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A Descriptive Analysis of Visual and Oculomotor Skills in Federated University Athletes

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Featured Application: The findings from this study have direct applications in the development of sport-specific visual training programs aimed at enhancing athletic performance. By identifying the visual and oculomotor skills that are critical for different sports, coaches and trainers can implement tailored training protocols that focus on improving these specific abilities. Additionally, the integration of advanced technologies such as the COI-Sport Vision system can provide precise assessments and monitor progress, leading to more effective training outcomes. These applications can significantly contribute to optimizing the training, performance, and overall health of athletes, particularly in high-speed and dynamic sports where visual acuity and oculomotor coordination are paramount.

Abstract: Background: Visual and oculomotor skills are essential components of athletic performance, particularly in sports that demand rapid visual processing and precise motor execution. This study aimed to provide a descriptive analysis of the visual and oculomotor abilities of federated university athletes and explore their relationship with self-perceived performance. Methods: A total of 52 federated university athletes (34 men and 18 women), aged 18 to 37 years, participated in this observational and descriptive study. Visual assessments were conducted using the digital COI-Sport Vision system, evaluating static and dynamic visual acuity, stereopsis, vergence, contrast sensitivity, visual memory, hand-eye coordination, anticipation time, peripheral awareness, and identification. Results: The findings revealed patterns in the visual and oculomotor skills of this cohort, particularly in parameters such as dynamic visual acuity, stereopsis, and hand-eye coordination, which are relevant to the demands of their sports. Athletes reporting a higher satisfaction with their performance exhibited faster response times in visual memory ($p = 0.039$) and anticipation tasks ($p = 0.022$). These results suggest a potential relationship between self-perceived performance and specific visual skills, although further research is needed to establish causal links. Conclusions: This study provides valuable insights into the visual and oculomotor abilities of federated university athletes, emphasizing the potential influence of self-perceived performance on visual skill execution. While the results do not allow for

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direct comparisons with other populations, they lay the groundwork for future research into sport-specific visual demands. Incorporating validated psychological assessments and exploring longitudinal designs could further enhance an understanding of the interplay between visual skills, motivation, and athletic performance.

Keywords: sports vision; motor performance; oculomotor behavior; dynamic visual skills; sport-specific training

1. Introduction

Vision is the predominant sense, essential for interpreting environmental information and enabling effective responses to stimuli [1]. In sports, optimal performance hinges on the ability to process visual information accurately and execute precise motor responses, a process mediated by three interconnected mechanisms: perceptual, decision-making, and effector mechanisms [2]. The perceptual mechanism organizes and interprets sensory inputs [2], the decision-making mechanism identifies the most suitable stimulus–response pairing within the sports context [3], and the effector mechanism orchestrates neural commands to produce the required motor actions [2].

Advancements in sports science increasingly focus on integrating cutting-edge technologies and tailored training regimens to refine visual capabilities and enhance athletic outcomes. Sports vision, a multidisciplinary domain, involves the coordinated functions of the visual, central, somatic nervous systems, and the musculoskeletal system [4]. Comprehensive sports vision programs emphasize a vision care designed for performance enhancement through correction, protection, education, development, and assessment [5]. Research by Zupan et al. [4] highlights that up to 85–90% of sensory input in sports originates from visual information. However, the importance of visual skills varies not only across different sports but also by an athlete's specific role and the visual demands associated with it [6]. Dynamic visual acuity, defined as the ability to resolve fine details in moving objects, is particularly crucial for referees and athletes engaged in high-movement scenarios [7]. Accommodation and vergence ensure rapid and stable visual focus across varying distances, while contrast sensitivity is indispensable in challenging conditions, such as during rain or fog [8]. Stereopsis facilitates three-dimensional environmental perception, allowing athletes to accurately estimate the distance and size of objects, which is vital for timing and spatial judgments [9,10].

Sports vision focuses on enhancing and maintaining visual function to optimize athletic performance [4]. Key performance indicators include eye-hand, eye-foot, and eye-body coordination, all of which play a critical role in various sports. Eye-tracking technology is used to analyze eye movements during training, while motor response time quantifies the duration needed to execute predetermined actions [11]. Essential skills such as speed of identification, peripheral vision, and visual memory are typically more developed in elite athletes compared to the general population and sub-elite athletes, as supported by evidence [12,13]. For instance, Boden et al. [14] compared depth perception in baseball and softball players, concluding that ball players exhibit superior abilities compared to non-ball players. Similarly, Quintana et al. [15] reported that basketball players aged 11 to 13 demonstrated visual skills comparable to or exceeding those of adults. However, discrepancies remain in some abilities across different studies.

Dynamic visual acuity, which relates to the precise control of eye movements, is strongly associated with better performance in manual interceptive tasks, particularly among interceptive athletes [16,17]. Scientific evidence also supports the predictive value of visual acuity in assessing on-field performance in baseball players [8]. However, peripheral visual acuity remains a subject of debate, with only two studies demonstrating differences in functional visual fields [16,18]. Research has also identified differences in contrast sensitivity between athletes and non-athletes. For instance, badminton players demonstrated an enhanced contrast sensitivity for blue–yellow contrasts compared to a control group [19], and table tennis players exhibited a superior contrast sensitivity overall [18]. Contrast sensitivity has proven useful in distinguishing interceptive sports athletes from non-athletes with an accuracy rate of 61% [16]. Additionally, variations in stereopsis values have been documented. A study involving 400 professional baseball players found that their stereopsis levels exceeded those of the general population [20]. Notably, stereopsis was positively correlated with the walk rate in baseball players [8], further emphasizing its importance in sports requiring three-dimensional spatial analysis.

Regarding eye movements, high-level tennis players exhibit smooth pursuit movements, which allow them to track moving objects with precision, whereas lower-ranking players predominantly rely on predictive saccadic movements [21,22]. Similarly, elite cricketers demonstrate advanced oculomotor strategies, including coordinated eye and head rotations, to keep the ball within the foveal field of vision and anticipate its bounce and subsequent bat–ball contact [23]. These precise eye movements are critical for accurate interception in dynamic sports scenarios [9].

Despite the well-documented importance of visual skills, the visual and oculomotor behaviors of elite athletes appear to vary significantly depending on the specific sport and even the position they play within a team [10,24,25]. As Hodges et al. [11] point out, differences in general cognitive skills between athletes from interceptive sports are relatively minor. However, existing research primarily focuses on specific sports or isolated skills, leaving a gap in understanding the broader visual skill profiles of athletes across disciplines.

This study seeks to address these gaps by providing a comprehensive descriptive analysis of the visual and oculomotor abilities of federated university athletes. Unlike previous studies that emphasize comparisons between athletes and non-athletes, our approach centers on analyzing a single cohort to identify patterns in visual skill development and explore their relationship with self-perceived performance indicators. This research contributes to a deeper understanding of the unique visual demands faced by university athletes, setting the stage for the development of sport-specific training interventions.

2. Materials and Methods

2.1. Study Design

This observational, descriptive, prospective study was conducted between October and December 2021. The study adhered to the principles of the Declaration of Helsinki and was approved by the Ethics Investigation Committee of Universidad Europea de Madrid (CEI-UE) under the code CIPI/21/19-05.

2.2. Participants

The participants were university athletes aged 18 to 37 years, all volunteers from the federated university teams of the European University of Madrid. While all participants were part of these teams, not all were affiliated with an external sports federation at the time of the study. The sample comprised 52 athletes (34 men and 18 women), from a variety of sports disciplines, including handball, football, rugby, tennis, volleyball, and others.

2.2.1. Sports-Specific Demands

The selected sports disciplines require advanced visual perception and eye-hand coordination. Football and rugby players rely heavily on peripheral awareness, anticipation skills, and rapid decision-making under dynamic and high-contact conditions. Volleyball and tennis emphasize depth perception, hand-eye coordination, and dynamic visual acuity for tracking fast-moving objects, while handball requires precise spatial awareness, quick reaction times, and an accurate execution of coordinated movements during high-speed plays. The average competitive experience of the participants was 2 ± 1.2 years within their sports teams and 9 ± 2.3 years of total professional sports experience.

2.2.2. Inclusion and Exclusion Criteria

Inclusion criteria required participants to be active members of federated university sports teams, aged between 18 and 37 years, with no history of uncorrected visual impairments or neurological conditions that could affect visual or oculomotor performance. Exclusion criteria included recent surgeries or ongoing injuries that could interfere with performance, the use of substances that might impair cognitive or motor functions, and an engagement in strenuous physical activity within 24 h prior to the testing.

2.3. Procedure

2.3.1. General Testing Protocol

The visual assessment of the participants was performed using the digital COI-Sport Vision system (Centro de Optometría Internacional, Madrid, Spain; https://optosolutions.es/tratamientos/coisportvision, accessed on 3 December 2024.). This system has been previously validated in studies evaluating visual and oculomotor skills in athletes, demonstrating its reliability for assessing parameters such as dynamic visual acuity, stereopsis, and anticipation time [26–28]. The calibration process followed the manufacturer's guidelines and included verifying the functionality of visual stimuli, optical alignment, and response recording accuracy. Additionally, the evaluator underwent specific training in the operation of the COI-Sport Vision system and adhered to a standardized protocol throughout the study. This included providing uniform instructions for all participants and conducting practice trials prior to formal assessments to ensure familiarity with the procedures. These steps minimized variability and ensured consistency in the measurements across all participants. Data collection was conducted mid-season to capture the athletes' visual and oculomotor skills during active competition, providing a realistic representation of their abilities under typical conditions. To minimize the potential influence of fatigue from training or matches, testing sessions were scheduled on rest days, ensuring that participants were not recovering from recent physical exertion. Additionally, participants were asked to confirm that they had not engaged in any strenuous physical activity within the 24 h preceding the assessments. This self-reported confirmation was supplemented by scheduling all testing sessions during mornings or early afternoons, times when cognitive and motor performance are typically optimal. To ensure consistency and minimize potential order effects, the sequence of tests was randomized for each participant. Additionally, practice trials were conducted for each test prior to the data collection to ensure participants were familiar with the procedures and equipment. All assessments were conducted in a dedicated testing room with consistent lighting and minimal distractions. The temperature and noise levels were monitored to maintain optimal conditions for performance. The full battery of tests, including breaks and practice trials, took approximately 45–60 min per participant. Participants were encouraged to report any discomfort or fatigue during the session, and additional breaks were provided as needed to ensure the quality of their performance.

2.3.2. Visual and Oculomotor Assessments

The assessment included the following tests:

Static Visual Acuity: This measures the ability to distinguish the details of a static object. Participants were assessed at a distance of 6 m with 100% contrast using the Tumbling E test.

Dynamic Visual Acuity: This evaluates the smallest identifiable size of a moving object, simulating scenarios where athletes must track fast-moving objects during gameplay. Participants were tested with optotypes of letters in motion at a consistent angular speed of 32 rpm, using the Wayne Rotator Robot. They stood at a distance of 6 m and read aloud specified lines on the rotating panel. The angular speed was chosen to replicate real-world dynamics, such as following a ball in sports like tennis or basketball. To ensure reliability, each participant completed two trials, and the best performance was recorded.

Contrast Sensitivity: This measures the ability to differentiate an object from its background. The "Luminosity Contrast Sensitivity Function Test" was used, where participants stood 3 m from the screen and identified the orientation of grating patterns with varying contrasts (4–0.10%) and spatial frequencies (1.5/3/6/12/18 cycles/degree).

Vergence: This assesses the simultaneous rotational movement of both eyes to maintain fixation on a target. Using red/green filters, participants viewed a double target, and the software measured the separation and prismatic diopters corresponding to the blur, breakup, and recovery points.

Stereopsis: This test evaluates the ability to merge visual inputs from both eyes into a single three-dimensional image, a skill critical for depth perception and spatial awareness in sports. Using random dot patterns displayed on a calibrated monitor, the program determined the minimum stereoscopic disparity detectable in seconds of arc. Participants were seated 40 cm from the screen and wore polarized glasses to view the stereograms. The test included a series of progressively finer disparities, and participants indicated the orientation or pattern they perceived.

Fixation Disparity: Participants aligned a red cross with a green arrow vertically and horizontally to measure horizontal and vertical disparity. Red/green filters were used, with the red filter placed over the dominant eye. Measurements were recorded in minutes of arc.

Visual Memory: Using the tic-tac-toe test, participants viewed a grid of nine spaces for 0.1 s. Five spaces were occupied by symbols, and participants had to recall and mark the correct locations as quickly as possible.

Identification: This test required participants to identify and touch a moving red ball on the screen while being distracted by other moving balls of various colors. Their accuracy was analyzed by sectors, and response times were recorded.

Anticipation Time: Participants predicted when a moving red ball would pass through a specified rectangular area on the screen. Accuracy and reaction times were measured, with tests performed using the dominant hand.

Peripheral Awareness: Participants detected peripheral icons displayed briefly (0.1 s) alongside a central letter. Accuracy percentages and mean response times were recorded.

Hand-Eye Coordination: Participants responded to sequentially displayed directional arrows on a screen, touching each arrow before its direction changed. Correct responses and execution times were recorded.

Additionally, participants completed a questionnaire (Supplementary Material) divided into three sections: demographic information, systemic and ocular history, and sports practice.

2.4. Statistical Analysis

Descriptive statistics were applied to summarize the quantitative variables. Depending on their distribution, determined using the Kolmogorov–Smirnov test, the variables were described using the arithmetic mean $\pm$ standard deviation (SD) for normally distributed data or the median and interquartile range (IQR) for non-normally distributed data. To assess associations between visual skill profiles and self-perceived performance categories, Kruskal–Wallis and U-Mann–Whitney tests were employed. To assess potential confounding effects of age, gender, and athletic experience on visual memory and anticipation tasks, the analysis revealed no statistically significant differences based on these factors across the various tests performed ($p > 0.05$).

All statistical analyses were performed using SPSS version 25.0 software (SPSS Inc., Chicago, IL, USA). A significance level of 5% ($p < 0.05$) was set for all tests to determine statistical significance.

3. Results

The sample consisted of 52 individuals aged 18 to 37 years (mean ± SD: 22.7 ± 4.1; median: 21). Regarding gender distribution, 65.4% (n = 34) were male, and 34.6% (n = 18) were female. Among the participants, 11.5% (n = 6) reported having experienced a concussion, and 38.5% (n = 20) had suffered a sports-related injury in the past year. The average training duration per session was 1.6 ± 0.9 h. Regarding ocular symptoms, 19.2% (n = 10) reported experiencing intermittent blurred vision, 9.6% (n = 5) complained of red eyes, 15.4% (n = 8) suffered from watery or itchy eyes, 17.3% (n = 9) experienced eye fatigue, 30.8% (n = 16) reported headaches, and 3.8% (n = 2) reported nausea associated with visual tasks. Additionally, 7.7% (n = 4) stated they observed flashes or halos around lights, 1.9% (n = 1) experienced double vision when focusing on objects both near and far, 15.4% (n = 8) noted the need to squint or close one eye, and 34.6% (n = 18) reported a sensitivity to light, lighting, or glare. In terms of their sports training, 38.4% (n = 20) reported that glare negatively affected their performance, 17.3% (n = 9) faced difficulties when it was excessively bright, 7.7% (n = 4) reported challenges training in foggy conditions, and 19.2% (n = 10) struggled when training in darkness. Additionally, 15.4% (n = 8) indicated that they performed better at night, 59.6% (n = 31) preferred daytime performance, and 25% (n = 13) stated that the time of day did not affect their performance. Table 1 presents the percentages of "yes" or "no" responses to the questions included in the training questionnaire.

Table 1. Responses provided by participants regarding their training and performance.

	Yes	**No**
Are you affiliated with a sports federation?	18 (34.6%)	34 (65.4%)
Do you do any visual warm-up exercises?	2 (3.8%)	50 (96.2%)
Do you have any problems with balance?	1 (1.9%)	51 (98.1%)
Is your overall sports performance as consistent as you would like it to be?	26 (50.0%)	26 (50.0%)
Is your level of sporting performance consistent throughout the game?	29 (55.8%)	23 (44.2%)
Does your performance decrease when you are under pressure?	18 (34.6%)	34 (65.4%)
Does your performance increase when you are under pressure?	33 (63.5%)	19 (36.5%)
Does your performance vary when you train indoors rather than outdoors?	17 (32.7%)	35 (67.3%)
Does your performance decrease when there are shadows on the playing field?	8(15.4%)	44 (84.6%)

Visual Assessment

The mean static binocular visual acuity, measured using the decimal scale, was 1.2 ± 0.1 (median [IQR]: 1.3 [0.06]), while the mean dynamic binocular visual acuity was 0.9 ± 0.2 (median [IQR]: 0.9 [0.10]). Regarding the percentage of visually resolved targets, the right eye achieved 76.2 ± 21.9% (median [IQR]: 80 [20]%), the left eye achieved 68.9 ± 32.9% (median [IQR]: 80 [50]%), and both eyes together achieved 90.4 ± 13.7%

(median [IQR]: 100 [20]%). Figure 1 illustrates the monocular static and dynamic visual acuity values.

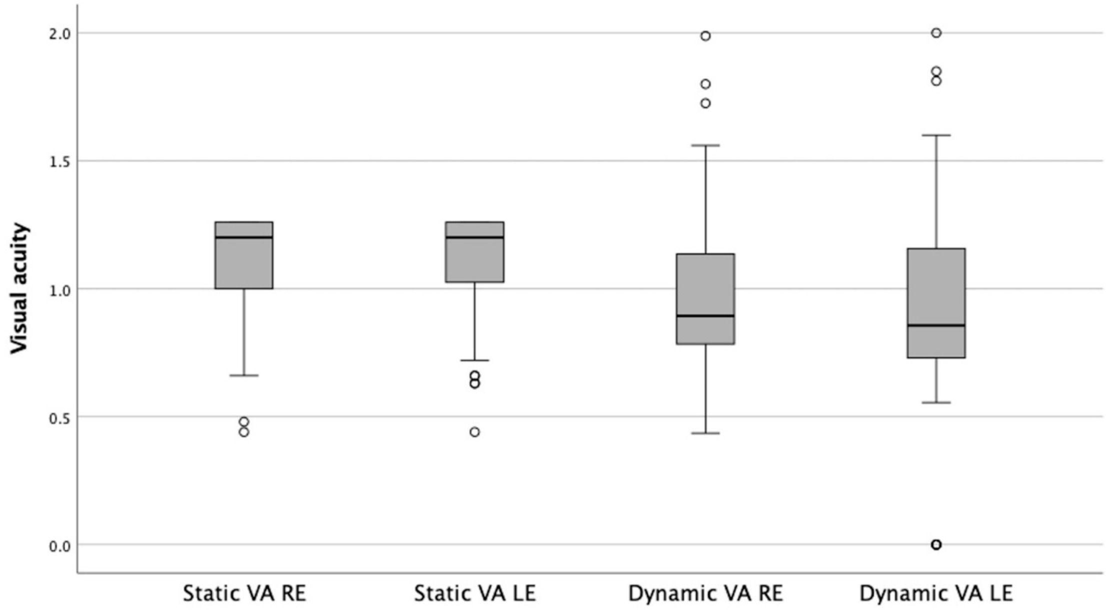

Figure 1. Monocular static and dynamic visual acuity. Box = 1 standard deviation, line = median, whiskers = confidence interval (95%), o = outlier, VA = visual acuity, RE = right eye, LE = left eye.

Table 2 presents the contrast sensitivity values for both monocular and binocular vision across spatial frequencies of 1.5, 3, 6, 12, and 18 cycles per degree (cpd). Contrast sensitivity, a critical measure of the visual system's ability to discern objects against varying background contrasts, was assessed using standardized testing protocols. The results highlight distinct variations in sensitivity across spatial frequencies, reflecting the participants' ability to detect finer details as the spatial frequency increased. Monocular performance for both the right and left eyes demonstrated a comparable sensitivity across all frequencies, with slight variations likely attributed to individual differences. Binocular contrast sensitivity, as expected, outperformed monocular measures at each frequency, underscoring the benefits of binocular summation in enhancing visual perception.

The mean fixation disparity for binocular status was -0.004 ± 0.088 (median [IQR]: -0.128 [0.12]) minutes of arc. The mean value for base-out horizontal fusional vergence was 2.1 ± 2.6 (median [IQR]: 1.4 [0.75]) minutes of arc at the breaking point and 0.9 ± 1.9 (median [IQR]: 0.6 [0.4]) minutes of arc at the recovery point. Similarly, the base-in horizontal vergence measured 1.5 ± 0.6 (median [IQR]: 1.4 [0.8]) minutes of arc at the breakpoint and 0.7 ± 0.4 (median [IQR]: 0.6 [0.5]) minutes of arc at the recovery point. The mean stereopsis value was 67.18 ± 43.6 (median [IQR]: 40 [40]) seconds of arc.

Table 3 summarizes key results for visual memory, identification, anticipation time, peripheral awareness, and hand-eye coordination. Players who reported satisfaction with their performance on the playing field (n = 26) demonstrated significantly faster response times in both visual memory (satisfied: 1.38 ± 0.27 s; not satisfied: 1.63 ± 0.42 s; $p = 0.039$) and anticipation time (satisfied: 0.11 ± 0.20 s; not satisfied: 0.16 ± 0.20 s; $p = 0.022$) compared to those who were not satisfied with their performance (n = 26). These results suggest a positive relationship between self-perceived performance satisfaction and faster response speeds. In the identification test, participants who reported no variation in their performance based on the playing conditions (indoors vs. outdoors) achieved a higher percentage of visually resolved targets (no variation: 93.02 ± 4.49%; n = 35) than those who indicated variability (variation: 88.86 ± 6.4%; n = 17; $p = 0.004$). In Table 4, statistically significant differences in visual parameters based on evaluated categories are presented. No statistically significant differences ($p > 0.05$) were found in the other visual tests, indicating consistency across these measures regardless of self-reported satisfaction or environmental conditions.

Table 2. Contrast sensitivity results at different spatial frequencies.

	Right Eye (100/Contrast Threshold)	Left Eye (100/Contrast Threshold)	Binocular (100/Contrast Threshold)
1.5 cpd			
Mean ± SD	99.1 ± 40.6	116.0 ± 43.0	133.9 ± 32.2
Median [IQR]	103 [0]	150 [47]	150 [47]
3 cpd			
Mean ± SD	174.4 ± 69.1	184.6 ± 63.6	197.1 ± 44.2
Median [IQR]	210 [0]	210 [0]	210 [0]
6 cpd			
Mean ± SD	182.3 ± 96.7	199.9 ± 89.5	230.4 ± 54.5
Median [IQR]	250 [144]	250 [63]	250 [0]
12 cpd			
Mean ± SD	103.6 ± 63.4	105.2 ± 60.1	118.5 ± 55.6
Median [IQR]	150 [111]	150 [111]	150 [89]
18 cpd			
Mean ± SD	42.6 ± 35.4	45.9 ± 33.1	50.0 ± 39.4
Median [IQR]	50 [43]	50 [43]	50 [93]

SD: standard deviation; IQR: interquartile range.

Table 3. Results of the visual skills.

	n	Mean ± SD	Median [IQR]	CI
Visual memory:				
Correct answers (%)	52	97.2 ± 5.2	100 [6.7]	95.6–98.5
Average time (s)		1.5 ± 0.4	1.5 [0.4]	1.4–1.6
Identification:				
Correct answers (%)	51	91.7 ± 5.4	93.6 [5]	90.2–93.2
Average time (s)		545.6 ± 123.5	557.8 [87]	510.9–580.4
Anticipation time:				
Correct answers (%)	52	20.6 ± 17.3	20 [20]	15.8–25.4
Average time (s)		0.006 ± 0.005	0.008 [0.006]	0.005–0.008
Peripheral awareness:				
Correct answers (%)	48	52.7 ± 14.1	50 [18.7]	48.6–56.8
Average time (s)		1.4 ± 0.3	1.3 [0.4]	1.3–1.5
Correct answers, right side (%)		55.2 ± 25.8	50 [33.3]	47.7–62.7
Correct answers, left side (%)		48.6 ± 20.3	50 [33.3]	42.7–54.5
Hand-eye coordination:				
Correct answers (%)	52	81.8 ± 20.8	88 [27]	76.0–87.6
Average time (s)		0.6 ± 0.1	0.6 [0.10]	0.5–0.6

n = sample size; SD: standard deviation; IQR: interquartile range; CI: confidence interval; s: seconds.

Table 4. The visual skill profiles of federated athletes and their relationships with self-perceived performance.

Question	Visual Parameter	Group	Median	IQR	*p* Value
Do you perform any visual warm-up exercises?	Peripheral Awareness—Average Time (s)	Yes	0.9	-	0.004
		No	1.4	0.4	

Table 4. *Cont.*

Question	Visual Parameter	Group	Median	IQR	p Value
Is your overall sports performance as consistent as you would like?	Contrast Sensitivity (6 cpd-Binocular)	Yes	250.0	0.0	0.044
		No	250.0	32.0	
	Contrast Sensitivity (12 cpd-Binocular)	Yes	150.0	0.0	0.01
		No	150.0	111.0	
	Visual Memory—Average Time (s)	Yes	1.4	0.47	0.039
		No	1.5	0.53	
	Anticipation Time—Average Time (s)	Yes	0.0	0.0	0.022
		No	0.1	0.1	
Is your level of sporting performance consistent throughout the game?	Monocular Static VA (RE)	Yes	1.3	0.0	0.025
		No	1.1	0.4	
Does your performance decrease under pressure?	Contrast Sensitivity (6 cpd-Binocular)	Yes	250.0	0.0	0.043
		No	250.0	0.0	
	Vergence Break Base-in	Yes	1.2	0.4	0.004
		No	1.5	0.9	
Does your performance increase under pressure?	Dynamic Binocular VA	Yes	0.8	0.2	0.025
		No	0.8	0.0	
Does your performance vary when playing indoors compared to outdoors?	Binocular Static VA	Yes	1.2	0.2	0.016
		No	1.3	0.0	
	Contrast Sensitivity (6 cpd-Binocular)	Yes	250.0	124.0	0.018
		No	250.0	0.0	
	Vergence Break Base-in	Yes	1.6	0.8	0.005
		No	1.3	0.4	
	Identification Correct answers (%)	Yes	89.4	8.2	0.004
		No	93.7	3.7	
Does your performance decrease when there are shadows on the field?	Disparity	Yes	−0.1	0.1	0.04
		No	−0.0	0.1	
	Vergence Recovery Base-out	Yes	0.4	0.2	0.006
		No	0.7	0.4	

4. Discussion

In this study, we conducted a comprehensive descriptive analysis of visual and oculomotor skills in federated university athletes, focusing on basic visual functions (visual acuity, stereopsis, vergence, and contrast sensitivity), oculomotor skills (dynamic visual acuity, identification, anticipation time, peripheral awareness, and hand-eye coordination), and inspection time (visual memory). The findings provide valuable insights into the visual and oculomotor abilities that underpin sports performance, contributing to a deeper understanding of how these skills vary among athletes. This aligns with the special issue's focus on innovative approaches to training, performance, coaching, and health in sports science.

The objective of the study was to examine the visual skill profiles of federated athletes and explore their relationship with self-perceived performance. The results reflect patterns in the visual and oculomotor abilities of this specific cohort, particularly in parameters such as dynamic visual acuity, anticipation, and visual memory. However, it is important to clarify that no direct comparisons were made between federated university athletes and general or non-athlete populations; therefore, such extrapolations cannot be drawn from the presented data. Instead, our findings should be interpreted as a descriptive analysis focusing on this specific athletic cohort.

Additionally, variations in self-perceived satisfaction with performance were linked to faster visual memory and anticipation times. This suggests a possible relationship between certain visual skills and athletic success, although further research with longitudinal designs and validated tools is necessary to establish stronger causal relationships.

The findings of our study underscore the pivotal role of visual skills in sports performance, corroborating previous research on the subject. Jorge et al. [26] similarly highlighted the importance of dynamic visual acuity in goalkeepers, emphasizing its relevance in high-speed decision-making and execution during gameplay. Our results further suggest that sports requiring constant attention to moving objects, such as football, handball, rugby, and tennis, place significant demands on athletes' dynamic visual acuity. These findings align with the idea that dynamic visual acuity is a key performance indicator for interceptive sports, where tracking and responding to rapidly changing stimuli is critical.

Additionally, cricketers and baseball players, who depend heavily on dynamic visual acuity for tasks such as predicting ball trajectories and timing interceptions, exhibited superior performance levels. This reinforces the necessity of sport-specific visual training programs designed to enhance dynamic visual acuity and other related skills [24,29]. Such programs could target not only the refinement of tracking and anticipation abilities but also the development of complementary visual functions like contrast sensitivity and stereopsis, which are essential for depth perception and object recognition in varying conditions. However, our results cannot be used to confirm the efficacy of visual training programs, as these evaluations were not conducted within the scope of this study. Normative data for stereopsis indicate values around 100–200 arc s for the general population [28] and approximately 40–60 arc s for athletes in sports requiring high spatial precision, such as basketball and volleyball. In this study, participants recorded a mean stereopsis value of 67 $\pm$ 44 arc s, closely approaching values typically associated with high-performance athletes, especially in sports with dynamic visual demands.

High levels of stereopsis were found to be associated with an enhanced perception of stimuli in sports such as basketball, volleyball, and hockey [30]. These sports require rapid and precise three-dimensional spatial awareness to judge distances, predict object trajectories, and make split-second decisions during dynamic gameplay. Conversely, sports like golf, which involve stationary targets and less reliance on depth perception during active play, demonstrated lower stereopsis levels, reflecting the differing visual demands across sports disciplines [14,31]. These findings highlight the importance of tailoring visual training interventions to address the unique visual skill requirements of specific sports. By focusing on enhancing stereopsis in athletes where depth perception is critical, such interventions could improve overall performance and decision-making accuracy.

In our study, fixation disparity values were lower than those reported by Nascimento et al. [32] for both athlete and control groups. This discrepancy may stem from the differences in participant age, as younger athletes often exhibit better ocular alignment and binocular coordination. Additionally, variations in the reliability and repeatability of the evaluation methods used across studies may contribute to the observed differences. These findings underline the necessity of adopting standardized and consistent methodologies for assessing visual skills to facilitate meaningful comparisons between different populations and ensure accurate evaluations. The results further reinforce the importance of integrating customized visual assessments and training programs into sports science to optimize specific visual and oculomotor skills. By addressing these unique visual demands, sports professionals can enhance athletes' capabilities, ultimately bridging performance gaps between elite and non-elite players while fostering overall athletic development.

Specifically, hand-eye coordination response times for the general population average around 0.8 ± 0.2 s, while elite athletes often achieve times of 0.5 ± 0.1 s in dynamic sports like rugby and tennis [33]. The athletes in this study achieved a mean response time of 0.6 ± 0.1 s, placing them closer to elite performance levels, and being significantly faster than non-athletes.

The descriptive analysis presented in this study provides valuable baseline data for future research on visual skills in athletes, laying the groundwork for the further exploration of sport-specific visual demands. The findings emphasize the necessity of developing tailored visual training programs to address the unique requirements of each sport, optimizing athletes' abilities to perform under varying conditions. Furthermore, the study highlights the critical role of intrinsic motivation in influencing athletic performance. Insights into this relationship can inform coaching strategies aimed at enhancing both athlete satisfaction and performance outcomes. These results underscore the importance of integrating advanced technologies and individualized training programs to optimize visual and oculomotor skills, aligning seamlessly with the special issue's focus on innovative trends in sports science.

A notable strength of this study is its comprehensive assessment of a wide range of visual and oculomotor skills, facilitated by the use of standardized and reliable tests. The application of the digital COI-Sport Vision system ensured precise and consistent measurements, bolstering the validity of the findings. Moreover, the study's focus on federated university athletes offers novel insights into a specific population that has not been extensively studied, bridging a gap in the existing literature. However, the profile of this population lies between that of high-performance athletes and non-athletes, offering a degree of interest, albeit with limitations. No sample power calculation was conducted, which restricts the potential conclusions that can be drawn from the results. On the other hand, the sample size was relatively small and consisted exclusively of athletes from a single university, which may limit the generalizability of the findings to broader athletic populations. Furthermore, the cross-sectional design provides a snapshot of visual and oculomotor skills at a specific point in time, making it unsuitable for establishing causal relationships. The lack of longitudinal data also prevents an analysis of how visual skills evolve over time or how they may be influenced by consistent training and competition. Additionally, while logMAR charts are widely accepted as the standard for visual acuity assessment, this study employed the Tumbling E test due to its integration within the COI-Sport Vision system. This method ensured consistency across all evaluations and was well suited to the sports-focused context of the study, although future research could consider incorporating logMAR charts for broader comparability with clinical research. Finally, the psychological assessment used in this study was not a validated questionnaire, which limits the reliability of the self-reported data on performance perception. Future studies should consider using standardized and validated instruments to better explore the relationship between intrinsic motivation and athletic performance. These limitations highlight the need for cautious interpretation of the results and underline the importance of addressing these gaps in future research.

To strengthen the evidence base, future studies should replicate this research with larger and more diverse samples, including athletes from various universities, sports disciplines, and levels of expertise. Expanding the sample size and diversity would enhance the generalizability and applicability of the findings. The decision to focus on federated athletes was based on their unique characteristics as a population. Federated athletes are typically engaged in structured training routines and regular competitive events, which place significant demands on their visual and oculomotor skills. These factors make them an ideal group for studying the relationship between these skills and athletic performance. Additionally, the controlled nature of their training and competition schedules reduces variability in the dataset, allowing for a more precise analysis of their visual abilities. However, this focus also introduces limitations regarding the generalizability of the findings to non-federated or recreational athletes. Future studies should consider including broader populations to provide a more comprehensive understanding of visual demands in sports across different levels of expertise. Additionally, longitudinal studies are essential to investigate how visual and oculomotor skills develop over time, particularly in response to targeted training programs. Exploring the long-term effects of visual training interventions on performance outcomes would provide more definitive insights into their efficacy. Future research should include longitudinal studies to track the development of visual and oculomotor skills over time and their evolution in response to targeted training programs. Such designs would provide critical insights into the long-term impact of visual training on performance outcomes. Furthermore, exploring alternative training modalities, such as virtual reality-based interventions or sport-specific drills, could help identify the most effective strategies for enhancing visual skills across different athletic contexts and disciplines. Incorporating a broader range of psychological assessments, including validated instruments, would further enrich the understanding of the relationship between intrinsic motivation and visual performance. Future studies should also evaluate how demographic and experience-related variables, such as age, gender, and years of competition, influence the interaction between visual skills and self-perceived performance. Additionally, interdisciplinary research combining sports science, psychology, and technology could foster the development of more comprehensive training protocols that address both physiological and cognitive demands. A key limitation of this study is its focus on federated athletes, a population with structured training routines and competitive schedules. While this provides valuable insights into a high-performance group, it limits the generalizability of the findings to non-federated or recreational athletes, whose training environments and visual demands may differ significantly. Future studies should explore these populations to assess how variability in training frequency, intensity, and exposure to competition affects visual skills. Additionally, the cross-sectional design of this study restricts the ability to infer causal relationships. Longitudinal studies are needed to track the progression of visual skills over time and evaluate the effectiveness of targeted interventions. Expanding the sample to include diverse athletic groups would also help determine whether findings in federated athletes are representative of broader populations or unique to this specific group. Future research should also assess the impact of different training modalities tailored to specific sports, as this could yield valuable information on optimizing visual skills for various athletic contexts. Incorporating psychological assessments would further enrich the analysis by examining the interplay between intrinsic motivation, visual skills, and overall performance, offering a more holistic understanding of athlete development.

Practical Applications

The findings of this study have several practical applications that can benefit both athletes and sports professionals. Firstly, the development of sport-specific visual training programs can directly enhance key skills such as dynamic visual acuity, stereopsis, and hand-eye coordination, which are critical for athletic performance. Coaches and trainers can use these insights to design individualized training regimens that target the specific visual demands of different sports. Additionally, integrating advanced technologies like the COI-Sport Vision system into regular training routines can provide precise and real-time feedback, enabling athletes to monitor and improve their visual performance systematically.

Psychological assessments could also be incorporated into training to address the motivational and psychological factors that influence performance. These combined approaches would help athletes not only refine their visual skills but also enhance their overall readiness and adaptability in competitive environments. Lastly, sports organizations and universities could adopt these training programs to foster a more scientific and comprehensive approach to athlete development, maximizing both performance and injury prevention.

5. Conclusions

This study provides a descriptive analysis of the visual and oculomotor skills of federated university athletes, emphasizing their potential relevance to sports performance. The findings highlight patterns in dynamic visual acuity, stereopsis, hand-eye coordination, and anticipation skills within this cohort. Additionally, faster response times and better visual memory were associated with higher self-perceived performance satisfaction, suggesting potential links between these visual skills and athletic outcomes.

While the study offers valuable insights, it is important to acknowledge its limitations. The small, homogeneous sample and cross-sectional design restrict the generalizability of the findings and preclude causal inferences. Furthermore, the psychological assessment tool used was not validated, which limits the reliability of the self-reported data on performance perception. Future studies should address these limitations by incorporating larger, more diverse samples, longitudinal designs, and validated assessment instruments to better understand the interaction between visual skills, intrinsic motivation, and athletic performance.

The findings emphasize the need for the systematic evaluation of visual and oculomotor skills in athletes as a foundation for developing targeted training programs. While practical implications for training and performance optimization are promising, these should be interpreted cautiously within the study's context and limitations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app15010418/s1, Questionnaire S1: Sports Vision Questionnaire.

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