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Research Article

Evaluation of Eye Health Parameters of Construction Industry Workers in Terms of Turkish Occupational Safety Standards

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ABSTRACT

In the construction industry, which is one of the sectors where occupational accidents occur most frequently, the evaluation of workers' eye health parameters is critical for occupational safety. This study aims to analyze the central visual acuity, color blindness, and peripheral visual field performance of construction workers in line with international occupational safety standards OSHA and HSE criteria. Within the scope of the study, Auto-Refractometer Test, Snellen Visual Acuity Test, Ishihara Color Blindness Test, and peripheral vision tests with Dynamic Tangent Screen were applied to 51 construction workers. According to the results, all participants met the lower threshold of 3/60 for central vision, while 78.4% met the OSHA required level of 20/40. The results of the one-sample t-test and single proportion test revealed that the workers' central vision levels were statistically and significantly higher than the reference value of 0.5. In the color blindness assessment, only one participant was found to be color blind and the overall sample met OSHA/HSE standards. However, in the peripheral vision tests, ANOVA and Tukey HSD analyses for three different stimuli sizes (5 mm, 10 mm, 20 mm) showed that the peripheral vision scores measured under 5 mm stimuli were significantly lower than the others. One-sample t-tests revealed that no group's mean peripheral vision score exceeded the OSHA limit of 85 degrees. These findings suggest that peripheral awareness is particularly inadequate under narrow stimuli conditions posing potential safety risks in the construction industry. The findings of the study suggest that eye health parameters should be systematically assessed in recruitment processes and provide an important recommendation for the inclusion of peripheral vision testing in occupational health procedures.

1. Introduction and Research Background

The construction industry has been facing serious challenges in ensuring worker health and safety for years. The complexity of construction projects, the need to work at heights, the use of heavy machinery, and working conditions that require intense physical effort make the sector a high-risk area in terms of occupational accidents. According to data from the Social Security Institution [1], a total of 1,753 workers in the construction industry lost their lives as a result of occupational accidents between 2018 and 2023. This means that almost every day a construction worker loses his/her life.

Research on the causes of accidents in the construction industry has tended to examine the root causes of occupational accidents in detail. These

studies show that occupational accidents are not only caused by technical or environmental factors, but also factors such as human behavior, lack of training and managerial negligence play an important role. Studies conducted by [2] revealed that one of the major causes of accidents on construction sites is the unsafe behavior of workers. According to the study, it was determined that workers exhibit faulty behaviors such as not wearing hard hats, not using fall prevention equipment, neglecting personal protective equipment, and not following safe working procedures due to lack of safety awareness. This situation shows that occupational accidents are largely caused by human errors and carelessness. [3] conducted a comprehensive investigation of 26 construction-related accidents in the UK offering detailed insights into the underlying causes and contributing factors. In the study, it was found that the main cause of the majority of occupational accidents was the unsafe actions of workers. Lack of adequate safety training, risky behavior under intense work pressure, indifference to safety precautions, and normalization of unsafe working conditions were evaluated as critical factors in the occurrence of accidents. As a result, it is not enough to take only technical measures to prevent occupational accidents in the construction sector, it is of great importance to increase the safety awareness of workers and to gain safe working habits.

The high rate of occupational accidents highlights the need to implement more effective standards and regulations in the field of occupational health and safety. Although occupational health and safety (OHS) regulations and technological developments are an important agenda item to prevent occupational accidents, the impact of these regulations is limited when there is not enough supervision and awareness raising in the field. In the literature, it is emphasized that workers' physical and mental health conditions have a significant impact on safety violations [4, 5]. For example, in a study conducted by [4], it was stated that unreported health problems of workers may lead to unsafe behaviors. In addition, it was stated that workers in high-risk areas such as the construction industry should have full physical and mental competencies [5].

In order to prevent occupational accidents, it is critical to determine the suitability of workers' health status for the job. [6] defined the construction industry as one of the "high-risk" business areas and emphasized that the health status of workers in this sector should be continuously monitored. The International Labor Organization stated that occupational accidents cause approximately 2.7 million deaths and 374 million injuries worldwide annually [6]. In this context, it is necessary to increase occupational health and safety trainings, raise awareness of employees and continuously monitor their health status [7].

The Occupational Health and Safety Law No 6331 dated 30.06.2012 came into force in Turkey to determine the health status of workers [8]. Article 15 of this law states that employees working in hazardous and very hazardous jobs cannot start work without a health report. Employees are obliged to obtain a medical report at the time of recruitment or job change. Eye examination has an important place among these health reports. In Turkey, visual acuity and color blindness tests are widely used, but the obligation of these tests is not determined by a legal regulation and is left to the discretion of doctors. However, these tests are mandatory in many countries. For example, the Health and Safety Executive (HSE) in the UK and the Occupational Safety and Health Administration (OSHA) in the US require vision tests with certain standards [9]. The HSE requires workers to have at least 3/60 visual acuity [10], while OSHA requires field workers to meet 20/40 visual acuity [11]. However, visual acuity and color blindness tests alone are not enough; the peripheral vision abilities of individuals working in high-risk occupations should also be assessed [9]. Peripheral vision is the ability to perceive the surrounding space while focusing the eyes on a fixed point. While the central vision of a healthy individual is about 5 degrees, the peripheral field of vision with two eyes is up to 100 degrees [12]. Peripheral vision is critical in high-risk workplaces such as the construction industry [13, 14].

The significance of central vision has been highlighted in many fields. Central vision plays a fundamental role in the perception of visual details, the recognition of objects, and the recognition of critical hazards. In this context, a simulator-based experimental study by [15] examined in detail the effects of central vision on driving safety. The researchers measured hazard perception performance by applying simulated central vision loss (e.g., central scotoma) to individuals of different age groups. The findings showed that impaired central vision, especially in older drivers, leads to delayed detection of hazards and, in some cases, complete misses. Furthermore, distractions (such as phone use) further exacerbate this negative effect. The study highlights the criticality of central vision for safe driving and highlights the importance of assessing this ability, especially in high-risk occupations (e.g., construction machinery operators) [15]. Similarly, a comprehensive literature review by [16] examined

eye-tracking studies in aviation to reveal pilots' visual attention strategies. The study demonstrates that pilots' task performance is largely dependent on information processing processes based on central vision. Because cockpit displays, external reference points, and warning systems are generally located in the center of the visual field during flight, any disruption in central vision can significantly reduce a pilot's situational awareness. [16] study demonstrates that central vision is essential not only for object perception but also for visual attention allocation and task management. These findings demonstrate that central vision should be evaluated not only in terms of health but also in the context of occupational safety. Especially in the construction industry, assessing the central vision of workers operating cranes, forklifts, and other heavy equipment is a crucial step that can contribute to accident prevention.

Color perception also plays a critical role in the accurate interpretation of environmental signals, warning systems, and safety signs in many occupations. This can pose a potential risk for individuals with color vision deficiency (CVD), particularly in sectors where occupational safety is a priority, such as construction, transportation, and industrial production. A study by [17] emphasized the need to re-evaluate color vision proficiency and testing methods across various occupational groups. The researchers noted that color perception is directly related to occupational safety, particularly in individuals working in the healthcare, transportation, defense, and construction sectors. The study indicated that, while employment can be maintained despite color blindness in some occupational groups, this should be supported by appropriate task analyses and task limitations [17]. Similarly, a field study conducted by [18] examined the prevalence of visual impairments such as color blindness and refractive errors among commercial vehicle drivers in India. The study found that 7.1% of drivers were color blind. These individuals reported difficulty correctly perceiving traffic lights, road signs, and color-coded warning systems. It was noted that this situation jeopardizes not only driving safety but also workplace safety. Researchers recommend that color blindness screening should be an integral part of the driver licensing process [18]. These studies demonstrate that color blindness should be considered not only as an individual visual impairment but also as a societal risk factor in the context of occupational safety. Given the widespread use of color-coded warning systems, particularly in the construction industry, it is crucial that employees undergo appropriate testing and job descriptions are tailored to their visual abilities. The impact of color blindness on visual attention and hazard perception should be re-evaluated from an employee health and safety perspective.

The importance of peripheral vision has been clearly recognized in many fields outside the construction industry. In a study conducted by [19], the role of peripheral vision in driving safety was examined in detail. The results revealed that peripheral vision has a great influence on drivers' perception of hazards and decision-making processes while driving. In this context, it is emphasized that drivers' peripheral vision abilities are a critical factor in preventing traffic accidents and improving overall road safety. Similarly, a tool developed by [20] examined the effectiveness of pilots' field of vision during flight. The study demonstrated the importance of peripheral vision in aviation safety, emphasizing the need for pilots to maintain situational awareness and be alert to potential hazards. This research demonstrates how critical peripheral vision is, especially in high-risk sectors such as driving and aviation. The construction industry is an area where the importance of environmental vision becomes even more evident. In a pioneering study by [13], the field of vision of individuals working on construction sites was assessed. The study examined how vision deficiencies can cause accidents on sites, and in particular situations that can lead to eye injuries. The findings of the study show that the peripheral vision and eye health of construction workers is of vital importance. This suggests that the peripheral vision skills of construction workers need to be improved to increase their safety and reduce occupational accidents. However, it is obvious that this issue is not given due importance in Turkey. Assessment of peripheral vision and protection of eye health should be an important part of occupational health and safety policies. Employers and managers need to take the necessary measures to increase employees' peripheral vision abilities and raise awareness on this issue. In this context, providing regular eye examinations will contribute to reducing occupational accidents.

Taken together, while the importance of eye health has been proven in areas such as driving safety and aviation safety, it is also a factor that should not be ignored in high-risk industries such as construction. Studies show that appropriate eye health is a critical step in preventing occupational accidents and improving the safety of workers. Therefore, further research and regulation are needed to assess and improve central and peripheral vision abilities in relevant sectors. It should be emphasized that workers' eye health and vision abilities are critical factors for safety. Making eye examinations and

peripheral vision tests mandatory in the field of occupational health and safety is of great importance for the prevention of occupational accidents. Implementation of such regulations will increase the safety of workers and contribute to the reduction of occupational accidents.

The main purpose of this study is to test the suitability of workers working in the construction industry in terms of eye health by utilizing the researches in the existing literature. In this context, the four investigations of the study are to examine the hazardous conditions that may arise in the construction industry due to eye health deficiencies and to examine the possible effects of these conditions on occupational safety by measuring the adequacy of the central vision levels, the presence of color blindness, and the peripheral vision angle adequacy of the workers. Healthy peripheral vision, sharp central vision, and absence of color blindness are critical for occupational safety, especially in high-risk occupations. The construction industry offers a dynamic and hazardous working environment, where potential peripheral vision deficiencies have the potential to lead to occupational accidents. Within the scope of the study, three different peripheral field of vision tests, color blindness test, and central visual acuity tests were administered to 51 individuals who were Turkish and actively working as workers in various Turkish construction companies, using different stimuli sizes. The results of these tests include examining the extent to which workers' peripheral vision abilities change with different stimuli magnitudes, the adequacy of central vision levels, and color blindness status, and to determine the extent to which these levels comply with the standards set by HSE [10, 11].

One of the main objectives of this study is to raise awareness in the field of occupational safety. It is emphasized that peripheral vision testing should be taken into account during eye examinations of workers during the recruitment process. In this context, employers and managers are encouraged to assess employees' visual capabilities and take necessary measures in this regard. Furthermore, the results of the study are intended to assist legislation-making bodies in the development of occupational health and safety standards. In conclusion, this research aims to make an important contribution to the field of occupational safety by revealing the effects of vision deficiencies on hazardous situations in the construction industry. The findings of the study will be critical in preventing occupational accidents and protecting worker health.

2. Material and Methods

2.1. Hypothesis Development and Dataset

In Turkey, employees are obliged to obtain a medical report when they start work for the first time or when they change their current job. If employees are going to work in a high-risk job such as construction, they are obliged to obtain a medical report stating that they are fit for the work to be done in accordance with subparagraph b) of Article 15 of the Occupational Health and Safety Law No 6331 [8]. Eye examination is one of the health checks performed at the stage of employment. In other words, an eye examination is absolutely necessary during the recruitment process in high-risk sectors in Turkey. During this examination, employees are usually tested for visual acuity and color blindness, but there is no legal obligation to perform these tests; therefore, it is up to the medical doctor's discretion which tests are performed during the examination. However, eye examinations abroad are mandated through specific tests and regulations. Individuals working on construction projects are required to obtain a fitness for work certificate for eye health, which requires them to meet certain visual acuity standards. For example, the HSE in the UK and the OSHA in the US require workers to meet certain success criteria in near and distance vision tests. The HSE requires workers to have an average visual acuity of 3/60 [10], while OSHA requires 20/40 [11]. The absence of color blindness is also a requirement. However, the results of these tests alone are not sufficient proof of adequate eye health. The construction industry is one of the highest risk "life-threatening" occupations abroad, and workers must also have adequate peripheral vision. Although refractive errors significantly affect central visual clarity and may impair task performance in visually demanding environments such as construction sites, no specific regulatory standard or occupational threshold currently exists in OSHA, HSE, or similar institutional guidelines. Therefore, despite its clinical relevance, refractive status was not included as a basis for hypothesis development in this study. Instead, the auto-refractometer test was conducted solely to support and complement the central vision assessment provided by the Snellen visual acuity test. For this reason, the following hypotheses and sub-hypotheses were developed (Table 1).

Within the scope of the study, 51 construction workers were evaluated. The age range of the participants varied between 24 and 62. All of the subjects were male. Their working period varies between 1 year and 30 years, with an average of 12

years. All of the participants are actively working in the construction site environment.

Before beginning the field experiments, written consent was obtained from each participant following a clear explanation of the study objectives and procedures. To prepare for the main data collection, a preliminary study was carried out with four field experts. These individuals, each with a minimum of ten years of experience in construction safety, provided insights on how peripheral vision may influence safety behavior and how it could be assessed to improve awareness in the field. The experts, mainly occupational safety and health engineers with prior experience in eye-related workplace injuries, discussed potential causes of reduced peripheral vision stemming from improper safety practices. Data collection was supported by a semi-structured questionnaire designed for this study. Eye health assessments were carried out in collaboration with both an ophthalmologist and a general practitioner, who worked closely with the researchers. During these assessments, the author was responsible for recording the data.

Table 1: Developed hypotheses related to eye health.

Hypotheses
H1 Workers' central vision levels meet HSE and OSHA standards.
H1.1 Workers' center vision levels are significantly higher than 3/60 center vision levels.
H1.2 Workers' center vision levels are significantly higher than 20/40 center vision levels.
H2 Workers meet HSE and OSHA standards for color blindness.
H3 Workers' peripheral vision levels meet HSE and OSHA standards.
H3.1 The right temporal peripheral visual angles of workers exceed 85 degrees significantly.
H3.1.1 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 5 mm visual stimuli.
H3.1.2 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 10 mm visual stimuli.
H3.1.3 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 20 mm visual stimuli.
H3.2 The left temporal peripheral visual angles of workers exceed 85 degrees significantly.
H3.2.1 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 5 mm visual stimuli.
H3.2.2 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 10 mm visual stimuli.
H3.2.3 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 20 mm visual stimuli.

2.2. Examination Methods

All workers participating in the experiment underwent four basic tests (Figure 1). The auto-refractometer test is a widely used objective method for measuring refractive errors and assists in determining the optical correction needs of individuals (Figure 1-a). The Snellen test is a commonly used method of measuring visual acuity and helps to determine the level of visual ability of individuals (Figure 1-b). The Ishihara test is a standard test used to assess for color blindness (Figure 1-c). The Tangent Screen Peripheral Vision Test is critical in measuring individuals' peripheral vision abilities and assessing the environmental perception of workers, especially those in high-risk industries such as construction (Figure 1-d). All tests and examinations were carried out by an operator ophthalmologist and a general practitioner on site. This ensures that the tests are performed by an expert observer, increasing the reliability of the results.

a - Auto-Refractometer Test

b - Snellen Visual Acuity Test

c - Ishihara Color Blindness Test

d - Dynamic Tangent Screen

Figure 1: Tests administered to participants in the experiment.

2.2.1. Auto-Refractometer Test

The Auto-Refractometer Test is a commonly used diagnostic method to objectively assess refractive errors in the human eye, including myopia, hyperopia, and astigmatism. As highlighted by [21], this test employs an automated device that measures how light changes direction as it enters the eye and reflects off the retina. During the test, the patient is asked to fixate on a target within the machine, while the device rapidly analyzes the reflected light using

infrared technology to calculate refractive values such as sphere, cylinder, and axis. According to [22], the auto-refractometer provides a quick and non-invasive estimate of a person's refractive status, which is especially beneficial for children or individuals who are unable to participate in subjective testing procedures. The resulting measurements serve as a preliminary guide for prescribing corrective lenses and can also assist in monitoring refractive changes over time. Briefly, the Auto-Refractometer Test stands as an integral component of modern ophthalmologic practice.

2.2.2. Snellen Visual Acuity Test

The Snellen Visual Acuity Test is a common method of measuring a person's visual acuity, or the ability to see objects clearly at a given distance. As noted by [23], this test involves reading letters of various sizes from a chart placed at a standard distance of about 6 meters from the patient. As the patient moves down the chart, the letters become smaller in size, making it more difficult to read accurately. The patient's score corresponds to the smallest line of letters they can read correctly, indicating their visual acuity. This test is widely used by ophthalmologists to assess a patient's vision and detect possible problems [24]. Snellen visual acuity test is a widely used standard method for assessing visual acuity in varied forms. For example, [25] showed that measuring visual acuity using computers and other electronic devices can accurately reproduce standard visual acuity tables. Such innovations contribute to making visual acuity tests more accessible and user-friendly [26]. Moreover, the results of visual acuity testing have a significant impact on patients' overall eye health and treatment processes. [27] reported a relationship between visual acuity and macular sensitivity measurements in conditions such as age-related macular degeneration. Such studies show that visual acuity testing helps to assess not only individual visual perception but also a broader perspective on eye health [28]. In conclusion, the Snellen Visual Acuity Test is an important tool for assessing visual acuity. Ophthalmologists continue to use Snellen visual acuity test to better understand their patients' visual function and optimize treatment processes [29].

2.2.3. Ishihara Color Blindness Test

The Ishihara test is a commonly applied method for identifying color vision impairments, specifically forms of color blindness [30]. It involves a set of plates covered with colored dots arranged in particular patterns. These patterns form numbers or shapes that are easily recognizable by individuals with normal color perception but are often indistinct or invisible to those with color vision deficiencies [31]. Among the various types of color blindness, red-green deficiency is the most prevalent, impairing one's ability to differentiate between these two hues [30]. The Ishihara test is frequently utilized by eye care professionals, including ophthalmologists and optometrists, to detect such deficiencies and to inform patients about the nature of their color perception issues [32]. So, the Ishihara color blindness test is an important tool for assessing color vision deficiencies. Ophthalmologists and healthcare professionals are working to better understand their patients' color perception and optimize treatment processes using these new methods.

2.2.4. Tangent Screen Peripheral Vision Test

Visual field testing has a widespread application in ophthalmology as it provides an objective assessment of functional visual impairments. As emphasized by [31], this test plays a critical role in determining the extent and quality of visual perception of individuals. The primary aim of a visual field assessment is to map the individual's "visual island" and detect any deviations from normal visual function. This test involves first adapting the eye to a consistent background luminance followed by presenting a stimulus that is brighter than the background at a defined point in the visual field. This structured procedure enables comprehensive evaluation of different aspects of visual perception.

Given that the focus of this study is to investigate workers' peripheral vision under typical construction site conditions, the method chosen must closely mimic the real-world lighting environment of such settings. Since lighting on construction sites does not shift rapidly, static visual field testing is considered inappropriate for this context. Instead, the tangent screen method, a dynamic approach, is deemed more suitable. This technique involves the use of moving targets (pins) of varying sizes and angles, placed against a background that sharply contrasts in color [24].

The process begins with the participant fixating on a central reference point. Once the examiner has properly adjusted the distance between the eye and this fixed point, the stimulus is slowly moved from the outer edge of the screen toward the center along a specific meridian. The participant signals when the stimulus is first detected. This step is repeated for multiple angles, and the fixation points are recorded to outline the isopter. By repeating the test for each eye independently, the binocular visual field—

formed by the overlapping monocular fields—is ultimately mapped [33].

All stages of the dynamic tangent screen visual field examination used in this study facilitate its systematic implementation and analysis of the data obtained. Visual field testing not only assesses the visual perception of individuals but also plays an important role in the diagnosis and treatment of visual disorders. As a result, the application of this test stands out as a critical tool in ophthalmologic evaluations and the examination of the peripheral visual field is of great importance, especially in terms of occupational safety and performance.

2.3. Experiment Method

Auto-refractometer testing was conducted under standardized conditions within a protected indoor area on the construction site. To minimize ambient light interference and ensure consistent measurement quality, all tests were performed in a controlled environment using a portable, clinically validated auto-refractometer device. Participants were individually seated with their heads stabilized using an integrated chin and forehead rest to maintain alignment with the device's optical axis. The procedure was conducted by a licensed ophthalmologist, who ensured that each measurement adhered to clinical refraction standards and device calibration protocols. Each eye was assessed separately, with the non-tested eye gently occluded using a soft patch to eliminate visual interference. Participants were instructed to fixate on the target image projected within the device while the auto-refractometer emitted a series of infrared beams to capture the reflection from the retina. These measurements were automatically analyzed by the device to determine the spherical, cylindrical, and axial components of the eye's refractive status. The process took approximately 15–20 seconds per eye, and the results were recorded immediately for further evaluation. In instances where measurement variability or blinking disrupted the data, the test was repeated to ensure accuracy and minimize instrument-induced or operator-related bias. This protocol enabled the objective assessment of refractive errors, which is critical for evaluating whether workers possess adequate visual clarity for tasks such as reading measurements, identifying hazards, or operating precision tools on site.

Central vision testing was conducted under controlled conditions within a designated protected area on the construction site. To ensure standardization and minimize environmental distractions, all tests were carried out indoors, using a portable visual acuity chart specifically calibrated for close-range testing. Participants were instructed to stand at a fixed distance of 3 meters from the chart, which was illuminated uniformly according to standard ophthalmologic testing protocols. A licensed ophthalmologist supervised the procedure to guarantee proper alignment and adherence to test instructions. Each eye was tested separately, with the contralateral eye covered using an occlusive monocular patch. Participants were required to identify optotypes (e.g., letters, numbers, or symbols) of decreasing size, progressing from top to bottom. This procedure allowed for an accurate measurement of central visual acuity, which is essential for detecting objects, reading labels, and performing fine motor tasks common in construction activities. In cases where inconsistent responses were observed, the test was repeated to confirm reliability and reduce observer bias.

Color vision testing was administered immediately following the central vision test using the Ishihara Pseudoisochromatic Plates—the most widely recognized tool for screening congenital red-green color deficiencies. Participants were asked to remain seated at a table under natural daylight-equivalent illumination, positioned approximately 75 cm from the test booklet. One plate at a time was shown to each participant for a maximum of 5 seconds, during which they were instructed to identify the number or pattern embedded within the dots. The test was administered monocularly to capture any interocular differences, and the untested eye was again occluded. To ensure validity, participants were unaware of the number of plates presented or the correct responses. The test was evaluated based on the standard Ishihara scoring system, with failure to correctly identify four or more plates considered indicative of color vision deficiency. Participants who demonstrated borderline or inconclusive results were re-evaluated using an extended version of the test, and if necessary, were referred for further diagnostic evaluation.

Tangent screen-based peripheral visual field testing was performed under the same conditions in a protected area at the construction site through dynamic tangent display (Figure 2-a). Throughout the testing procedures, a qualified ophthalmologist ensured that the distance between the participant's eye and the tangent screen was maintained at 25 cm. Participants were instructed to stand upright, keep their heads facing forward, and maintain visual focus on the designated fixation point. This process was carefully implemented to increase the reliability of the test. Another practitioner moved the target objects (stimuli) used during testing from the outside to the

inside of the screen by fixing them on the end of a 150 cm stick (Figure 2-b). Three black pins of 5 mm, 10 mm and 20 mm in size were used as target objects (stimuli) during the tests. These stimuli sizes were selected to simulate varying levels of visual demand that might be encountered during different construction site activities. The use of multiple stimuli dimensions allowed for a comparative assessment of detection thresholds across different eccentricities and directions of the visual field. Smaller stimuli (5 mm) provided insight into the fine sensitivity of peripheral vision, while larger stimuli (10 mm and 20 mm) were used to assess the extent of broader peripheral awareness. This multi-scale approach facilitated a more nuanced analysis of visual field performance under conditions that better reflect the visual challenges faced by workers on construction sites. During the test, subjects held an audio device in their hands and pressed a button when they detected a moving stimulus. Each time the participants pressed the button, the device beeped a warning beep so that tangent points could be recognized. All tangent points were determined by an ophthalmologist based on the participants' responses. Each eye was tested with different stimuli magnitudes in different meridians respectively and the untested eye was covered with a monocular eye mask (Figure 2-c). When inconsistent responses were received from participants, the ophthalmologist repeated the test to ensure the reliability of the tangent points, thereby reinforcing the validity of the results. This type of approach is critical to improving the reliability of eye health testing. Furthermore, peripheral visual field testing plays an important role in the early detection of vision loss and other eye diseases.

a - Dynamic Tangent Display b - Stimuli Movement c - Binocular Eye Closure Apparatus

Figure 2: Dynamic tangent screen experiment.

3. Results

In this study, a one-sample t-test was used to determine whether there were statistically significant differences in terms of both central vision in accordance with the standards set by OSHA regulations and angles in the horizontal and vertical planes of the visual field. For color blindness, the Chi-Square test was used since there was no numerical data but binary data. The raw results of the study are shown in Table 2.

3.1. Refractive Status

Auto-refractometer testing was conducted on all participants to obtain objective measurements of refractive errors. The spherical (SPH) values for the right eye ranged from –3.50 to +4.50 diopters, while for the left eye, values ranged between –3.00 and +5.00 diopters. These results indicate the presence of both myopic and hyperopic refractive patterns across the participant group. Cylindrical (CYL) values, which reflect the presence of astigmatism, varied between –2.50 and 0.00 diopters in both eyes, suggesting a range of mild to moderate astigmatic errors. No axis or dominance patterns were analyzed in this phase of the study, as the auto-refractor data were collected for descriptive support only. In line with ethical and safety considerations, participants, who had been previously diagnosed with refractive errors were permitted to wear their corrective glasses or contact lenses during work and testing procedures. This ensured that all participants operated under their typical vision conditions, allowing for a more accurate interpretation of their functional visual capabilities.

Table 2: Raw examination results.

Participant	Central Visual Acuity				Presence of Color Blindness	Peripheral Vision					
						Right Side			Left Side		
	Feet	Decimal	Over 3/60	Over 20/40		5 mm	10 mm	20 mm	5 mm	10 mm	20 mm
1	20/30	0,67	Yes	Yes	No	80	88	89	80	87	84
2	20/30	0,67	Yes	Yes	No	77	84	84	75	80	88
3	20/45	0,44	Yes	No	No	84	88	89	73	86	85
4	20/25	0,8	Yes	Yes	No	73	79	79	80	82	83
5	20/30	0,67	Yes	Yes	No	86	78	78	88	88	88
6	20/50	0,4	Yes	No	No	85	85	87	74	84	82
7	20/45	0,44	Yes	No	No	83	86	86	85	84	81
8	20/32	0,63	Yes	Yes	No	75	88	89	78	81	81
9	20/32	0,63	Yes	Yes	No	81	86	87	87	82	84
10	20/40	0,5	Yes	Yes	No	78	87	88	74	83	86
11	20/40	0,5	Yes	Yes	No	86	83	83	80	79	84
12	20/30	0,67	Yes	Yes	No	87	79	80	81	78	86
13	20/30	0,67	Yes	Yes	No	85	81	81	73	88	88
14	20/32	0,63	Yes	Yes	No	86	83	85	86	87	82
15	20/60	0,33	Yes	No	No	79	84	84	84	82	82
16	20/32	0,63	Yes	Yes	No	77	87	88	81	82	83
17	20/32	0,63	Yes	Yes	Yes	84	78	80	85	88	82
18	20/20	1	Yes	Yes	No	77	80	80	79	86	87
19	20/32	0,63	Yes	Yes	No	80	84	84	77	87	84
20	20/30	0,67	Yes	Yes	No	77	84	85	75	82	81
21	20/30	0,67	Yes	Yes	No	77	78	80	76	81	82
22	20/20	1	Yes	Yes	No	75	82	82	82	79	88
23	20/60	0,33	Yes	No	No	81	82	83	86	88	87
24	20/60	0,33	Yes	No	No	88	87	89	73	84	87
25	20/40	0,5	Yes	Yes	No	85	84	86	87	87	87
26	20/50	0,4	Yes	No	No	80	85	85	86	88	88
27	20/40	0,5	Yes	Yes	No	85	82	82	88	86	86
28	20/40	0,5	Yes	Yes	No	84	88	89	80	81	84
29	20/45	0,44	Yes	No	No	84	79	79	78	83	84
30	20/40	0,5	Yes	Yes	No	80	85	87	85	87	85
31	20/30	0,67	Yes	Yes	No	88	79	79	74	82	82
32	20/40	0,5	Yes	Yes	No	88	78	80	75	80	82
33	20/48	0,42	Yes	No	No	75	86	86	77	84	85
34	20/32	0,63	Yes	Yes	No	83	84	85	74	80	84
35	20/32	0,63	Yes	Yes	No	82	86	87	75	76	78
36	20/32	0,63	Yes	Yes	No	75	76	78	73	73	76
37	20/30	0,67	Yes	Yes	No	76	80	82	83	87	87
38	20/32	0,63	Yes	Yes	No	79	79	79	77	79	81
39	20/32	0,63	Yes	Yes	No	81	83	84	74	77	80
40	20/30	0,67	Yes	Yes	No	78	80	81	74	77	77
41	20/32	0,63	Yes	Yes	No	82	82	84	85	86	90
42	20/40	0,5	Yes	Yes	No	84	86	88	74	75	75
43	20/25	0,8	Yes	Yes	No	85	89	91	73	75	76
44	20/40	0,5	Yes	Yes	No	84	84	84	85	87	91
45	20/20	1	Yes	Yes	No	82	82	82	75	75	75
46	20/20	1	Yes	Yes	No	84	85	87	80	80	83
47	20/45	0,44	Yes	No	No	83	85	86	78	79	82
48	20/45	0,44	Yes	No	No	80	82	84	81	84	86
49	20/30	0,67	Yes	Yes	No	74	74	74	79	79	80
50	20/32	0,63	Yes	Yes	No	77	78	78	77	81	82
51	20/20	1	Yes	Yes	No	85	86	88	83	85	88

3.2. Visual Acuity

The results of the one-sample t-test for the assessment of central visual acuity on the basis of the total sample showed that the sample mean was 0.1726 which was significantly higher than the reference value of 0.5 ($t=4.5176$; $\rho=0.0047$). Moreover, since 78.43% of the participants met the 20/40 threshold, the single ratio

test was also statistically significant (z=4,0608; ρ<0.0000). These findings, when evaluated in general, show that the majority of workers meet the international safety criteria in terms of central vision. However, the fact that 21.5% of subjects did not meet this criterion indicates that serious attention is required, especially for high-risk positions and tasks that require responsibility. Moreover, the statistical power for both the one-sample t-test (1.0) and the single proportion z-test (0.863) indicates that the sample size (n=51) was adequate to detect the observed effects with high reliability. Therefore, the results related to central visual acuity can be considered statistically robust. Hypothesis H1 is based on two sub-components: H1.1 assumes that workers' center vision levels are significantly higher than 3/60; H1.2 assumes that this level is also significantly higher than 20/40. Both sub-hypotheses of H1 are accepted as a result of the analysis.

3.3. Color Blindness

This study assessed whether workers met HSE and OSHA standards for color blindness. Only one participant in the sample was found to be color blind (1.96%), which was lower than the average prevalence in the community (8%). This difference was not statistically significant (z=6,8614; ρ<0.000). Furthermore, the HSE and OSHA standards' approach to color blindness is based on task-based risk assessment rather than absolute prohibition. Moreover, the power analysis revealed a statistical power of 0.816, indicating that the sample size was sufficient to detect the observed difference in color blindness prevalence with a high level of confidence. Accordingly, one can conclude that the current sample meets occupational health and safety standards in terms of color blindness. Therefore, hypothesis H2 is accepted.

3.4. Peripheral Vision

3.4.1. Right Temporal Area

The aim of the analyses was to compare the peripheral vision scores obtained under three different viewing angles (5 mm, 10 mm and 20 mm) and to evaluate whether each group mean was significantly greater than 85 at right temporal side. Firstly, one-way analysis of variance (ANOVA) was applied to determine whether there was a significant difference between the groups and it was concluded that there was a statistically significant difference (F = 5.8892; ρ = 0.0034). The results of the Tukey HSD post-hoc test conducted to see between which groups this difference was between showed that there was a significant difference between the 5 mm and 20 mm group (ρ=0.0026), whereas no significant difference was found between the 5 mm and 10 mm (ρ=0.0794) and 10 mm and 20 mm (ρ=0.446) groups. This finding suggests that peripheral vision performance measured at the 5 mm viewing angle was significantly lower than at the 20 mm viewing angle.

In the second analysis, a one-sample t-test was performed to determine whether the mean peripheral vision scores obtained for each viewing angle were significantly higher than the reference value of 85 at right temporal side. For the 5 mm (mean = 81.25), 10 mm (mean = 82.90) and 20 mm (mean = 83.82) groups, t test statistics were -7.443, -5.459 and -3.303, respectively, and the one-way ρ-values were 0.0001, 0.0001 and 0.0009, respectively. According to these results, the mean of none of the groups was significantly greater than 85, and thus the peripheral vision performances obtained under these viewing angles at right temporal side were below the reference value. When all the findings are evaluated together, it is seen that the vision values obtained at 5 mm angle are lower not only compared to the other groups but also compared to the reference level. Briefly, in the analyzes made within the framework of these hypotheses

For the 5 mm group, the mean score was 82.90, the test statistic was t = -7.443 and the one-way ρ-value was 0.0001. This ρ-value is well below the significance level of 0.05. Therefore, H3.1.1 for this group is rejected, i.e. it cannot be shown that the mean is significantly greater than 85. In this case, it can even be said that the mean is lower than 85. Similarly, the mean for the 10 mm group was 82.90, the t-statistic was -5.459 and the ρ-value was 0.0001. These values reveal that the mean of the 10 mm group is also not significantly greater than 85. Therefore, hypothesis H3.1.2 is also rejected. For the 20 mm group, the mean was 83.82, the t-statistic was -3.30 and the ρ-value was 0.0009. The ρ-value for this group is well below 0.05 and hypothesis H3.1.3 is also rejected. As a result, the mean values for all three groups were lower than the threshold of 85 and statistical analysis showed that these differences were not significant. Therefore, in the hypothesis tests conducted for each group, the alternative hypotheses that "vision scores are significantly greater than 85" were rejected. That is, it cannot be said that peripheral vision performance for any group exceeds the reference value of 85. Therefore, the main hypothesis H3.1 is rejected.

Finally, power analysis was conducted to understand and to determine whether the sample size is adequate. In this sense, For the 5 mm, 10 mm and 20 mm groups, power scores were 1.0, 1.0 and 0.947,

respectively. In applied research, a commonly accepted convention is to set the significance level at 0.05 and the statistical power at 0.80, using reasonable default assumptions for other parameters [34]. The obtained power values of 1.0, 1.0, and 0.947 indicate a highly adequate level of statistical power, demonstrating that the analyses are sufficiently sensitive to detect true effects, and that the sample size is sufficient to support the reliability of the statistical inferences.

Table 3: Hypoteses results.

Hypotheses	Status
H1 Workers' central vision levels meet HSE and OSHA standards.	Accepted ($\rho<0.01$)
H1.1 Workers' center vision levels are significantly higher than 3/60 center vision levels.	Accepted ($\rho<0.01$)
H1.2 Workers' center vision levels are significantly higher than 20/40 center vision levels.	Accepted ($\rho<0.01$)
H2 Workers meet HSE and OSHA standards for color blindness.	Accepted ($\rho<0.01$)
H3 Workers' peripheral vision levels meet HSE and OSHA standards.	Rejected
H3.1 The right temporal peripheral visual angles of workers exceed 85 degrees significantly.	Rejected
H3.1.1 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 5 mm visual stimuli.	Rejected
H3.1.2 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 10 mm visual stimuli.	Rejected
H3.1.3 The right temporal peripheral visual angles of workers significantly greater than 85 degrees under 20 mm visual stimuli.	Rejected
H3.2 The left temporal peripheral visual angles of workers exceed 85 degrees significantly.	Rejected
H3.2.1 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 5 mm visual stimuli.	Rejected
H3.2.2 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 10 mm visual stimuli.	Rejected
H3.2.3 The left temporal peripheral visual angles of workers significantly greater than 85 degrees under 20 mm visual stimuli.	Rejected

3.4.2. Left Temporal Area

One-way analysis of variance (ANOVA) was performed to determine whether there was a significant difference between the mean peripheral vision scores obtained at 5 mm, 10 mm and 20 mm viewing angles at left temporal side. As a result of the analysis, $F = 13.6872$ and $\rho<0.00001$, indicating that the mean score of at least one of the three groups was significantly different from the others. A Tukey HSD post-hoc test to determine between which groups this significant difference was between revealed that the 5 mm viewing angle had a statistically significantly lower mean score than both the 10 mm and 20 mm viewing angles ($\rho<0.001$). In contrast, no significant difference was observed between the 10 mm and 20 mm groups ($\rho=0.3697$). These results suggest that peripheral vision performance decreased significantly at the narrow (5 mm) viewing angle, but remained similar at the 10 mm and 20 mm angles at left temporal side. When ANOVA and Tukey HSD analyses were evaluated together, it was statistically supported that narrow-angle vision has a limiting effect on peripheral perception.

In this study, a one-sample t-test was performed to examine whether the peripheral vision scores for each viewing angle group (5 mm, 10 mm and 20 mm) at left temporal side were statistically significantly greater than 85. The purpose of the test was to assess whether the mean of each group was significantly greater than the established reference level of 85. In the analyses, the one-way alternative hypothesis "group mean > 85" was assumed. In the 5 mm viewing angle group, the mean peripheral vision score was 79.2549. The t-statistic testing whether this value was significantly greater than 85 was found to be -11.929 and the one-way ρ-value was less than 0.000001. Since this ρ-value is much lower than the significance level of 0.05, H3.2.1 is rejected and it is concluded that the mean of the 5 mm group is not significantly higher than 85. In fact, the negative t-statistic indicates that the mean is significantly lower than 85. The mean of the 10 mm group is 82.37, for which the t-statistic is -7.189 and the ρ-value is less than 0.000001. In this case, the ρ-value is well below the 0.05 limit and H3.2.2 is rejected, meaning that it is statistically confirmed that the peripheral vision scores measured at 10 mm viewing angle are not significantly higher than 85. In the 20 mm group, the mean was 83.5098, the t-statistic was -2.442 and ρ was 0.0182. The mean of this group is closest to the reference value of 85; however, due to the high ρ-value, H3.2.3 is rejected here as well, i.e. it cannot be said that the mean is statistically significantly greater than 85. The t-statistics obtained for all groups are negative, indicating that the mean scores of each group are below the reference value. Furthermore, since all ρ-values were well below the 0.05

significance level, it could not be shown that the mean peripheral vision for any group was significantly greater than 85. These results suggest that the peripheral vision levels measured at all tested viewing angles did not reach the targeted upper level of 85, and that this difference was especially pronounced at narrow viewing angles. For this reason, the main hypothesis H3.2 is rejected.

Finally, a power analysis was performed to assess whether the sample size was sufficient for reliable statistical inference. For the 5 mm, 10 mm and 20 mm groups, power scores were 1.0, 1.0 and 0.778, respectively. Considering that 0.778 is very close to the commonly accepted threshold of 0.80, the sample size can be deemed sufficient to support the robustness of the statistical analyses. The hypothesis results developed as a result of all the analyses are visualized in Table 3.

4. Discussion

4.1 Refractive Status

Although refractive errors do not directly measure visual performance, they significantly influence central visual clarity and visual comfort, especially in visually demanding tasks. Uncorrected myopia, hyperopia or astigmatism may cause blurred vision, eye strain, and reduced attention, which can impair workers' ability to perceive hazards and react quickly.

In this context, assessing refractive status—even in the absence of visible symptoms—is important for occupational safety. Workers with significant refractive errors should be encouraged to use corrective lenses, and regular vision checks should be part of periodic health screenings on construction sites.

While this study did not develop hypotheses based on refractive error due to the absence of specific regulatory standards, the findings highlight the importance of including refractive status as a supportive component in comprehensive visual assessments.

4.2 Visual Acuity

It is stated in the literature that central vision loss is associated not only with occupational accidents but also with visual attention deficit and delays in reaction time [27]. In this context, it can be said that individuals with poor central visual acuity may notice warning signs late, hesitate in situations where they need to make quick decisions, and react to potential risks later. In particular, individuals working in scaffolds, crane areas, narrow passages and excavation areas should have full central visual acuity.

This component of the study reveals that central visual acuity should be regularly assessed in occupational health and safety processes in the construction sector, not only during the entry examinations but also during periodic health screenings. In addition, the workplaces and responsibilities of individuals with poor central visual acuity should be reconsidered, and if necessary, glasses, lighting support or task adaptations should be made to improve visual performance.

As a result, while the overall results may appear positive in terms of central vision, inadequacies in certain individuals pose a risk to the sectoral safety culture. Therefore, in recruitment processes, qualified assessments should be made not only on the "eye examination has been performed", but also on which tests have been applied, which threshold has been met and for which task eligibility has been granted. This approach will offer a more sustainable safety approach in terms of both protecting employee health and preventing occupational accidents.

4.3 Color Blindness

In the literature, it is stated that color blindness alone does not eliminate the ability to work; however, it may pose a risk especially in jobs where color-coded systems are critical [30, 35]. For example, failure to correctly perceive electrical installations, warning lights, safety signage, and color-based markings used on a construction site can jeopardize both the individual's own safety and the safety of colleagues around them. However, authorities such as OSHA and HSE do not treat color blindness as an absolute disability, instead recommending a task-based assessment. That is, while colorblind individuals can be assigned to positions where color discrimination is not critical, the distribution of tasks should be restructured for tasks involving critical color coding.

In this context, in light of the findings of the study, hypothesis H2, that is, the assumption that workers meet OSHA and HSE standards in terms of color blindness, is accepted. However, this acceptance should not be interpreted as a complacency in terms of occupational health. On the contrary, making colorblindness tests mandatory in employment examinations and integrating the test results into job descriptions will directly contribute to increasing the level of safety in the field. Furthermore, the adaptation of next-generation testing and filtering solutions (e.g. color-correcting lenses and augmented

reality applications) to work environments, supported by digital systems and wearable technologies, can reduce the impact of such visual limitations.

In conclusion, although the low rate of color blindness in this study can be considered as a positive finding, it is clear that color perception competence should be assessed with a more systematic and task-oriented approach, considering the distribution of tasks, equipment uses and warning systems in the construction industry. This approach should be part of a sustainable OHS strategy for the safety of not only workers but also all individuals in the workplace.

4.4 Peripheral Vision

In the light of these findings, it is noteworthy that peripheral vision performance was significantly lower than the other groups, especially at the 5 mm stimuli size, and did not exceed the 85 degrees threshold. In environments that require fast reflexes and broad peripheral awareness, such as construction sites, this poor performance could potentially lead to serious safety vulnerabilities. Since the relatively high scores observed in the 10 mm and 20 mm groups also did not statistically exceed 85 degrees, it can be concluded that the level of peripheral vision is generally below expectations in the industry.

The present study provides a comprehensive statistical evaluation of peripheral vision performance under varying visual stimuli sizes (5 mm, 10 mm, and 20 mm) in both the right and left temporal fields of construction workers. The findings, which consistently show that mean peripheral vision scores fall significantly below the reference threshold of 85 across all stimulus sizes and visual fields, align with and further elaborate on the earlier results reported in the literature. In particular, the outcomes are broadly consistent with those of [13], who assessed the general impact of peripheral vision limitations on construction site safety. Their study emphasized that workers' peripheral visual field angles frequently failed to meet the international safety benchmark of 85°, especially when tested under realistic worksite constraints. Similar to the present study, they identified that limited peripheral awareness, especially on the temporal sides, could lead to a higher likelihood of undetected hazards and near-miss incidents. However, the current research adds further nuance by introducing different stimulus sizes, revealing that narrower stimuli (5 mm) result in significantly lower peripheral vision performance—an important detail not specifically analyzed in the 2022 study. Moreover, the results of this research echo the experimental findings of [14], which investigated how the use of different types of hard hats impacted peripheral vision. In that study, it was demonstrated that certain helmet designs restricted lateral visual fields to below the 85° threshold, particularly when combined with narrow-angle stimuli. The authors suggested that both the physical characteristics of personal protective equipment and individual perceptual limitations contribute jointly to reduced visual awareness. While their study focused on external equipment-induced constraints, the current research isolates the role of visual stimulus detectability itself, showing that even in the absence of PPE interference, performance remains suboptimal at small stimulus sizes. This underlines that peripheral vision limitations are not solely the result of protective gear, but may also reflect inherent physiological or occupational factors that compromise visual alertness. Notably, the integration of power analysis in the present study provides a methodological advancement over previous works. High statistical power values (ranging from 0.778 to 1.0) confirm that the observed effects are robust and unlikely to result from insufficient sample size—a limitation noted in earlier research. While [13, 14] highlighted peripheral vision as a safety concern, the current study supports these concerns with rigorous hypothesis testing and clear statistical refutation of performance thresholds. Overall, this study reinforces prior conclusions that peripheral vision in construction workers often fails to meet occupational safety standards and extends the evidence by demonstrating how visual acuity under different stimulus sizes systematically affects perception. These findings substantiate the call for incorporating peripheral vision testing into routine occupational health screenings and suggest that both ergonomic design and visual training interventions may be required to mitigate visual field limitations in high-risk environments.

These findings have significant implications for occupational safety in the construction sector. The fact that peripheral vision performance, particularly at the 5 mm stimulus size, did not exceed the 85-degree threshold indicates a critical limitation in workers' ability to detect small or rapidly approaching hazards from the sides. This is particularly alarming in construction environments where dynamic and unpredictable elements—such as moving machinery, falling objects, and co-worker movements—require a high degree of peripheral awareness. Poor performance in this area suggests that workers may fail to perceive potential threats until they are too close to respond, increasing the likelihood of accidents or injuries. Even though larger stimuli (10 mm and 20 mm) yielded slightly better results, the inability to statistically surpass the 85-degree

benchmark suggests that the overall field of vision remains constrained under realistic conditions. This limitation may be exacerbated by environmental factors on construction sites, such as insufficient lighting, visual distractions, and protective equipment (e.g., helmets or goggles) that may further narrow the field of view. From a safety management perspective, these findings highlight the need for enhanced vision screening protocols, ergonomically informed site layouts, and possibly augmented visual alert systems to compensate for workers' limited peripheral awareness. Ultimately, understanding and addressing these visual limitations is crucial for designing safer construction environments and reducing occupational accident rates.

5. Conclusion

This study aimed to assess construction workers' compliance with national and international occupational health and safety standards (particularly OSHA and HSE) by evaluating key eye health parameters: central visual acuity, color blindness, and peripheral vision. Highlighting the role of visual factors in occupational accidents, the study emphasized that fitness for work should be evaluated not only through general health checks but also by assessing sensory functions. met the standards in terms of central vision and color perception, but there were significant weaknesses in peripheral visual field competence. This indicates that workers' peripheral awareness decreases, especially at narrow viewing angles, which may jeopardize occupational safety. In this context, it is of great importance to include peripheral vision testing during induction examinations and periodic health screenings, and to ensure that visual performance is not limited to central abilities. It is also recommended that peripheral vision deficiencies should be reflected in task allocations, and ergonomic improvement, training and visual support solutions should be offered where necessary.

In conclusion, this study presents a unique set of findings that point to the need for a systematic assessment of visual health parameters in the construction industry and reveals that peripheral vision deficiencies are an area that should not be ignored in terms of preventing occupational accidents. Accordingly, regulatory bodies, employers and OHS professionals should expand the assessment methods for eye health and develop a holistic visual competence assessment system that includes peripheral vision performance.

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