HUMAN MOVEMENT (ISSN 1899-1955)
2026; 27(4): 81–92

# Relationship between visual skills and spike and reception performance in elite volleyball players

© Wroclaw University of Health and Sport Sciences

original paper
DOI: https://doi.org/10.5114/hm/241528

AHMET KAAN ASLAN[1], HALIL IBRAHIM CICIOGLU[1], BETÜL SEHER UYSAL[2]

[1] Faculty of Sport Sciences, Gazi University, Ankara, Turkey
[2] Faculty of Medicine, Department of Ophthalmology, Gazi University, Ankara, Turkey

ABSTRACT

**Purpose.** This cross-sectional correlational study examined associations between visual and visuomotor measures and spike and reception performance in elite volleyball players.

**Methods.** Thirty-six elite volleyball players (20 male, 16 female) competing in the top Turkish leagues participated. Static near stereopsis, visual acuity, colour perception, ocular aberrations, and point spread function were assessed, while hand-eye response time was measured using the BlazePod system. Spike and reception performance were quantified using Data Volley software. Associations between variables and outcomes were examined using Spearman's rank-order correlations. Because of the modest sample size and small numbers within several playing-position categories, analyses were not adjusted for playing position. The Benjamini–Hochberg false discovery rate correction was applied for multiple testing.

**Results.** Static near-stereopsis scores were negatively associated with spike performance ($\rho = -0.780$, raw $p < 0.001$, FDR-adjusted $p < 0.001$) and reception performance ($\rho = -0.487$, raw $p = 0.003$, FDR-adjusted $p = 0.023$). Because lower arcsecond values indicate better static near stereopsis, better laboratory-based binocular depth-discrimination performance was associated with higher standardised volleyball-performance scores. No other visual or visuomotor variable remained significant after correction. Sex-specific subgroup analyses were exploratory because of limited subgroup sizes.

**Conclusions.** Static near-stereopsis scores were associated with spike and reception performance, with a stronger association for spike performance. These unadjusted findings suggest that laboratory-measured binocular depth discrimination may relate to standardised volleyball-specific motor performance. However, static near stereopsis is not equivalent to dynamic in-game visual processing. Larger studies using dynamic sport-vision assessments and adjustment for playing position are required.

**Key words:** visual skills, stereopsis, volleyball, spike performance, reception performance

## Introduction

Athletes involved in team sports are required to possess complex physical, technical, and tactical skills, and their athletic performance is influenced by the development of these abilities [1]. In volleyball, postural stability plays a critical role in most movements performed by players. Actions considered fundamental techniques, such as attacking, serving, spiking, blocking, reception, and positioning, are affected by numerous factors that combine physical and technical abilities. Technical capacity is shaped by athletes' visual, auditory, kinaesthetic, and tactile perceptions, and the coordination among these senses [2].

When evaluating performance, in-game positioning and movement are vital for volleyball players. Effective movement and repositioning require analysing visual information [3]. Vision is the system that guides the body's responses and provides athletes with information on where and when to move [4]. The ability to perform specific tasks in sports is closely related to the visual system [5], which contributes to psychological, perceptual, and physical capacities [6]. Moreover, one of the most demanding contexts for the visual system is athletic performance, where the ability to quickly and accurately interpret external stimuli is critical [7].

In many team sports, the visual system is highly active, but in volleyball, its role is particularly pro-

*Correspondence address:* Ahmet Kaan Aslan, Faculty of Sport Sciences, Gazi University, 06560, Ankara, Turkey, e-mail: ahmetkaanaslan@gmail.com; https://orcid.org/0000-0001-9484-1625

Received: December 09, 2025
Accepted for publication: October 07, 2026

*Citation*: Aslan AK, Cicioglu HI, Uysal BS. Relationship between visual skills and spike and reception performance in elite volleyball players. Hum Mov. 2026;27(4):81–92; doi: https://doi.org/10.5114/hm/241528.

nounced due to the continuous tracking of the ball and rapid interaction with opponents and teammates. Players constantly adjust their gaze as they react to the opposing team's actions and execute their own team's strategies. The human brain processes large volumes of visual information in dynamic environments, and athletes transform this processed data into anticipation and decision-making during gameplay. Visual attention, therefore, holds a significant place in team sports [8]. In this context, the proper functioning of the visual system is closely related to both performance and decision-making processes.

However, not all visual system parameters are expected to relate to performance equally. Certain aspects, such as depth perception (stereopsis) and light scattering (point spread function, PSF), may play a particularly important role in perceiving the direction, distance, and speed of the ball [9, 10]. Yet the relationship between some optical parameters (*e.g.*, PSF, MTF) and athletic performance remains debated [11]. Therefore, this study selected visual skills not only based on general visual acuity but also on features that may contribute to rapid and accurate decision-making and timely responses to the ball.

From a sensorimotor perspective, binocular disparity is one of several visual cues that may contribute to spatial judgments. However, static near stereopsis, as measured under controlled laboratory conditions, should be distinguished from the dynamic visual processing required during volleyball. Spiking and reception involve continuous integration of vergence adjustments, ocular pursuit, retinal motion cues, anticipation, and motor planning while tracking a rapidly moving ball across changing distances. Therefore, laboratory-based static stereopsis may represent only one limited component of the broader visuomotor system involved in volleyball-specific performance. Sport performance is defined as the total effort exerted to succeed in a given athletic task [12]. For optimal performance, athletes must possess physical attributes suitable to their sport [13], but performance is also influenced by various internal and external factors [12]. There is growing evidence showing associations between visual skills and performance across different disciplines [14, 15]. In recent years, enhancing visual skills has become increasingly important to help athletes reach peak performance levels [16]. If the optical and visual processing abilities developed through training are not optimised, athletic performance may be constrained [5]. Coaches can play a key role by identifying athletes with weaknesses in this area and helping to develop their visual skills, thereby supporting overall performance [17].

In sport, visual skills include hand–eye coordination, static and dynamic visual acuity, peripheral vision, stereopsis, and the ability to perceive the speed and distance of surrounding objects [18]. In volleyball, visual skills are considered one of the factors related to ball control and striking abilities during spiking and reception. However, there is a notable gap in the literature regarding how visual skills, particularly stereopsis, are associated with performance in elite volleyball players.

In this context, it is necessary to develop a theoretical framework to understand how each laboratory-based visual or visuomotor measure (*e.g.*, static near stereopsis, hand–eye response time, and ocular aberrations) links to in-game tasks. For example, visual information may support spatial judgments concerning the ball and net during volleyball actions [19]. However, laboratory-based static stereopsis represents only one limited component of the broader dynamic visual processing required during play, while PSF and ocular aberration values may influence optical image quality, although their relationship with sport-specific performance remains uncertain [5, 11]. Therefore, the present study examines the extent to which different visual parameters are related to two key volleyball skills: spike and reception.

The present study aimed, in particular, to examine the associations between laboratory-based visual measures, including static near stereopsis, and standardised spike and reception performance in elite-level volleyball players. It was hypothesised that static near-stereopsis scores are associated with spike and reception performance.

## Material and methods

### Participants

A total of 36 elite volleyball players from Ankara, Turkey (20 male, 16 female; mean age: 20.75 ± 4.56 years), participated voluntarily in this cross-sectional correlational study. Elite status was defined as active participation in the Turkish Men's First Volleyball League or the Turkish Women's First Volleyball League, with regular involvement in official matches and structured team training.

Playing position was recorded to characterise the sample because volleyball roles differ substantially in their habitual perceptual-motor, spatial-temporal, attacking, and reception demands. The sample included outside hitters ($n$ = 10), opposite hitters ($n$ = 8), middle blockers ($n$ = 10), setters ($n$ = 4), and liberos ($n$ = 4).

However, the modest total sample size and the small number of athletes within several position categories did not permit reliable position-stratified analyses or stable multivariable adjustment for playing position. Consequently, playing position was not included as a covariate, and the reported correlations should be regarded as unadjusted associations that may partly reflect position-specific skill specialisation, task exposure, and perceptual–motor demands. Prior to data collection, all participants were informed about the study procedures, measurement methods, and voluntary nature of participation. Written informed consent was obtained from all participants aged 18 years and above. For participants under 18 years of age, written consent was obtained from their parents or legal guardians. Participants were included only if they had no self-reported health condition that would prevent participation in visual or volleyball-specific performance assessments.

### Study design and procedures

This study used a cross-sectional correlational design to examine the associations between visual skills and spike and reception performance in elite volleyball players. The relational screening model is a survey approach that aims to reveal whether there is a co-variation between two or more variables. This model determines whether variables change together and, if so, how this change occurs [20]. In this study, the measurement process was conducted in a planned and systematic manner, and all data were collected in controlled environments.

### Visual skill measurements

Visual skills were evaluated through static near stereopsis, visual acuity, colour vision, ocular aberration values, and point spread function (PSF) measurements, all conducted at the Faculty of Medicine, Department of Ophthalmology, which was blinded for review. All ocular measurements were performed and recorded by a specialist ophthalmologist. Separately, hand-eye response time was assessed using the BlazePod system. Hand-eye response time, spike performance, and reception performance assessments were conducted under the supervision of professional volleyball coaches. Prior to testing, all participants were informed about the procedures and given the opportunity to familiarise themselves with the equipment. Laboratory assessments, including visual acuity, colour vision, static near stereopsis, ocular aberrations, and PSF, were conducted by the ophthalmology specialist, whereas field assessments, including BlazePod, spike, and reception testing, were conducted under the supervision of professional volleyball coaches.

### Hand-eye response time

To assess hand–eye response time, the BlazePod™ system (New Zealand), consisting of wireless light-emitting pods controlled through a smartphone application, was used. The "Formula Reactions" protocol available in the mobile application was employed. Four pods were arranged in a square configuration at 1.5-m intervals, and a fifth pod was positioned in the centre. Each pod emitted visual signals independently.

Before data collection, participants were introduced to the procedure and completed one familiarisation trial. During testing, participants stood facing the wall-mounted pods and were instructed to tap each illuminated pod as quickly as possible using both hands. The task continued for 30 s. Each participant completed two trials separated by a 2-minute rest interval, and the best application-generated score, expressed in milliseconds, was retained as the hand–eye response time [21].

Because the recorded interval included both visual stimulus detection and the movement required to contact the illuminated pod, the outcome was interpreted as hand–eye response time rather than pure reaction time. Since the continuous 30-second protocol also required repeated upper-limb responses and sustained attention, possible within-task attentional or neuromuscular fatigue could not be excluded. In addition, the fixed wall-mounted task did not directly reproduce the full-body movements, three-dimensional ball trajectories, or anticipation demands of volleyball-specific performance.

### Visual acuity test

Visual acuity was assessed using the Snellen chart, a tool developed by Dutch ophthalmologist Herman Snellen, which measures the ability to read letters from a distance of 6 m (20 feet). Letters of varying sizes were presented on a chart, and each eye was tested separately. A visual acuity value of 20/20 is considered normal in healthy individuals. This test was used to determine the degree of visual impairment and assess the need for optical correction [22].

### Colour vision test

Colour perception was evaluated using the Ishihara colour vision test, which is widely used in the diagnosis of colour blindness and consists of 38 plates featuring different colours and patterns. The participants were asked to correctly identify the numbers and shapes on each plate. A total of 12 plates were presented. Participants who correctly identified all plates were classified as having normal colour vision, those who failed to identify any plates were classified as fully colour blind, and those who identified only some plates correctly were classified as partially colour blind [23, 24].

### Titmus Fly Test

Stereopsis was measured using the Stereo Fly Test (Stereo Optical Co. Inc.). The participants wore polarised glasses and were asked to identify three-dimensional circles on the test sheet. Stereopsis levels corresponding to correct answers were recorded in arcseconds, with values ranging from 40 to 800 arcseconds [25]. The Titmus Fly Test assesses static near stereopsis primarily through binocular disparity discrimination under controlled laboratory conditions. It does not directly assess dynamic stereopsis, long-distance ball tracking, rapid vergence adaptation, retinal motion processing, or real-time visuomotor responses to moving objects. Accordingly, the resulting scores were interpreted as laboratory-based measures of static binocular depth discrimination rather than direct measures of volleyball-specific dynamic visual processing.

### Ocular aberration and point spread function test

Ocular aberration and point spread function (PSF) values were measured using the Nidek OPD-Scan III system (Optical Path Difference; NIDEK Co. Ltd., Gamagori, Japan), an ophthalmic imaging device capable of performing corneal topography, aberrometry analysis, pupil measurements, and related optical assessments [26]. Measurements were obtained separately from both eyes. For each optical parameter, values were summarised as better-eye and worse-eye measurements according to the parameter-specific favourable or unfavourable result. These terms were used only to describe measurement-based optical performance and should not be interpreted as a functional eye-preference classification.

### Spike and reception performance measurement

Athletic performance was evaluated using the Data Volley 4 software (Data Project, Salerno, Italy), a digital analysis tool widely used in international-level volleyball performance assessments and known for its high data validity [27]. The software enables analysis of technical skills such as serving, spiking, blocking, reception, defence, and attack.

In the assessment of spike performance, athletes performed a total of 10 valid spike attempts under three blocking conditions: no block, fixed block, and moving block. The trial structure consisted of 2 spike attempts without a block, 4 spike attempts against a fixed block, and 4 spike attempts against a moving block. The same 2-4-4 trial structure was applied to all athletes to ensure standardised task composition across participants.

The analysis included only sets that allowed the athlete to complete a normal approach, jump, and spike action. Sets were excluded when they were too low, too close to the net, too far from the optimal attacking zone, too wide, or otherwise prevented technically valid spike execution. Acceptable sets were confirmed by the performance analysts according to these predefined criteria before inclusion in the final performance score. Across participants, excluded attempts were repeated until 10 valid spike attempts were obtained.

Each spike was coded using Data Volley 4 software, with performance expressed as a percentage score. The resulting percentage score represented the athlete's spike performance [28, 29].

Reception performance was assessed using 10 valid serve-receive attempts consisting of three tennis serves, three float serves, and four jump serves. Serves were delivered by an experienced volleyball coach from the standard service zone behind the end line and were directed toward the middle and backcourt reception areas. Because the three serve types differ technically, release height was not fixed across serve types; however, the same serve-type structure, serving area, and target-zone criteria were applied consistently to all athletes. Serves that landed outside these predefined target areas or were impossible to receive under normal technical conditions were not included in the analysis and were repeated until 10 valid reception attempts were obtained.

The same 3-3-4 serve-type structure was applied to all athletes to ensure standardised task composition across participants. Participants attempted to receive each valid serve, and reception performance was coded using Data Volley 4 software. The resulting percentage score represented each athlete's reception performance [30].

*Inter-rater reliability and coding procedure*

Spiking and reception actions were coded using Data Volley 4 by two independent performance analysts with more than five years of professional experience in elite volleyball. To minimise potential bias, both analysts were blinded to the athletes' visual skill test results throughout the coding process. All actions were coded independently, and any discrepancies were resolved through consensus. Inter-rater reliability was assessed on 20% of all coded actions using Cohen's kappa coefficient, yielding $\kappa = 0.86$ for spiking actions and $\kappa = 0.83$ for reception actions, indicating strong agreement between analysts. This procedure ensured the objectivity, consistency, and methodological rigor of the performance assessments.

Data analysis

Descriptive statistics were reported according to variable type and distributional characteristics. The normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of distributional patterns. Normally distributed continuous variables were presented as mean ± standard deviation, whereas non-normally distributed continuous variables were presented as median [interquartile range]. Categorical variables, including colour vision classification and playing position, were reported as frequencies and percentages.

Because several variables showed non-normal distributional characteristics and some visual measures had rank-like or limited-scale properties, associations between the assessed visual and visuomotor variables and volleyball-specific performance outcomes were examined using Spearman's rank-order correlation coefficients. Colour vision was summarised descriptively and was not included in the correlation analyses because it was a categorical classification variable and showed limited variability across participants.

To reduce the risk of type I error due to multiple testing, the Benjamini–Hochberg false discovery rate (FDR) correction was applied. In the main analysis, FDR correction was applied across 18 correlation tests, consisting of nine assessed visual and visuomotor variables examined in relation to two performance outcomes. FDR correction was also applied separately within each sex-specific subgroup analysis. Raw $p$-values and FDR-adjusted $p$-values were reported in the correlation tables.

Correlation coefficients were interpreted using conventional thresholds: small = 0.10–0.29, moderate = 0.30–0.49, and large ≥ 0.50. Given the modest sample size, particularly in subgroup analyses, multiple regression models were not retained in the final analysis because of the risk of overfitting and unstable parameter estimation. Playing position was not included in an adjusted correlation or regression model because the five position categories contained small and unequal numbers of athletes, including only four setters and four liberos. Introducing multiple position parameters into a model with 36 participants would have produced a high risk of overfitting, unstable estimates, and unreliable position-specific coefficients. Therefore, the primary analyses were limited to unadjusted bivariate Spearman correlations. No position-stratified inferential analyses were performed, and the resulting correlation coefficients cannot be interpreted as associations that are independent of playing position. Sex-specific subgroup analyses were considered exploratory and interpreted cautiously. All statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Statistical power analysis

A post hoc power analysis was conducted for the primary correlations between static near-stereopsis scores and performance outcomes using a two-tailed $\alpha$ level of .05. The overall sample ($n = 36$) provided sufficient power to detect large effect sizes, particularly for the stereopsis–spike association. However, the study was underpowered to reliably detect small-to-moderate effects, especially in subgroup analyses. Therefore, non-significant findings should be interpreted with caution.

## Results

Colour vision was summarised descriptively as a categorical variable and was not included in the correlation analyses because of its categorical structure and limited variability across participants.

Table 2 shows Spearman's rank-order correlations between visual skill variables and spike and reception performance in all athletes. After applying the Benjamini–Hochberg FDR correction, static near-stereopsis scores remained significantly associated with both reception performance ($\rho = -0.487$, raw $p = 0.003$, FDR-adjusted $p = 0.023$) and spike performance ($\rho = -0.780$, raw $p < 0.001$, FDR-adjusted $p < 0.001$). Because lower Titmus Fly Test values indicate better static near stereopsis, these negative correlations indicate that better performance on the laboratory-based binocular depth-discrimination test was associated with higher stand-

Table 1. Demographic, visual, and performance characteristics of the athletes by sex

| Variable | Male (*n* = 20) | Female (*n* = 16) | Total (*n* = 36) |
|---|---|---|---|
| Age (years) | 18.00 [17.00–19.00] | 23.50 [19.00–25.25] | 19.00 [17.75–23.25] |
| Height (cm) | 192.70 ± 5.70 | 181.94 ± 5.60 | 187.92 ± 7.78 |
| Hand–eye response time (ms) | 636.60 ± 80.01 | 816.25 ± 64.56 | 716.44 ± 116.01 |
| Visual acuity (Snellen) | 1.50 [1.20–1.50] | 1.50 [1.20–1.50] | 1.50 [1.20–1.50] |
| Colour vision, *n* (%) | | | |
| Normal colour vision | 18 (90.0%) | 16 (100.0%) | 34 (94.4%) |
| Partial colour vision deficiency | 1 (5.0%) | 0 (0.0%) | 1 (2.8%) |
| Complete colour vision deficiency | 1 (5.0%) | 0 (0.0%) | 1 (2.8%) |
| Static near stereopsis (arcsec) | 40.00 [40.00–80.00] | 45.00 [40.00–80.00] | 40.00 [40.00–80.00] |
| Total aberration (μm, better eye) | 1.21 [0.90–2.52] | 1.20 [0.62–1.86] | 1.20 [0.80–2.27] |
| Total aberration (μm, worse eye) | 1.91 [1.29–3.21] | 1.60 [0.91–2.27] | 1.76 [1.21–2.79] |
| High-order aberration (μm, better eye) | 0.39 ± 0.17 | 0.35 ± 0.19 | 0.37 ± 0.18 |
| High-order aberration (μm, worse eye) | 0.60 ± 0.29 | 0.50 ± 0.23 | 0.56 ± 0.27 |
| Point spread function (better eye) | 0.01 [0.00–0.03] | 0.02 [0.00–0.04] | 0.02 [0.00–0.04] |
| Point spread function (worse eye) | 0.00 [0.00–0.02] | 0.01 [0.00–0.02] | 0.01 [0.00–0.02] |
| Reception performance (%) | 44.00 [22.00–44.00] | 44.00 [37.50–46.25] | 44.00 [33.00–45.00] |
| Spike performance (%) | 63.55 ± 13.14 | 62.62 ± 11.51 | 63.14 ± 12.28 |

Values are presented as mean ± standard deviation for normally distributed continuous variables, median [*Q1–Q3*] for non-normally distributed continuous variables, and *n* (%) for categorical variables. Hand–eye response time is reported in milliseconds, with lower values indicating faster responses during the BlazePod task. Visual acuity is expressed in Snellen decimal notation and static near stereopsis is measured in arcseconds, with lower values indicating better performance on the laboratory-based depth-discrimination test. Better-eye and worse-eye values refer to measurement-based optical performance and do not indicate functional eye preference. Additionally, the playing-position distribution was as follows: outside hitter, 10 (27.8%); opposite hitter, 8 (22.2%); middle blocker, 10 (27.8%); setter, 4 (11.1%); and libero, 4 (11.1%).

Table 2. Spearman's rank-order correlations between visual skills and performance outcomes in all athletes

| Variable | Outcome | ρ | Raw *p* | FDR-adjusted *p* |
|---|---|---|---|---|
| Hand-eye response time (ms) | reception performance | 0.165 | 0.337 | 0.937 |
| Hand-eye response time (ms) | spike performance | 0.022 | 0.899 | 0.937 |
| Visual acuity (Snellen) | reception performance | –0.131 | 0.445 | 0.937 |
| Visual acuity (Snellen) | spike performance | 0.110 | 0.523 | 0.937 |
| Static near stereopsis (arcsec) | reception performance | –0.487 | 0.003 | 0.023 |
| Static near stereopsis (arcsec) | spike performance | –0.780 | < 0.001 | < 0.001 |
| Total aberration (μm, better eye) | reception performance | 0.044 | 0.798 | 0.937 |
| Total aberration (μm, better eye) | spike performance | 0.067 | 0.700 | 0.937 |
| Total aberration (μm, worse eye) | reception performance | –0.100 | 0.562 | 0.937 |
| Total aberration (μm, worse eye) | spike performance | 0.074 | 0.668 | 0.937 |
| High-order aberration (μm, better eye) | reception performance | 0.018 | 0.917 | 0.937 |
| High-order aberration (μm, better eye) | spike performance | 0.125 | 0.466 | 0.937 |
| High-order aberration (μm, worse eye) | reception performance | 0.043 | 0.801 | 0.937 |
| High-order aberration (μm, worse eye) | spike performance | 0.258 | 0.128 | 0.768 |
| Point spread function (better eye) | reception performance | –0.035 | 0.841 | 0.937 |
| Point spread function (better eye) | spike performance | –0.106 | 0.537 | 0.937 |
| Point spread function (worse eye) | reception performance | 0.130 | 0.448 | 0.937 |
| Point spread function (worse eye) | spike performance | 0.014 | 0.937 | 0.937 |

Raw *p*-values and Benjamini–Hochberg FDR-adjusted *p*-values are reported. FDR correction was applied across 18 correlation tests in the main analysis. Colour vision was excluded from the correlation analyses because it was a categorical variable with limited variability. Negative correlations for static near stereopsis reflect the scoring method in arcseconds, where lower values indicate better performance on the laboratory-based binocular depth-discrimination test. All reported correlations are unadjusted for playing position.

ardised reception and spike performance scores. However, these associations were not adjusted for playing position and therefore should not be interpreted as position-independent relationships.

No other assessed visual or visuomotor variable showed a statistically significant association with spike or reception performance after FDR correction. Sex-specific subgroup analyses are presented in the Supplementary material (Tables S1 and S2) and should be interpreted as exploratory because of the limited subgroup sample sizes.

## Discussion

The principal finding of this study was that static near-stereopsis scores remained significantly associated with both spike and reception performance after FDR correction in the unadjusted analyses, with a stronger association observed for spike performance. This interpretation aligns with evidence indicating that visuomotor factors become increasingly important as competitive level rises and that actions involving high ball velocity and limited decision time – such as the spike – require complex dynamic visual and visuomotor processing [31]. In this context, static near-stereopsis performance may be associated with standardised volleyball-specific tasks that require rapid decision-making and spatial positioning [9, 19]. Nevertheless, the present measure assessed static near stereopsis and should not be interpreted as a direct measure of the dynamic visual processes used during actual volleyball actions.

When the associations between stereopsis and performance outcomes were examined, significant negative correlations were observed for both reception and spike performance after FDR correction. Because lower values on the Stereo Fly Test indicate better static near stereopsis, the negative correlations show that better performance on this laboratory-based test was associated with higher standardised volleyball-specific performance scores. The association was stronger for spike performance than for reception performance, suggesting that laboratory-measured binocular depth-discrimination ability may be more strongly associated with the standardised spike task than with the standardised reception task.

The Titmus Fly Test and dynamic in-game depth processing represent related but distinct constructs [9, 10]. The test assesses static binocular disparity discrimination at near distance, whereas volleyball requires continuous integration of binocular disparity, rapidly changing vergence, ocular pursuit, retinal motion cues, anticipation, and motor planning [9, 10, 19]. Therefore, the observed association should not be interpreted as evidence that the Titmus Fly Test directly measures ball tracking, time-to-contact estimation, or dynamic depth processing during volleyball. Instead, athletes who performed better on the static laboratory test also tended to obtain higher standardised performance scores. The mechanisms underlying this relationship remain unknown because gaze behaviour, vergence responses, dynamic stereopsis, and motion-based depth judgments were not measured.

Playing position is an important potential confounding factor in the interpretation of these associations. Volleyball roles differ markedly in their habitual visual environments, spatial–temporal constraints, technical responsibilities, and exposure to attacking and reception tasks. For example, middle blockers typically perform rapid actions close to the net, whereas liberos and outside hitters are more frequently exposed to deep serve trajectories and reception-related visual demands. Playing position may therefore be associated with both the visual characteristics of the athletes and their performance on the standardised spike or reception tasks. Because position was not statistically controlled, the observed correlations may have been inflated, attenuated, or partly generated by differences in role specialisation and task experience. Accordingly, the stronger association observed for spike performance cannot be attributed solely to static near-stereopsis ability and should not be interpreted as independent of playing position.

To explore possible sex-related patterns, subgroup analyses were also examined. Stereopsis-related associations appeared more pronounced in female athletes, whereas in male athletes the association was more apparent for spike performance than for reception performance. However, these subgroup findings should be interpreted as exploratory because of the limited subgroup sample sizes. Accordingly, the present data do not support definitive conclusions regarding sex-specific effects.

Correlation analyses also revealed no significant relationships between visual acuity and either spike or reception performance. Prior work has shown that static visual acuity is not associated with object tracking, whereas dynamic visual acuity is [32]. Because the present study assessed static visual acuity, this may help explain the absence of a significant relationship. In this respect, visual acuity may function as a supportive visual skill rather than a primary factor associated with volleyball-specific performance.

Given the rapid movement of both the ball and the players, volleyball requires the rapid formation of a clear

and usable visual image. Successful players must quickly perceive ball trajectory and player positioning, a process linked to eye mobility [33]. Previous research has emphasised the importance of visual-motor skills in athletic performance [34] and has suggested that hand-eye coordination and reaction-related abilities may contribute to volleyball-specific actions [35, 36]. However, the present study found no significant relationship between hand-eye response time and either spike or reception performance. This may indicate that laboratory-based hand-eye response time measures do not fully capture the complex perceptual–motor demands of volleyball performance. In addition, variables such as age, playing position, and skill specialisation may affect this relationship and should be controlled more explicitly in future studies [21]. This is in line with previous findings showing that dynamic visual acuity is associated with multiple visual system components, including stereopsis and static visual acuity, in elite athletes [37].

The sequential and interdependent nature of volleyball skills highlights the importance of serve reception in shaping subsequent offensive actions. Fatahi *et al.* [38] demonstrated significant associations between reception zone, setting zone, and attack quality in elite male volleyball players. Their findings suggest that the quality of reception constrains the setter's tactical options and may affect the efficiency of the subsequent attack [38]. In this context, the association between static near-stereopsis scores and reception performance may reflect a relationship between laboratory-based binocular depth-discrimination ability and performance on the standardised reception task. However, the present findings do not demonstrate that the Titmus Fly Test directly captures serve tracking, ball-speed judgment, or dynamic approach-angle estimation. Moreover, the stronger unadjusted association observed for spike performance should be interpreted cautiously because it may partly reflect playing-position differences, role specialisation, and task-specific experience.

Stereopsis is generally regarded as a threshold measure of the ability to interpret binocular disparity as perceived depth [39]. Comparative studies between athletes and non-athletes have shown that athletes often demonstrate superior visual skills [40]. In that context, the present findings indicate that performance on a static laboratory-based stereopsis test was associated with standardised sport-specific performance scores. This association does not establish equivalence between static stereopsis and the dynamic visual processing required during match play. However, based on the correlational design of the present study, these results should not be interpreted as evidence that stereopsis determines performance outcomes or should be used in isolation for talent identification or position assignment.

With the advancement of training science, factors associated with athletic performance are being examined in greater detail. Memmert *et al.* [41] emphasised that, in addition to motor and physical abilities, sensory and perceptual skills are essential for athletic performance. Since a substantial proportion of sensory input is acquired through visual perception [42], athletes are generally expected to possess well-developed visual skills and to continue improving them to optimise performance [43]. Moreover, visual skills may shape not only performance outcomes but also training efficiency, suggesting that such attributes may function as integral components of training adaptation rather than isolated characteristics [44]. Within this broader framework, the present study indicates that static near-stereopsis scores showed significant unadjusted associations with both spike and reception performance among the visual parameters examined, with a stronger association observed for spike performance.

The study also has statistical and methodological limitations. The sample size was modest, particularly for subgroup analyses, and this limits the stability and generalisability of the findings. In addition, performance was assessed through a limited number of standardised spike and reception trials rather than full match play. Although this approach improved measurement control, it may not fully reflect the ecological complexity of competitive volleyball [10, 30]. Similarly, stereopsis was assessed using the Titmus Fly Test under static laboratory conditions, whereas real volleyball actions require dynamic binocular depth processing and continuous visuomotor integration [25, 38]. These issues should be considered when interpreting the present results.

### Limitations

The spike and reception assessments were based on only 10 valid attempts per participant and used unequal condition distributions (2-4-4 for spike and 3-3-4 for reception). Although the same protocols were applied consistently to all athletes, these restricted and unbalanced trial blocks may not fully represent the tactical, situational, and psychological variability of competitive match play. Future studies should use larger and fully balanced trial blocks and complementary in-match analyses.

The Titmus Fly Test measures static near stereopsis under controlled laboratory conditions and does not directly reproduce the dynamic visual demands of volleyball, including changing vergence, ball tracking,

retinal motion processing, and continuous visuomotor adaptation. Therefore, the observed correlations should be interpreted as associations with laboratory-based binocular depth discrimination rather than direct evidence of in-game depth-processing ability. More sensitive and dynamic stereopsis assessments should be used in future studies.

Playing position was not statistically controlled because of the modest sample size and the small, unequal numbers of athletes across position categories. Because volleyball roles differ substantially in attacking, reception, and perceptual-motor demands, playing position may have influenced the observed correlations. Consequently, the reported associations cannot be interpreted as independent of playing position.

The BlazePod task included both visual stimulus detection and upper-limb movement toward fixed targets and should therefore be interpreted as hand-eye response time rather than pure or volleyball-specific reaction time. Its fixed two-dimensional structure did not reproduce the full-body or three-dimensional visuomotor demands of volleyball. Because responses were repeated continuously for 30 s, the measure may also reflect a short-duration reactive endurance component in addition to hand–eye response speed. Moreover, the correlational design precludes causal inference, statistical power was limited for medium-sized and subgroup effects, and unmeasured factors such as training background and experience may have influenced the results.

**Acknowledgements**

This study was derived from a doctoral thesis and was supported by the Gazi University Scientific Research Projects Coordination Unit (BAP) under project code TDK-2022-7496.

**Ethical approval**

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Ethics Committee of Gazi University (Code: 2021-964; Meeting No. 16; 19.10.2021).

**Informed consent**

Informed consent has been obtained from all individuals included in this study. Written informed consent was obtained from all participants aged 18 years and above. For participants under 18 years of age, written consent was obtained from their parents or legal guardians.

**Conflict of interest**

The authors declare no conflicts of interest.

**Disclosure statement**

No author has any financial interest or has received any financial benefit from this research.

**Funding**

This research was funded by the Gazi University Scientific Research Projects (BAP) unit (Project code: TDK-2022-7496).

**References**

[1] Pino-Ortega J, Rojas-Valverde D, Gómez-Carmona CD, Rico-González M. Training design and talent identification – a systematic review about the most relevant variables through the principal component analysis in soccer, basketball, and rugby. Int J Environ Res Public Health. 2021;18(5): 2642; doi: 10.3390/ijerph18052642.

[2] Kaluga E, Straburzynska-Lupa A, Rostkowska E. Hand-eye coordination, movement reaction time and hand tactile sensitivity depending on the practiced sports discipline. J Sports Med Phys Fitness. 2020;60(1):17–25; doi: 10.23736/S0022-4707.19.09726-3.

[3] Kaszuba M, Klocek O, Spieszny M, Filip-Stachnik A. The effect of caffeinated chewing gum on volleyball-specific skills and physical performance in volleyball players. Nutrients. 2023;15(1):91; doi: 10.3390/nu15010091.

[4] Vickers JN. Perception, Cognition, and Decision Training. The Quiet Eye in Action. Champaign: Human Kinetics; 2007; pp. 17–28.

[5] Millard L, Breukelman GJ, Mathe N, Shaw I, Shaw BS. A review of the essential visual skills required for soccer: beyond 20–20 optometry. Front Sports Act Living. 2022;4:965195; doi: 10.3389/fspor.2022.965195.

[6] Millard L, Breukelman GJ, Burger T, Nortje J, Schulz J. Visual skills essential for rugby. Med Hypothesis Discov Innov Ophthalmol. 2023;12(1): 46–54; doi: 10.51329/mehdiophthal1469.

[7] Erickson GB. Sports vision: vision care for the enhancement of sports performance. St. Louis: Elsevier; 2020; pp. 115–26.

[8] Jin P, Li X, Ma B, Guo H, Zhang Z, Mao L. Dynamic visual attention characteristics and their relationship to match performance in skilled basketball players. PeerJ. 2020;8:e9803; doi: 10.7717/peerj.9803.

[9] Presta V, Vitale C, Ambrosini L, Gobbi G. Stereopsis in sports: visual skills and visuomotor integra-

tion models in professional and non-professional athletes. Int J Environ Res Public Health. 2021; 18(21):11281; doi: 10.3390/ijerph182111281.
[10] Lenoir M, Musch E, La Grange N. Ecological relevance of stereopsis in one-handed ball-catching. Percept Mot Skills. 1999;89(2):495–508; doi: 10.2466/pms.1999.89.2.495.
[11] Perez GM, Manzanera S, Artal P. Impact of scattering and spherical aberration in contrast sensitivity. J Vis. 2009;9(3):19.1–10; doi: 10.1167/9.3.19.
[12] Bayraktar B, Kurtoğlu M. Sports performance: influencing factors, evaluation, and improvement [in Turkish]. Klinik Gelişim. 2009;22(1):16–24.
[13] Aslan AK, Erkmen N, Aktaş S, Güven F. Postural control and functional performance after core training in young soccer players. Malays J Mov Health Exerc. 2018;7(2):23–38; doi: 10.15282/mohe.v7i2.234.
[14] Jafarzadehpur E, Aazami N, Bolouri B. Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. Scand J Med Sci Sports. 2007;17(2): 186–90; doi: 10.1111/j.1600-0838.2005.00535.x.
[15] Piras A, Lobietti R, Squatrito S. A study of saccadic eye movement dynamics in volleyball: comparison between athletes and non-athletes. J Sports Med Phys Fitness. 2010;50(1):99–108.
[16] Cust EE, Sweeting AJ, Ball K, Robertson S. Machine and deep learning for sport-specific movement recognition: a systematic review of model development and performance. J Sports Sci. 2019; 37(5):568–600; doi: 10.1080/02640414.2018.1521769.
[17] Khanal S. Impact of visual skills training on sports performance: current and future perspectives. Adv Ophthalmol Vis Syst. 2015;2(1):26–8; doi: 10.15406/aovs.2015.02.00032.
[18] Regan D, Gray R. Hitting what one wants to hit and missing what one wants to miss. Vision Res. 2001; 41(25–26):3321–29; doi: 10.1016/S0042-6989(01)00068-2.
[19] Castro HDO, Praça GM, Costa GDCT, Pedrosa GF, Greco PJ. Visual behavior and the quality of decision-making in volleyball. Rev Bras Cineantropom Desempenho Hum. 2016;18(6):638–47; doi: 10.1590/1980-0037.2016v18n6p638.
[20] Karasar N. Scientific research methods [in Turkish]. Ankara: Nobel; 2011; pp. 108–10.
[21] Aslan AK, Cicioğlu Hİ, Kocaoğlu Y, Erkmen N. The relationship between music genre and hand-eye reaction times in children aged 11–14 years [in Turkish]. Ulusal Kinesyol Dergisi. 2023;4(1): 38–46; doi: 10.5281/zenodo.8165069.
[22] Azzam D, Ronquillo Y. Snellen chart. In: StatPearls. Treasure Island: StatPearls Publishing; 2023; pp. 1–6.
[23] Birch J, McKeever LM. Survey of the accuracy of new pseudoisochromatic plates. Ophthalmic Physiol Opt. 1993;13(1):35–40; doi: 10.1111/j.1475-1313.1993.tb00423.x.
[24] Ishihara S. Ishihara's tests for colour deficiency: 24 plates edition. Tokyo: Kanehara; 1997; pp. 3–41.
[25] Gawęcki M. Threshold values of myopic anisometropia causing loss of stereopsis. J Ophthalmol. 2019;2019:2654170; doi: 10.1155/2019/2654170.
[26] Asgari S, Hashemi H. OPD scan III accuracy: topographic and aberrometric indices after accelerated corneal cross-linking. J Curr Ophthalmol. 2017;30(1):58–62; doi: 10.1016/j.joco.2017.09.004.
[27] Palao JM, Santos JA, Ureña A. Effect of team level on skill performance in volleyball. Int J Perform Anal Sport. 2004;4(2):50–60; doi: 10.1080/24748668.2004.11868304.
[28] Şentuna M. Offensive and defensive variables in volleyball [in Turkish]. Spormetre. 2005;3(2):85–92; doi: 10.1501/Sporm_0000000047.
[29] Silva M, Marcelino R, Lacerda D, João PV. Match analysis in volleyball: a systematic review. Montenegrin J Sports Sci Med. 2016;5(1):35–46.
[30] de Leeuw AW, van Baar R, Knobbe A, van der Zwaard S. Modeling match performance in elite volleyball players: importance of jump load and strength training characteristics. Sensors. 2022; 22(20):7996; doi: 10.3390/s22207996.
[31] Tremblay M, Couëpel B, Abboud J, Descarreaux M. What are the individual characteristics or skills associated with baseball batting performance? A scoping review. Sports Med Open. 2025;11(1): 150; doi: 10.1186/s40798-025-00947-1.
[32] Vera J, Redondo B, Molina R, Jiménez R, Dalton K. Relationship between dynamic visual acuity and multiple object tracking performance. Perception. 2022;51(8):539–48; doi: 10.1177/03010066221104281.
[33] Jafarzadehpur E, Yarigholi MR. Comparison of visual acuity in reduced lumination and facility of ocular accommodation in table tennis champions and non-players. J Sports Sci Med. 2004; 3(1):44–48.
[34] Riemann BL, Lephart SM. The sensorimotor system. Part II: the role of proprioception in motor control and functional joint stability. J Athl Train. 2002;37(1):80–84.
[35] Ngadiyana H. The effect of eye-hand coordination training on accuracy of service in volleyball

players. In: Proceedings of the 1st South Borneo International Conference on Sport Science and Education (SBICSSE 2019). Atlantis Press; 2020; pp. 138–40; doi: 10.2991/assehr.k.200219.040.
[36] Sari YBC, Guntur G. The effects of training method and eye-hand coordination on the results of volleyball serving skill. J Keolahragaan. 2017;5(1): 100–10, doi: 10.21831/jk.v5i1.12773.
[37] Jorge J, Jorge JP. Relationship between dynamic visual acuity and static visual acuity, refractive error, and binocular vision in elite soccer players. Clin Exp Optom. 2024;107(8):820–25; doi: 10.1080/08164622.2024.2301981.
[38] Fatahi A, Yousefian Molla R, Drikos S, Alriyami SA, Jadidoleslam S. A comprehensive analysis of the serve reception zone, set zone and attack quality of the top-level volleyball players. Eur J Hum Mov. 2022;48:54–63; doi: 10.21134/eurjhm.2022.48.6.
[39] O'Connor AR, Tidbury LP. Stereopsis: are we assessing it in enough depth?. Clin Exp Optom. 2018; 101(4):485–94; doi: 10.1111/cxo.12655.
[40] Laby DM, Kirschen DG, Govindarajulu U, DeLand P. The effect of visual function on the batting performance of professional baseball players. Sci Rep. 2019;9(1):16847; doi: 10.1038/s41598-019-52546-2.
[41] Memmert D, Simons DJ, Grimme T. The relationship between visual attention and expertise in sports. Psychol Sport Exerc. 2009;10(1):146–51; doi: 10.1016/j.psychsport.2008.06.002.
[42] Coetzee D, de Waal E. An exploratory investigation of the effect of a sports vision program on grade 4 and 5 female netball players' visual skills. Int J Environ Res Public Health. 2022;19(16):9864; doi: 10.3390/ijerph19169864.
[43] Appelbaum LG, Erickson G. Sports vision training: a review of the state-of-the-art in digital training techniques. Int Rev Sport Exerc Psychol. 2018; 11(1):160–89; doi: 10.1080/1750984X.2016.1266376.
[44] Sánchez-Tena MÁ, Rodríguez-Alonso X, Martinez-Perez C, Tornero-Aguilera JF, Clemente-Suárez VJ, Sanchez-Ramos C, Alvarez-Peregrina C. Comparison of visual skills between federated and non-federated athletes. Int J Environ Res Public Health. 2023;20(2):1047; doi: 10.3390/ijerph20021047.

## Supplementary materials

Table S1. Spearman's rank-order correlations between visual skills and performance outcomes in male athletes

| Variable | Outcome | ρ | raw *p* | FDR-adjusted *p* |
|---|---|---|---|---|
| Hand–eye response time (ms) | reception performance | 0.268 | 0.253 | 0.676 |
| Hand–eye response time (ms) | spike performance | –0.139 | 0.559 | 0.719 |
| Visual acuity (Snellen) | reception performance | –0.165 | 0.488 | 0.676 |
| Visual acuity (Snellen) | spike performance | 0.251 | 0.286 | 0.676 |
| Static near stereopsis (arcsec) | reception performance | –0.325 | 0.162 | 0.676 |
| Static near stereopsis (arcsec) | spike performance | –0.786 | < 0.001 | < 0.001 |
| Total aberration (μm, better eye) | reception performance | 0.216 | 0.360 | 0.676 |
| Total aberration (μm, better eye) | spike performance | 0.200 | 0.397 | 0.676 |
| Total aberration (μm, worse eye) | reception performance | 0.005 | 0.984 | 0.984 |
| Total aberration (μm, worse eye) | spike performance | 0.198 | 0.402 | 0.676 |
| High-order aberration (μm, better eye) | reception performance | –0.057 | 0.812 | 0.969 |
| High-order aberration (μm, better eye) | spike performance | 0.174 | 0.462 | 0.676 |
| High-order aberration (μm, worse eye) | reception performance | 0.042 | 0.862 | 0.969 |
| High-order aberration (μm, worse eye) | spike performance | 0.264 | 0.261 | 0.676 |
| Point spread function (better eye) | reception performance | –0.173 | 0.466 | 0.676 |
| Point spread function (better eye) | spike performance | –0.455 | 0.044 | 0.393 |
| Point spread function (worse eye) | reception performance | 0.023 | 0.925 | 0.979 |
| Point spread function (worse eye) | spike performance | –0.203 | 0.391 | 0.676 |

Raw *p*-values and Benjamini–Hochberg FDR-adjusted *p*-values are reported. FDR correction was applied across 18 correlation tests within the male subgroup. Color vision was excluded from the correlation analyses because it was a categorical variable with limited variability. Negative correlations for static near stereopsis reflect the scoring method in arcseconds, where lower values indicate better performance on the static near-stereopsis test. Subgroup analyses were exploratory and should be interpreted cautiously because of the limited sample size. The BlazePod measure represents response performance during a continuous 30-second task involving repeated upper-limb movements toward fixed visual targets and should not be interpreted as pure or volleyball-specific reaction time. Correlations within the sex-specific subgroup analyses were also unadjusted for playing position.

Table S2. Spearman's rank-order correlations between visual skills and performance outcomes in female athletes

| Variable | Outcome | ρ | raw *p* | FDR-adjusted *p* |
|---|---|---|---|---|
| Hand–eye response time (ms) | reception performance | –0.148 | 0.585 | 0.931 |
| Hand–eye response time (ms) | spike performance | 0.092 | 0.735 | 0.931 |
| Visual acuity (Snellen) | reception performance | –0.010 | 0.970 | 0.970 |
| Visual acuity (Snellen) | spike performance | –0.038 | 0.889 | 0.941 |
| Static near stereopsis (arcsec) | reception performance | –0.807 | < 0.001 | 0.002 |
| Static near stereopsis (arcsec) | spike performance | –0.799 | < 0.001 | 0.002 |
| Total aberration (μm, better eye) | reception performance | –0.108 | 0.689 | 0.931 |
| Total aberration (μm, better eye) | spike performance | –0.181 | 0.502 | 0.931 |
| Total aberration (μm, worse eye) | reception performance | –0.077 | 0.776 | 0.931 |
| Total aberration (μm, worse eye) | spike performance | –0.058 | 0.831 | 0.935 |
| High-order aberration (μm, better eye) | reception performance | 0.085 | 0.755 | 0.931 |
| High-order aberration (μm, better eye) | spike performance | 0.131 | 0.629 | 0.931 |
| High-order aberration (μm, worse eye) | reception performance | 0.162 | 0.549 | 0.931 |
| High-order aberration (μm, worse eye) | spike performance | 0.226 | 0.400 | 0.931 |
| Point spread function (better eye) | reception performance | 0.102 | 0.707 | 0.931 |
| Point spread function (better eye) | spike performance | 0.302 | 0.256 | 0.931 |
| Point spread function (worse eye) | reception performance | 0.210 | 0.434 | 0.931 |
| Point spread function (worse eye) | spike performance | 0.392 | 0.134 | 0.802 |

Raw *p*-values and Benjamini–Hochberg FDR-adjusted *p*-values are reported. FDR correction was applied across 18 correlation tests within the female subgroup. Color vision was excluded from the correlation analyses because it was a categorical variable with limited variability. Negative correlations for static near stereopsis reflect the scoring method in arcseconds, where lower values indicate better performance on the static near-stereopsis test. Subgroup analyses were exploratory and should be interpreted cautiously because of the limited sample size. The BlazePod measure represents response performance during a continuous 30-second task involving repeated upper-limb movements toward fixed visual targets and should not be interpreted as pure or volleyball-specific reaction time. Correlations within the sex-specific subgroup analyses were also unadjusted for playing position.

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs (CC BY-NC-ND).