]), and categorical variables as number (percentage). Percentage differences were calculated as [(mean score of field hockey players − mean score of non-athletes) / mean score of field hockey players] × 100. The normality of continuous variables was assessed using the Shapiro−Wilk test together with visual inspection of histograms, and homogeneity of variances between groups was evaluated using Levene's test. Differences in VSI skills between field hockey players and non-athletes were examined using independent-samples *t*-tests, consistent with the between-group study design and independence of observations. All hypothesis tests were conducted using a two-tailed approach. The a priori hypothesis was that field hockey players would demonstrate superior VSI performance compared with non-athletes. Statistical significance was set at $P < 0.05$. Because the study was exploratory, no adjustments for multiple comparisons were applied; consequently, findings across the multiple VSI domains were interpreted with appropriate caution.

RESULTS

Table 1 presents the demographic characteristics of the study. Included were 80 participants, comprising 40 field hockey players and 40 non-athlete controls. Both groups had an equal sex distribution, with 20 men (50%) and 20 women (50%) in each group. Among field hockey players, mean (SD) age was 20.4 (2.3) years for men and 21.8 (2.8) years for women. Among non-athletes mean (SD) age was 22.1 (2.2) years for men and 21.3 (1.8) years for women.

Table 2 shows that field hockey players displayed significantly superior performance across five of the six VSI domains compared with non-athletes. Specifically, accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, and hand-eye coordination were all significantly higher in field hockey players (all $P < 0.001$). In contrast, visual memory did not differ significantly between the groups, with mean (SD) scores of 45.9 (5.2) in field hockey players and 44.8 (5.5) in non-athletes ($P > 0.05$). The greatest relative score difference was observed for speed of recognition (66%), followed by saccadic eye movement (32%), accommodation facility and hand-eye coordination (23% each), and peripheral awareness (22%). Visual memory showed the smallest relative score difference (2%), consistent with the absence of a statistically significant difference ($P > 0.05$) (Table 2).

DISCUSSION

The present study investigated differences in VSI between field hockey players and non-athlete controls across six domains relevant to field hockey performance. Field hockey players performed significantly better in five of the six assessed domains: accommodative facility, saccadic eye movements, speed of recognition, peripheral awareness, and hand-eye coordination, whereas visual memory was comparable between the two groups.

Table 1. Demographic characteristics of field hockey players and non-athlete controls

Variables	Field hockey players (n = 40)		Non-athletes (n = 40)	
	Men	Women	Men	Women
Age (y), Mean± SD	20.4 ± 2.3	21.8 ± 2.8	22.1 ± 2.2	21.3 ± 1.8
Sex, n (%)	20 (50)	20 (50)	20 (50)	20 (50)

Abbreviation: n, number of participants; y, years; %, percentage; SD, standard deviation.

Table 2. Comparison of VSI skills between field hockey players and non-athletes

VSI skills	Field hockey players (n = 40), Mean± SD	Non-athletes (n = 40), Mean± SD	Relative score difference, %	*P*-value
Accommodation facility	36.4 ± 5.4	28.2 ± 3.7	23	**< 0.001**
Saccadic eye movement	48.0 ± 8.6	32.5 ± 4.8	32	**< 0.001**
Speed of recognition	35.8 ± 15.7	12.1 ± 6.6	66	**< 0.001**
Peripheral awareness	70.7 ± 4.3	54.9 ± 2.9	22	**< 0.001**
Hand-eye coordination	25.7 ± 4.3	19.7 ±4.5	23	**< 0.001**
Visual memory	45.9 ± 5.2	44.8 ± 5.5	2	0.349

Abbreviation: VSI, visio-spatial intelligence; SD, standard deviation. Note: Statistically significant *P*-values are shown in bold. Note: Percentage differences were calculated as [(mean score of field hockey players − mean score of non-athletes) / mean score of field hockey players] × 100 and represent the percentage by which the non-athlete score was lower than the field hockey player score.

Non-athletes showed a 23% lower accommodative facility score than field hockey athletes. Accommodative facility, which enables rapid adjustment of the crystalline lens to maintain a clear retinal image when shifting focus between objects at different distances, is mediated through neural mechanisms that regulate changes in lens curvature in response to retinal blur [39, 40]. Athletes in the present study evidenced higher dynamic focusing scores, which may be associated with differences in visual attention, anticipatory processing of advance cues, motor imagery, and perception-action coupling; these factors may support perceptual-cognitive processing and anticipatory responses through the interpretation of advance visual cues and prediction of subsequent ball flight during gameplay [41–43]. However, not all studies showed superior visual function in athletes compared with non-athletes, suggesting that associations between sports participation and visual performance may be domain-specific rather than universal and may not be fully captured by conventional clinical assessments [44]. Consistent with this variability, findings regarding accommodative facility have also been inconsistent. Omar et al. [45] reported superior accommodative facility in non-athletes, whereas the more recent study by Mathe et al. [36] supports the present findings, evidencing significantly better accommodative facility in athletes. In field hockey, efficient dynamic focusing facilitates the rapid identification of teammates, opponents, and other task-relevant visual information during fast-paced play [18, 43]. Furthermore, athletes' ability to accurately judge distance, execute precise strokes, and make effective tactical decisions may be facilitated by efficient visual processing and perception-action coupling, highlighting the functional importance of accommodative facility during high-level performance [18, 20, 43, 46].

Field hockey requires athletes to simultaneously engage in physical pursuit and continuous visual pursuit of rapidly changing game situations. Efficient gaze control, involving coordinated saccadic eye movements and visual tracking, enables players to monitor multiple moving targets while simultaneously executing complex motor actions [47, 48]. This study observed that non-athletes had 32% lower scores than athletes on the saccadic eye movement task. Similar differences in saccadic eye movement performance have been reported in comparative studies of team-sport athletes, supporting an association between sports participation and oculomotor efficiency [20, 36]. Further evidence supports the role of saccades in sports performance. Experienced basketball players evidenced more effective tracking of opponents than novice players, providing a perceptual advantage during game situations [49]. Saccadic eye movements facilitate efficient visual scanning and supporting anticipatory responses to rapidly changing visual information [34, 48]. In addition, elite players outperform non-elite players when tracking highly dynamic targets [50, 51].

Speed of recognition was assessed using the Batak Pro, which required participants to respond rapidly to visual stimuli [28]. Non-athletes had 66% lower speed-of-recognition scores than field hockey players. This advantage may reflect differences in visuomotor processing and integration of visual information with motor responses associated with sport participation [20, 48]. Exposure to training environments that closely replicate match demands has been associated with better visual processing and perceptual performance, potentially supporting rapid recognition skills in athletes [20, 52].

Peripheral awareness scores were 22% lower among non-athletes than athletes, suggesting superior processing of peripheral visual information among athletes rather than differences in the anatomical extent of the visual field. This finding is consistent with studies in first-division rugby players, who displayed significantly better peripheral awareness than non-athletes; this highlights the importance of efficiently processing peripheral visual information during dynamic team sports [28]. Peripheral awareness enables athletes to simultaneously monitor teammates, opponents, and the moving ball, thereby facilitating rapid decision-making and more effective responses during play [34, 48]. Research has also shown that athletes and non-athletes often exhibit only small differences in basic visual acuity or field of view, whereas athletes utilize peripheral visual information more effectively during sport-specific tasks, indicating that expertise depends more on perceptual-cognitive processing than on superior visual hardware alone [53]. Consistent with this interpretation, recent cross-sectional Useful Field of View (UFOV) research demonstrated component-specific differences in divided and selective attention among groups with different experiential backgrounds, suggesting an association between visually demanding experience and attentional performance under peripheral and distractor conditions [54]. Likewise, Vera et al. [55] compared basketball players with sedentary individuals and proposed that athletic superiority reflects a multidimensional interaction between selected visual functions and enhanced perceptual-cognitive processing rather than uniformly superior baseline visual abilities. They observed that basketball players outperformed non-athletes in visual discrimination and eye-hand coordination despite showing no advantage in several conventional visual measures, further supporting the view that sport expertise is driven largely by more efficient processing and integration of visual information [55]. Their interpretation is consistent with the greater peripheral awareness observed among athletes in the present study.

Hand-eye coordination is a fundamental visuomotor skill in both ball and non-ball sports, requiring seamless integration of visual information with motor responses [56, 57]. The present study showed that non-athletes had 23% lower hand-eye coordination scores than field hockey players. Similar findings have been reported in female netball players, who showed significantly better hand-eye coordination than non-athletes (16%); this further supports an association between sports participation and visuomotor performance [36]. Comparable results have also been reported in amateur rugby players, who exhibited superior hand-eye coordination compared with both netball players (19%) and sedentary controls (31%), while netball players likewise outperformed sedentary controls (14.8%); this suggests that the magnitude of visuomotor performance differences may vary according to the visual and motor demands of different sports [58]. In field hockey, efficient hand-eye coordination is particularly important during high-pressure situations, supporting accurate ball control, precise passing, and execution of advanced technical skills [20]. Improved hand-eye coordination is associated with more efficient visuomotor control and perception-action coupling, characteristics that distinguish expert athletes from less skilled performers [59]. Given the complexity of this skill, hand-eye coordination may warrant further evaluation as a potential component of athlete development and talent identification [60].

Unlike the other visuospatial domains evaluated, visual memory did not differ significantly between athletes and non-athletes. Research shows that visual-spatial memory contributes to neuromuscular control during sport-specific movements, where poorer visual memory is associated with movement patterns linked to increased injury risk [61]. This observation is also consistent with a recent randomized trial in which short-term exhaustive exercise enhanced several visual skills, including peripheral awareness, hand-eye coordination, and speed of recognition, whereas visual memory remained unchanged [30]. Nevertheless, visual memory remains relevant in team sports [62] because repeated video analysis and tactical review may strengthen athletes' ability to recognize game patterns, anticipate strategies of opponents, and retrieve previously learned tactical information during competition [48]. Although visual memory was not a distinguishing characteristic between groups in the present study, it remains an important cognitive component underlying tactical preparation, pattern recognition, anticipation, and strategic decision-making during competitive play [48, 63].

The findings of this study show that field hockey players exhibit superior performance across several key VSI domains, including accommodative facility, speed of recognition, peripheral awareness, hand-eye coordination, and saccadic eye movements, compared with non-athletes. These differences were associated with field hockey participation, but their causal direction cannot be determined. In contrast, visual memory did not differ significantly between groups, suggesting that the association with field hockey participation may vary across visual and cognitive domains. Overall, these findings support further investigation of sport-related visual skills in athlete training and performance. This study has several limitations. First, participants were recruited using convenience sampling from a single geographical region, which may limit generalizability of the findings. Second, the relatively modest sample size may have reduced the statistical power to detect small between-group differences, particularly for visual memory which was the only VSI domain that did not differ significantly between groups. Third, most field hockey participants were recreational athletes, so the findings may not fully reflect visuospatial performance in higher competitive levels such as semi-professional or elite. Fourth, the cross-sectional design precludes conclusions regarding causal relationships or the longitudinal effects of sport participation on visuospatial abilities. The observed differences may reflect self-selection into field hockey or unmeasured differences in previous sporting experience, baseline visual abilities, physical fitness, education or occupation, video-game exposure, motivation, socioeconomic factors, or other participant characteristics. Fifth, non-athletes were assessed before field hockey players rather than in a randomized or interleaved order. Consequently, participant group was confounded with testing order, and unmeasured temporal or procedural factors, such as examiner learning or drift or changes in the testing environment, may have contributed to the observed between-group differences. Sixth, although the assessed visual domains are relevant to field hockey, the test battery comprised generic visual and visuomotor tasks and did not reproduce field-hockey-specific stimuli or match situations. Accordingly, the findings should not be interpreted as direct measures of field-hockey-specific performance. Seventh, the published reliability and diagnostic-accuracy evidence cited for the illuminated-target tasks was obtained using Batak Lite [64], rather than Batak Pro [29]. Although Batak Lite and Batak Pro employ a similar general light-board reaction paradigm, they differ in target configuration and available routines; therefore, the psychometric findings reported for Batak Lite cannot be assumed to apply directly to the Batak Pro protocols used in this study. Future multicenter studies involving larger and more diverse populations are warranted to validate and expand these findings. Longitudinal investigations examining changes in VSI over time, as well as studies comparing athletes across different competitive levels, playing positions, and years of experience, would provide a more comprehensive understanding of sport-specific visuospatial adaptations. Future research should also evaluate the effectiveness of structured vision-training programs in both athletes and non-athletes, plus incorporate relevant physical performance measures such as anthropometric characteristics, joint range of motion, and cardiorespiratory fitness, to better elucidate their contribution to visuospatial performance.

CONCLUSIONS

This study revealed significant differences in VSI between field hockey players and non-athletes. Field hockey players exhibited superior performance in five of the six VSI domains evaluated, namely accommodative facility, speed of recognition, peripheral awareness, hand-eye coordination, and saccadic eye movements, whereas visual memory did not differ significantly between groups. These findings indicate an association between field hockey participation and performance in several key visuospatial tasks but do not establish whether field hockey training produced these differences. Importantly, the superior VSI performance observed among athletes should not be interpreted as evidence that non-athletes lack the capacity to perform well on or develop these skills. Rather, the findings suggest that visuospatial assessment warrants further evaluation as a potential component of talent identification programmes. Prospective studies are required to determine whether these assessments predict subsequent athletic performance or add value to established talent-identification methods. Finally, as sporting environments and human visual demands continue to evolve alongside technological advances, visuospatial assessment batteries should be regularly refined and validated to ensure their continued relevance and applicability in both athletes and non-athletes.

ETHICAL DECLARATIONS

Ethical approval: The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, ensuring that all research procedures respected the rights, safety, and well-being of the participants. Ethical approval was obtained from the University of Zululand Research Ethics Committee (UZREC; approval code: UZREC 171110-030 PGM 2022/70). Written informed consent was obtained from all participants prior to enrolment. Before participation, all participants received a detailed explanation of the study objectives, procedures, potential risks, and their right to withdraw from the study at any time without penalty. Participants were given ample opportunity to ask questions before providing written informed consent. To ensure confidentiality, all study data were stored in a password-protected Microsoft Excel file on the first author's password-protected laptop, with access restricted to authorized personnel only.

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