Performance in sport

Influence of physical fatigue on visual variables and skills in athletes and non-athletes

Influencia de la fatiga física en variables y habilidades visuales en deportistas y no deportistas

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ABSTRACT
The objective is to contrast the possible effects of visual fatigue on visual skills on athletes and non-athletes. Visual data have been collected from a population between 18 and 44 years of age before and after exercise. The measurements have been taken with Visiotest, Rotary disc for AVD taking, Blazepod reaction lights, Binovi reaction panel, ±2D flipper, Thoringthon test. A total of 34 subjects were selected, of which 17 were athletes and another 17 were non-athletes. After all the tests, the results were statistically studied with non-parametric tests. The results obtained reflected the evolution of the measurements throughout the phases of both groups, with which comparative tables between phases and subjects have been made.

The results have led us to the conclusion that physical exercise causes visual wear in aspects such as FL, causing a positive increase in values in athletes. However, it generates improvements in ADL and reaction speed, which are significantly greater in non-athlete subjects.

Keywords: dynamic visual acuity, binovi panel, blazepod lights, accommodative facility.

RESUMEN

El objetivo consiste en contrastar los posibles efectos de la fatiga visual en habilidades visuales sobre sujetos deportistas y no deportistas. Se han recopilado datos visuales a una población entre los 18 y 44 años antes y después de realizar ejercicio. La toma de medidas, se realizaron con Visiotest, Disco rotatorio para toma de AVD, Luces de reacción de Blazepod, Panel de reacción Binovi, Flipper de ±2D, test de Thoringthon. Se seleccionaron a 34 sujetos, los cuales 17 eran deportistas y otros 17 no eran deportistas. Tras la realización de todas las pruebas se han estudiado los resultados estadísticamente con pruebas no paramétricas. Los resultados obtenidos reflejaron la evolución de las medidas a lo largo de las fases de ambos grupos con los que se ha realizado tablas comparativas entre fases y sujetos.

Los resultados nos han llevado a la conclusión de que el ejercicio físico provoca un desgaste visual en aspectos como FL, provocando un aumento positivo de valores en sujetos deportistas. No obstante, genera mejoras en AVD y la velocidad de reacción siendo estas significativamente mayores en sujetos no deportistas.

Palabras clave: agudeza visual dinámica, panel de binovi, luces de blazepod, flexibilidad acomodativa.

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INTRODUCTION

Background on Visual Fatigue, Visual Skills and Physical Exercise

Visual skills play a Core role in everyday activities as well as in high-performance environments such as sport. The ability to perceive and process visual information efficiently is crucial for tasks ranging from reading and navigation to making quick decisions in dynamic situations. These skills include visual acuity, phoria (eye alignment), visual reaction time and eye-hand coordination. Physical exercise places significant physiological and cognitive demands on the body, and the interaction of these demands with visual function is an area of growing scientific interest. Understanding how acute physical exercise influences these visual functions is essential. The existing scientific literature on the relationship between levels of physical activity (e.g., athletes versus sedentary individuals) and various aspects of visual performance presents often complex and nuanced findings. For example, the relationship between exercise and reaction time is not linear; while moderate-intensity exercise may improve performance, high-intensity or prolonged activity may lead to temporary impairment (Vaillancourt & Christou, 2013). This complexity underscores the need for careful analysis of how exercise intensity and duration, in relation to individual fitness level, may affect visual Skill.

We have conceived of the visual system in sport as a mere input tool, a passive spectator of physical action. We have focused on physical conditioning, leaving the visual system in the background, a sort of appendage to athletic performance. But what if this perspective is fundamentally flawed? What if the true frontier of athletic performance lies not only in the visual system, but also in the visual system? What if the true frontier of athletic performance lay not just in muscles, but in visual endurance under extreme pressure (Poltavski & Biberdorf, 2015)?

This approach becomes relevant in the light of findings such as those of Klostermann et al. (2015), who show that the "quiet eye" - a measure of attentional visual control - decreases significantly after high-intensity exercise, and this change explains about 33% of the loss of accuracy in aiming sports such as basketball. Furthermore, classic studies by Bard & Fleury (1978) show that after subjects were driven to metabolic exhaustion, no significant changes in some Core visual Abilities were observed, suggesting a complex interplay between metabolic demand and specific visual functions.

The dynamic interplay between sustained metabolic stress and adaptive visual function is systematically underexplored, especially under conditions of high demand. Ando (2013) reviewed how intense physical exertion impairs peripheral visual perception, attributing this to a decrease in cerebral oxygenation. This is evidence that vision under fatigue is not a mere decoration, but a potentially performance-limiting actor.

Finally, research such as Tokarz et al. (2022) indicates that visual (sensory) blindness during walking increases oxygen consumption by 19%, showing that vision directly contributes to metabolic efficiency by altering kinematic patterns. The dynamic interaction between sustained metabolic stress and adaptive visual function has been systematically under-explored, representing a critical gap in performance optimisation.

The current paradigm recognised that visual fatigue impairs crucial Skills such as decision-making and coordination, affecting athletes and non-athletes alike (Mon-López et al., 2020); (Mon-López et al., 2022). The response has been to look for technologies that assess and train these Abilities, such as the Blazepod lights (de Oliveira et al., 2012)), the VisioTest (Belicard & Leonhardt-Jambon, Le Visiotest. Dépistage sommaire des défauts visuels./1978) or the Binovi Panel (Daub et al., 2023; Polikanova et al., 2024). However, are we simply measuring the problem, or are we addressing the root of the solution? The emergence of platforms such as the Blazepod reaction lights, which allow accurate quantification of reaction time and visual agility under physical demand, along with the VisioTest and Binovi Panel, which provide detailed characterisation of phorias and accommodative flexibility, equips us with the unprecedented ability to break down the visual response into its fundamental components during induced fatigue.

Rationale and significance of the study

Despite increasing attention in sports optometry, there is a specific knowledge gap on the differential impact of physical exercise and possible associated visual fatigue in populations with different levels of physical activity, such as athletes and sedentary individuals. This study seeks to address this gap by providing a deeper understanding of how visual responses to physical fatigue may vary between these groups. The findings have important practical implications for optimising sports training regimens, developing visual rehabilitation strategies, informing public health recommendations on screen time and physical activity, and improving overall visual well-being. By identifying specific response patterns, this study contributes to a more personalised approach to the assessment and improvement of visual function.

The main objectives of this study were:

- To analyse the evolution of visual measures collected throughout the test in athletes and non-athletes separately.
- To make a comparison between both groups and identify if there is any difference due to physical condition.

This study challenges conventional thinking and proposes that physical fitness not only influences the body, but actively reshapes the resilience of the visual system. Our research seeks not only to quantify the impairment of Skills such as phorias, monocular accommodative flexibility, elective reaction time and eye-hand coordination under induced physical stress. We go one step further: Hypothesis: high intensity physical fatigue, far from being a mere obstacle, acts as a potent stressor that, in adapted athletes, reveals and strengthens the inherent resilience of their visual system, marking a Core distinction with non-athletes.

Through this comparative analysis, we sought to discern whether the physiological adaptation inherent to the sporting condition confers superior resilience to the visual system in the face of the debilitating effects of fatigue. The findings of this study will not only inform more sophisticated visual training strategies, but could lay the groundwork for early detection of susceptibility to visual fatigue in high-performance contexts, and even redefine the parameters for monitoring athlete physiological state through ocular metrics.

METHODOLOGY

Participants and Study Design

The study included a total of 34 subjects, who were categorised into two groups: athletes and non-athletes (sedentary). The study design was a within-subjects pre-post intervention design, followed by between-group comparisons. It is important to note that relevant demographic differences were observed between the groups, particularly in age, with a higher proportion of athletes older than 30 years compared to non-athletes, a factor that will be crucial in the interpretation of the results.

The 34 volunteers (men and women of various ethnicities) were students and/or employees of the Faculty of Optics and Optometry of the Complutense University of Madrid (UCM). The participants were between 18 and 44 years old. Prior to participation, each volunteer completed a questionnaire that included informed consent and detailed questions about their medical and visual health history (including visual compensation and possible abnormalities). While this information was collected for a complete characterisation of the sample and to understand any factors that might influence the results, it was not a direct exclusion criterion other than age.

We divided the participants into two equal groups of 17 subjects each: athletes and non-athletes. This classification was based on the International Physical Activity Questionnaire (IPAQ7), which measures weekly physical activity level in Metabolic Equivalents (METs). A MET is a unit that estimates the energy expenditure of various activities. We calculated the total METs for each participant from the weekly time spent walking, moderate and vigorous physical activity, using these equivalencies:

- Walking: 3.3 METs per minute.
- Moderate Physical Activity: 4.0 METs per minute.
- Vigorous Physical Activity: 8.0 METs per minute.

The classification criteria according to the IPAQ7 were:

Athletes: those who exceeded 2100 METs/week. This included subjects who performed, for example, at least 3 days/week of vigorous physical activity with a minimum of 1500 METs accumulated, or 3 or more days/week of vigorous physical activity for at least 20 minutes/day.

Non-sporters: those who had a total value of less than 2100 METs/week. This group included those who performed less than 3 days of vigorous physical activity; less than 5 days of moderate physical activity; or less than 5 days of any combination of walking, moderate or vigorous physical activity, accumulating a value below 2100 METs.

The study was approved by the ethics committee 24/117-E of the Hospital Clínico San Carlos and strictly followed the principles of the Declaration of Helsinki. All participants signed an informed consent form.

Visual and Physical Assessments Performed

A series of visual and physical assessments were performed to measure the impact of exercise. Measurements were taken before and after a physical exercise sequence that included three 5-minute runs, in the context of "moderate exercise".

Material

To carry out the measurements, we used the following instruments:

Visiotest: A device to assess various visual parameters such as visual acuity (VA) in far and near vision, stereoscopic vision (depth perception), phoria (latent ocular deviations) and colour vision (Photo 1).

Flipper with ±2.00 D lenses: Used in conjunction with a 40 cm near optotype card to measure accommodative flexibility (Photo 1).

Rotary disc: A circular disc with Snellen letter optotypes (equivalent to Static Visual Acuity between 0.5 and 1.0), used to measure Dynamic Visual Acuity (DVA) (Photo 1).

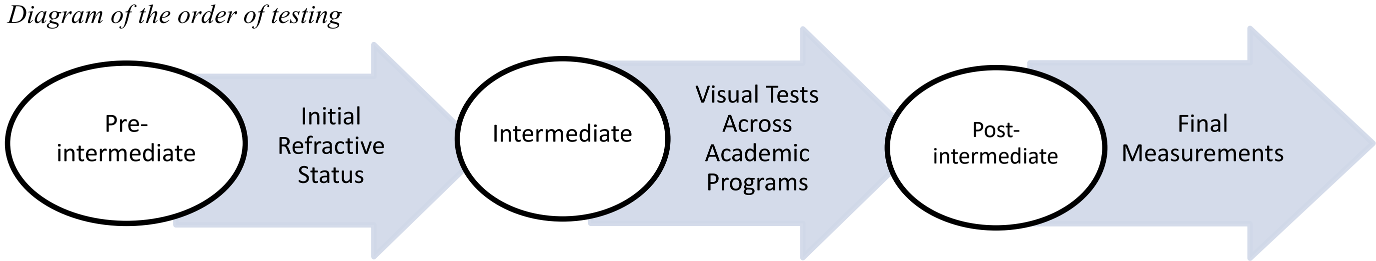
Binovi Reaction Panel: A board with LED lights designed to assess hand-eye coordination, reaction time and peripheral vision (Photo 1).

Blazepod reaction lights: Four touch-sensitive, flashing LED lights with variable intensity. They were used to measure reaction time and agility (Photo 1).

Method

The study was divided into three sequential phases: a Baseline Phase (initial assessments), an Intervention Phase (physical exercise) and a Post-Intervention Phase (final assessments). This design allowed us to observe whether there were changes in visual parameters as a result of exercise-induced fatigue.

Figure 1.
Diagram of the order of testing



Baseline Phase (Pre-Intervention)

Baseline assessments were conducted in the following order:

1. Visiotest (Far and Near Vision):
Monocular Visual Acuity (MVA): This was measured in both eyes separately, a requirement being a VA of 1.0 (20/20) or higher, identifying a minimum of three letters. Uncompensated astigmatism was also detected.
Binocular Visual Acuity (BVA) and Stereopsis: In Slide 3, BVA and depth perception ability were assessed. An integrated random dot test was used, and the stereopsis threshold was recorded in arcseconds.
Red-Green (Duochrome) test: Slide 4 allowed verification of refractive compensation: sharper vision in red indicated hyper-compensation, and in green, hypo-compensation.
Phoria: In Slide 5, latent deviation was assessed. The right eye saw a circle and the left eye saw a grid. The subject indicated the position of a cross in relation to a standardised Visiotest pattern (e.g., H-2 for orthophoria, A-G for exophoria, I-O for endophoria).
Colour Vision: Slide 6 consisted of an Ishihara-type test to assess colour perception.

2. Thorington Test Phoria: Horizontal phoria was measured at 40 cm using a horizontal Maddox lens and a torch. The subject, with one eye with the Maddox lens, indicated the position of a luminous line on the test. Orthophoria (line above the dot), exophoria (line to the left) or endophoria (line to the right) was recorded.

3. Accommodative Flexibility (AF): This was assessed monocularly with a ±2.00 D flipper. The accommodative response (indicating whether the subject failed with the positive or negative lens when attempting to clear text) and the number of cycles per minute (cpm) for 60 seconds were recorded.

4. Dynamic Visual Acuity (DVA) with Rotating Disc: The disc, located at 6 metres, displayed Snellen letter optotypes of different sizes. The subject began by reading optotypes equivalent to an AVE of 0.5 at a rotation speed of 50 rpm. If he failed to read, the speed was progressively reduced.

5. Binovi panel:
Random Mode: This was used to measure proactive reaction time (time from stimulus perception to response) for 60 seconds.
Exploratory Mode: This mode was used later in the intervention phase.
In both modes, "Hits" (correct responses) and "errors" were recorded. The panel was positioned at the subject's eye level.

6. Blazepod Reaction Lights: Four lights were placed equidistantly on a table (Photo 1, right). For 1 minute, one light was switched on randomly. The subject had to touch the light with one hand and turn the other hand to the centre. Hits and mean reaction time were recorded.

Photo 1.

Images of the materials used. From left to right: Visiotest, Flipper, Rotary disc, Binovi panel and Blazepod lights

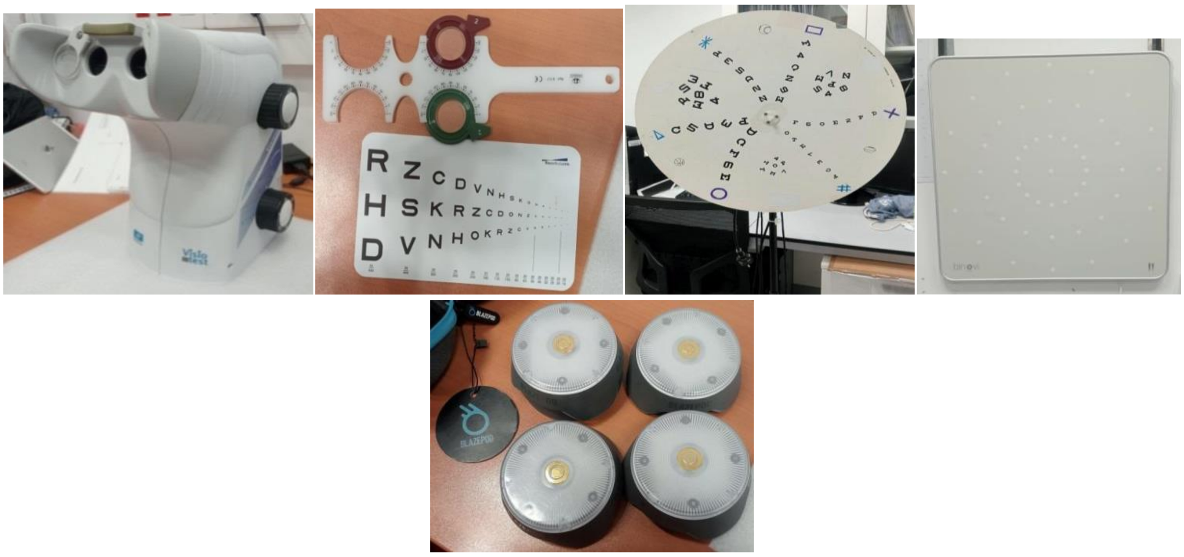


Photo 2.

Blazepod lights: 1st Placed on a table equidistant from each other (used in the pre and post phase). 2nd Placed in a zig-zag pattern on the ground about 6 m apart (used in the intermediate phase)

Intervention Phase

In this phase, the Blazepod lights were arranged in a zig-zag pattern on the ground, about 6 m apart (Photo 1, right). The subject was positioned in the centre before each set of exercise. This phase consisted of an intense physical exercise circuit, interspersed with visual assessments to measure the impact of fatigue.

The sequence was as follows:La secuencia fue la siguiente:

1. First Batch of Blazepod: For 5 minutes, lights were randomly turned on. The subject had to "turn them off" (touch them) by alternating one hand and one foot for each interaction, i.e., if he/she touched a light with the right hand, the next interaction could be with the left foot or the right foot, etc., varying the limb used to touch each light.

2. Post-Exercise Assessments (First Round):

Measurement of phoria with Visiotest in far and near vision.

Measurement of Monocular Accommodative Flexibility (FAM) with positive and negative lenses, verifying the ability to clear an optotype from 0.8 to 40 cm.

Use of the Binovi Panel in "exploratory mode" for 60 seconds. In this mode, the stimulus remained on for a specified time (regardless of whether it was pressed or not), and an error was counted if the subject did not press it in time. This mode assessed eye-hand coordination, reaction time and peripheral vision through the speed and accuracy of responses to stimuli at different locations on the panel.

3. Second Blazepod Run: Repetition of the Blazepod zig-zag run with the Blazepod lights for a further 5 minutes.

Post-Exercise Assessments (Second Run):
Repetition of FAM measurement.
Repetition of the exploratory test with Binovi.
Measurement of phoria with Visiotest in far and near vision.

4. Third Blazepod Run: Repetition of the run with the Blazepod lights in zig-zag for a third time, for another 5 minutes.

Post-Intervention Phase (Final Assessment)

This phase was performed immediately after the third run and followed this order:

1. Visiotest (Phoria in VL and VP): three phoria measurements were performed.
2. Monocular Accommodative Flexibility (FAM): The ability to clear text with both lenses (positive and negative) was checked, starting with the positive lens.
3. Dynamic Visual Acuity (DVA): Measured at maximum speed (50 rpm) with the rotating disc.
4. Binovi Panel: Used in "random mode" to measure reaction time.
5. Blazepod lights: These were again placed on the table (as in the Basal Phase) for a final reaction measurement.

The specific sequence of exercises and tests in different batches was designed to observe and quantify changes in visual parameters in the subject as exercise fatigue set in.

Statistical Analysis

Specific statistical tests were used for data analysis. The Friedman test, together with a post hoc analysis, was used to assess within-group changes in phoria measures. For within-group changes in ADL, the Wilcoxon signed-rank test was applied. For comparisons between the athlete and non-athlete groups, the Mann-Whitney U-test was used. The default statistical significance level for all tests was $p < 0,05$.

RESULTS

The results for each subject can be found in **Table 1**. First, we begin by analysing the table **of athletic subjects** at baseline.

Table 1.
Data on sports subjects

	AGE	BINOVI				AVD						BLAZEPOD LIGHTS	
		PRE	INT1	INT2	POST	AV PRE			AV POST			HITS	
						0,5	0,7	1	0,5	0,7	1	PRE	POS
n	Years	hpm				rpm						hpm	
17	28,82 ±7,61 (18 - 44)	60,59± 10,54	35,94 ±4,31	37,76 ±5,41	65,65 ±8,45	42,06± 12,55	42,18± 11,91	28,94± 16,32	46,12± 12,19	41,41± 15,97	28,12± 21,82	90,29± 18,05	100,53 ±16,11

Most of them practise sporting activity and are even members of a club. In addition, they have good AVE at distance and near, reaching 1.2.

In the pre-phase, we found more orthophoric subjects for FL, while in FC we found more XF. As for FAM in AO, there are more subjects who do not fail with any lens. At each AVD level, there are the same number of subjects who reach 50 rpm. Regarding the BINOVI, the mean is 60.59±10.54. In the HITS of the Blazepod Lights, we have a mean of 90.29±18.05.

In the inter-phase after the 1st run, LF has a majority in orthophoria and in FC the subjects are mostly exophoric. As for FAM, there are still more subjects who do not fail in any sign. And the mean with the BINOVI panel is 35.94±4.31. After the 2nd run, we find more orthophorics in FL compared to FC who are more XF. Moreover, in FAM there are still more subjects who do not miss anything. Finally, in the values collected with the BINOVI, the mean is 37.76±5.41.

In the post phase after the 3rd run, in FL there are still more orthophoric subjects as in the previous phase. In FC, there are more subjects with XF but almost the same number of orthophoric subjects. On FAM, the number of subjects who do not fail with both lenses is still higher. In AVD, more subjects are able to read AV 0.5, and less and less are able to read AV 1. In BINOVI, the mean is 65.65±8.45. In the HITS of the Blazepod Lights, we have a mean of 100.53±16.11.

The Friedman test statistic allows us to detect significant differences between values collected from one phase and another. As for FL, we found a chi-square value (X2) of 12.4 and P=.029 suggesting a high difference between the phorias measurements performed and significant changes.

A post-hoc Durbin-Conover test was performed to determine in which phases these differences are found. 1st, between the measurement of FLP1 and FLP3.2 (between the measurements after the 1st run and the 2nd measurement of the 3rd run) with the lowest value of P=.002 (P<.05). 2nd, between the FL-FLP1 measurements (between the initial measurement and after the 1st run) and FL-FLP3.3 (between the initial measurement and the last measurement after the 3rd run) with a value of P=.005. Both results reflect the magnitude of the difference. On the other hand, in FC; we have obtained a value of Xi2=3.13 and p=0.681 in the Friedman test, the latter is greater than that of the FL. It shows that there is no significant change.

Next, we performed a paired-sample comparison statistic with the AVD, HITS values obtained with Blazepod and BINOVI. It is hypothesised that the final values (Measure 2) would be higher than the initial values (Measure 1). The test reveals that there is a greater change in frequencies recorded for VA of 0.5 with a value of P=.001 (P<.05) and the Wilcoxon W value is the lowest recorded. The latter indicates a large difference between the measurements, the ranges of the differences between the pairs are very disparate. The rest of the VAs show values greater than P=.005, indicating no significant differences. The p value, in relation to the results of the BINOVI panel, indicates P=.46 (P>.05) in the random configuration and P=.086 (P>.05) in the exploratory. This indicates that there is no difference between the phases. As for the Hits of lights recorded, the test reflects a large significant difference as the value of P=.001 (P<.05).

Table 2.
Statistical data in athletes. The Friedman, Durbin-Conover and Wilcoxon statistics are all found

FRIEDMAN				DURBIN-CONOVER (Comparison between pairs			WILCOXON (Paired samples)		
	X^2	gl	p		Statistic	p		Statistic	p
FL	12,4	5	,029	FL-FLP1 (INTER 1)	2,917	,005	PRE-LIGHTING HITS - POST-LIGHTING HITS	13,0	,001
FC	3,13	5	,681	FL-FLP3.1 (POST 1)	2,083	,040	AVD PRE (0.5) – AVD POST (0.5)	3,00[a]	,007
				FL-FLP3.2 (POST 2)	3,155	,002	AVD PRE (0.7) – AVD POST (0.7)	31,50[b]	,291
				FL-FLP3.3 (POST 3)	2,917	,005	AVD PRE (1.0) – AVD POST (1.0)	54,00[d]	,377
				FL-FLP2 (INTER 2)	2,500	,014	BINOVI PRE – BINOVI POST	40,5	,46
							BINOVI INTER 1 – BINOVI INTER 2	25,50[e]	,086

Secondly, we analysed **Table 3** of **non-athletes** at the beginning. Most of them do not practice any sport.

Table 3.
Data on non-athletes

	AGE	BINOVI				AVD						BLAZEPOD LIGHTS	
		PRE	INT 1	INT 2	POST	AV PRE			AV POST			HITS	
						,5	,7	1	,5	,7	1	PRE	POST
n	years	hpm				rpm						hpm	
17	24,06 ±3,58 (18-31)	60,35±13,36	38,59 ±6,35	38,94 ±6,16	68,71±10,31	45,94 ±12,0	43±13,67	37,53±16,09	49,65 ±1,46	49,65 ±1,46	38,18±17,02	83,59±28,37	101,52±15,74

In the pre phase, in the FL results there are more subjects with XF, compared to FC where there are more orthophoric subjects. In AVD, we have 6 subjects able to read AV 0.5 at 50 rpm, however, the rest of AV decreases in subjects at 50 rpm. As for BINOVI, the mean is 60.35±13.36 hpm. In the Blazepod HITS, we have a mean of 83.59±28.37 hpm.

In the inter phase after the 1st run, LF maintains the number of orthophoric subjects and XF. However, in FC there are more XF. In BINOVI, the mean is 38.59±6.35 hpm. After the 2nd run, we have in FL more subjects with XF, as in FC. As for BINOVI, the mean is 38.94±6.16 hpm.

In the post phase after the 3rd run, FL has more orthophoric subjects and FC has more subjects with XF. In addition, the AVD measures have the same number of subjects reading at 50 rpm as the AV of 0.5 and 0.7. In BINOVI, the mean is 68.71±10.31 bpm and in Blazepod HITS it is 101.53±15.74 bpm. The Friedman test statistic for FL does not show much difference overall with $p>0.005$. However, the post hoc reveals that at least one comparison between FLP1 and FLP3.1 is statistically significant, $p=0.009$. A similar situation is found in FC. The value of Xi2=7.06 and $p=0.216$ indicates overall stability of the data between each phase.

The Wilcoxon statistic indicates a value of $p<0.05$ in the differences in the frequencies for AVD (0.5) and AVD (0.7). However, for the AV unit, the frequencies are stable as $p=0.173$ ($p>0.05$). For the values collected with BINOVI, the test shows that there is a change between the initial and final phase, with a value of $p<0.001$. On the other hand, between the EXPL1 and EXPL2 values there is no big difference as the p-value=0.128 ($p>0.05$). Finally, the data collected with the Blazepod shows a difference as a p-value of $p<0.001$ has been determined. This shows a noticeable difference after the exercise.

Table 4.
Statistical data in non-athletes. All statistics are found: Friedman and Wilcoxon

FRIEDMAN				WILCOXON (Paired samples)		
	X^2	gl	p		Statistic	p
FL	8,96	5	,111	HITS LIGHTS PRE - HITS LIGHTS POS	1,00	<,001
FC	7,06	5	,216	AVD PRE (0,5) – AVD POS (0,5)	0,00[a]	,001
				AVD PRE (0,7) – AVD POS (0,7)	9,00[b]	,003
				AVD PRE (1) – AVD POS (1)	37,00[b]	,173
				BINOVI PRE – BINOVI POST	0,0	<,001
				BINOVI INT 1 – BINOVI INT 2	40,0[a]	,128

Table 1.
Mann-Whithney statistic. Comparison between athletes and non-athletes.

Independent Samples t-Test. Mann-Whitney U Test		
	Statistic	P
Mesures FL	95,0	,090
Mesures FC	127,5	,569
AVD PRE (0.5)	100,0	,108
AVD PRE (1.0)	93,5	,081
AVD POST (0.5)	119,0	,080
AVD POST (0.7)	101,0	,036
AVD POST (1.0)	102,0	,142
BINOVI PRE	132,5	,692
BINOVI POST	89,5	,060
BINOVI EXPL1	106,5	,195
BINOVI EXPL2	116,0	,330
HITS LIGHTS PRE	128,0	,581
HITS LIGHTS POST	142,0	,945
Note. H_a μ *Sportsman* $\neq$ μ*Non Sportsman*		

Statistically, we have found that there is a significant difference in both groups between before and after. We have obtained for athletes (P=.001) and for non-athletes (P<.001), an even smaller value, which reinforces the significance of the difference. As for the statistic in athletes, W=13 indicates that the differences are moderately large, but not excessively so. In non-athletes, the value of W=1 suggests larger differences within the data. Although in both groups the difference is significant, the W value is lower in sedentary people and suggests a greater impact of exercise. In both groups, reaction time decreases after exercise, which increases the number of hits collected. This difference is more noticeable in non-athletes.

DISCUSSION

The present study assessed the influence of exercise-induced visual fatigue on the visual skills of 34 subjects, divided into athletes and sedentary subjects, by means of statistical tests and comparative analyses. The objectives were: (1) to analyse the evolution of visual measures throughout a physical exertion test in both groups separately, and (2) to compare the responses between athletes and sedentary subjects to identify differences attributable to the level of physical fitness. The results reveal that the visual system responds dynamically to physiological stress, with significant differences between groups that challenge the notion that the visual system is a passive component of athletic performance.

Baseline visual characteristics

At the beginning of the study, all participants exhibited a static visual acuity (SVA) greater than 0.9 and accommodative flexibility (AF) within the normative ranges established by Scheiman & Wick (2020). This baseline homogeneity eliminates the possibility that pre-existing visual anomalies biased the results, allowing the observed changes to be attributed to physical exercise and induced fatigue. The uniformity in baseline measurements strengthens the internal validity of the study, ensuring that post-exercise differences reflect physiological responses to exertion rather than pre-existing individual variations.

Evolution of phorias under physical exertion

Phorias in athletes

In the group of athletes, the far phorias (FL) showed a significant change after exercise, according to Friedman's test ($p < 0.05$), with a shift towards higher values of exophoria between the first and the last run. This finding, corroborated by post hoc analysis, is consistent with Marini (Marini et al., 2025), who report a quadratic increase in phoria after combined aerobic-anaerobic exercise, followed by a decrease. This pattern could reflect a transient relaxation of fusional convergence in far vision due to effort-induced visual fatigue (Marini et al., 2025). In contrast, near phoria (FC) remained stable ($p > 0.05$), suggesting that visual stress primarily affects far vision in athletes, possibly due to an increased demand for binocular coordination under these conditions.

Phorias in sedentary people

In the sedentary group, measures of FL ($p = 0.111$) and HR ($p = 0.216$) showed no significant change (Friedman's test, $p > 0.05$), with more than 50% of subjects maintaining stability in both measures. This lack of variation suggests that the moderate exercise used in the study did not reach the threshold necessary to induce significant visual stress in less trained individuals. Alternatively, it could indicate a lower adaptive ability of the visual system in sedentary subjects to acute stress, in contrast to athletes, who exhibit more dynamic responses due to their regular training (Vera et al., 2020).

Intergroup comparison of phorias

Comparison between groups revealed a higher prevalence of exophoria in the pre-exercise phase in athletes compared to sedentary subjects, especially in far vision. In sedentary subjects, a transient increase in exophoria in near vision (NV) was observed after the first run, which decreased after the third run, with no evidence of overall improvement. This pattern could reflect a temporary adaptive response to visual stress in sedentary subjects, possibly influenced by factors such as prolonged screen use or uncorrected refractive problems such as myopia (Jorge et al., 2024). The increased baseline exophoria in athletes could be a functional adaptation to regular training or a random variation, which requires further research.

Summary of findings on phorias

Overall, 50% of participants showed a decrease in convergence in FL after exercise, with higher values of exophoria, while FC remained stable in both groups. These results confirm that physical exercise, even of moderate intensity, induces significant changes in distant heterophoria, especially in athletes (Marini et al., 2025). This finding challenges the perception of the visual system as a passive component, highlighting its dynamic response to physiological stress and its relevance to sport performance.

Dynamic visual acuity (DVA) performance

Pre-exercise DVA

At baseline, both groups exhibited comparable performance on all measures of DVA (0.5, 0.7 and 1.0), indicating a similar dynamic visual Ability prior to physical exertion. This baseline equivalence reinforces the validity of the post-exercise comparisons.

Changes in post-exercise ADLs

After moderate exercise, sedentary people showed a significant improvement in ADLs of 0.5 and 0.7 (Wilcoxon test, $p < 0.05$), slightly outperforming athletes on these measures. No differences were observed in ADLs of 1.0 ($p > 0.05$). This unexpected result, which contradicts the supposed visual superiority of the athletes (Yee et al., 2021), can be explained by several factors. First, a learning effect might have benefited the sedentary subjects, who, having less experience with dynamic visual tasks, had more room for improvement. Second, moderate exercise intensity may have optimised cognitive and visual activation in the sedentary, while the more trained athletes may have reached a performance ceiling or experienced mild fatigue (Reddy et al., 2020).

A critical factor is the age difference between groups. Sedentary, predominantly younger (<30 years), showed better performance in ADLs 0.7 post-exercise, consistent with literature indicating a decline in ADLs with age, especially after 30 years (Baroud et al., 2025). This decline is associated with changes in visual accommodation, more pronounced at near distances, which explains the advantage of sedentary people on this measure (Baroud et al., 2025).

Visual reaction time and eye-hand coordination

BINOVI panel (exploratory and random modes).

Intra-group analysis of the BINOVI panel showed no significant differences in the exploratory and random modes for athletes ($p > 0.05$). In sedentary individuals, a significant improvement was observed in the post-exercise random mode ($p< 0.05$), with faster proactive reaction times (MPOST = 68.71 vs. MPRE = 60.35). This improvement suggests that moderate exercise may optimise visual reactivity in less trained individuals, possibly due to greater cognitive activation (Reddy et al., 2014). In contrast, athletes did not show significant improvements, which could reflect a performance ceiling due to their previous training or mild fatigue after exercise (Coetzee & de Waal, 2022).

Performance in Blazepod lights

In the pre-exercise phase, athletes outperformed sedentary subjects in the number of HITS ($p < 0.05$). However, post-exercise, sedentary individuals achieved a slightly higher mean ($p< 0.001$, $W = 1$) compared to athletes ($p = 0.001$, $W = 13$), indicating a more pronounced change in sedentary individuals. This finding aligns with the hypothesis that moderate exercise acutely improves reaction time in less trained individuals, whereas in athletes it may induce relative fatigue, reducing HITS (Reddy et al., 2014). In contrast, Sántha et al. (2024) found no significant changes in visuomotor reaction following continuous exercise, suggesting that exercise intensity and context are key determinants.

Overall comparison between athletes and sedentary individuals

The Mann-Whitney U test revealed that, overall, there were no significant differences between athletes and sedentary subjects in most of the visual Skills assessed ($p> 0.05$), challenging the notion of a generalised visual superiority in athletes. The exception was AVD 0.7, where sedentary people outperformed post-exercise athletes, probably due to their younger mean age (Baroud et al., 2025). This result highlights age as a critical confounding variable and suggests that athletes' visual advantages may not be universal, depending on the specific tasks and assessment conditions.

In the exploratory mode of the BINOVI panel, athletes showed a slight advantage (MEXPL2 = 37.76 vs. 38.94 in sedentary individuals), but the p-value = 0.06 did not reach statistical significance, indicating a trend that could be confirmed with a larger sample size. The more marked improvement in sedentary individuals in random mode ($p < 0.05$) reinforces the idea that moderate exercise acutely benefits less trained individuals.

IMPLICATIONS AND LIMITATIONS

The results suggest that the visual system responds dynamically to physical exercise, with differential effects according to training level and age. The increased sensitivity of athletes to changes in far phoria and the improvement in ADLs and reaction times in sedentary individuals challenge the perception of the visual system as a passive component, supporting the hypothesis that visual endurance under stress is a key frontier in athletic performance. However, the design of a single moderate exercise session limits the generalisability of the findings. Future studies should incorporate longitudinal designs, control for age as a confounding variable and explore varying exercise intensities to determine critical thresholds of visual stress.

CONCLUSIONS

This study demonstrates that physical exercise induces significant changes in far phoria and dynamic visual performance, with differential responses between athletes and sedentary individuals. Age emerges as a determining factor in ADL, while the level of training modulates visual reactivity to effort. These findings underline the importance of considering the visual system as an active and trainable component of sport performance, opening new lines of research on visual optimisation in high-pressure contexts.

ABBREVIATIONS

APP: Application; AV: Visual Acuity; AVB: Binocular Visual Acuity; AVD: Dynamic Visual Acuity; AVE: Static Visual Acuity; AVM: Monocular Visual Acuity; EF: Endophoria; FA: Accommodative Flexibility; FAM: Accommodative Flexibility Monocular; FL: Far Foria; FC: Near Foria; HPM: Hits per minute; MOES: Extra-ocular Muscles; OD: Right Eye; OI: Left Eye; RPM: Revolutions per minute; XF: Exophoria; WSF: Wayne Saccadic Fixator.

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