

Prevalence and lack of awareness of dyschromatopsia among students of four university courses

Prevalência e desconhecimento da discromatopsia entre estudantes de quatro cursos universitários

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ABSTRACT

Objective: To identify the prevalence of colour dyschromatopsia in students of engineering, medicine, dentistry, and pedagogy courses at a community college in a city in the Midwest of Santa Catarina, Brazil.

Methods: Applied research, a quantitative approach, and exploratory tests were conducted using the Ishihara Colour Test complemented by the Farnsworth D-15 Test.

Results: The study sample comprised 660 participants (414 females and 246 males; $p = 0.001$). Of the total cohort, eight (1.21%) presented colour vision abnormalities in the Ishihara or Farnsworth D-15 test; when considering only the male population, the prevalence of dyschromatopsia reached a rate of 3.25%, and six (75%) were unaware of their deficiency. Deutanopia was the most common disability (5 = 75%).

Conclusion: Dyschromatopsia was observed only in males, most of whom were unaware of their disabilities. This suggests the need to adopt diagnostic tests at the beginning of courses to provide better guidance for choosing a specialty.

RESUMO

Objetivo: Identificar a prevalência de discromatopsia entre estudantes dos cursos de engenharia, medicina, odontologia e pedagogia de uma universidade comunitária.

Métodos: Pesquisa com abordagem quantitativa e testes exploratórios que foram conduzidos utilizando o teste de Ishihara e complementado pelo teste Farnsworth D-15.

Resultados: A amostra do estudo foi composta de 660 participantes (414 mulheres; $p = 0,001$). Do total da coorte, oito (1,21%) apresentaram anormalidades na visão de cores no teste Ishihara ou Farnsworth D-15; considerando apenas a população masculina, a prevalência de discromatopsia atingiu 3,25%, sendo que seis (75%) desconheciam sua deficiência. Deuteranopia foi a deficiência mais comum (5; 75%).

Conclusão: A discromatopsia foi observada apenas em homens e a maioria desconhecia sua deficiência. Isso sugere a necessidade de se adotarem testes diagnósticos no início dos cursos para melhor orientação sobre a escolha de uma especialidade.



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INTRODUCTION

The worldwide prevalence of dyschromatopsia varies from 2 to 8% among men and 0.4% among women, with the rate being higher among Caucasians and slightly lower among Chinese and Japanese.⁽¹⁻³⁾ Dyschromatopsia affects colour perception, which compromises the performance of academic activities that require precise chromatic discrimination, and its implications are often underestimated.⁽⁴⁾

Congenital colour vision abnormalities can be classified according to the affected cone. Total or partial abnormalities in blue cones are rare and are called tritanopia or tritanomaly, respectively. Total or partial deficiency of red cones is called protanopia and protanomaly, and that of green is called deuteranopia and deuteranomaly.^(5,6) Congenital colour dyschromatopsia is more common in males, as it requires only one abnormal X chromosome for its manifestation, whereas for females it requires two abnormal X chromosomes.⁽⁷⁾

In relation to professions, studies conducted with medical students have identified significant difficulties in their practical training, particularly in the identification of colours during histological classes, which culminates in clinical errors associated with the evaluation of colour changes and skin diseases, as well as in microscopy, ophthalmoscopy, and otoscopy examinations.⁽⁸⁻¹⁰⁾ In dentistry, aesthetics is essential for patient satisfaction in prosthetic rehabilitation, which requires precision in the application of colors.^(11,12) However, a study revealed that both dentistry teachers and students have limited knowledge regarding colour blindness.⁽¹³⁾

In engineering, some functions may also be affected, such as occupational safety, which requires normal colour perception owing to the standardisation of coloured signs, a vital aspect of effective performance in the industrial environment.^(3,14) Another profession that also partially depends on good colour perception is pedagogy, whose deficiency may make it difficult to use coloured teaching materials, justifying its inclusion in studies related to dyschromatopsia.⁽¹⁵⁾

The need for early identification and professional guidance for students with dyschromatopsia in courses in the most affected professions justifies this research.^(4,5) Furthermore, several professions exclude individuals with colour vision deficiencies due to concerns related to safety and quality of work.⁽¹⁶⁾ However, some people with dyschromatopsia may be unaware of their condition, which could lead to mistakes in their professional choices and compromise some of their future activities.⁽¹⁷⁾

The hypothesis of this research was that students in professions that require colour discrimination are mostly unaware of their anomalies. The purpose is to check the rate of colour deficiency among students in these professions, and if candidates are aware of their condition. Thus, the aim of this study was to identify the prevalence of colour dyschromatopsia in students of engineering, medicine, dentistry, and pedagogy courses at a community college in a city in the Midwest of Santa Catarina, Brazil.

METHODS

This study used a quantitative and exploratory approach. Participants were informed of the objectives and information related to the work through the informed consent and assent forms before cooperating with the research that was approved by the Ethics and Research Committee of the *Universidade do Oeste de Santa Catarina* (Unoesc), under number 6,492,781, CAAE: 74850123.1.0000.5367.

The tests were administered to a university population exceeding 18-years-old, enrolled at the Unoesc, Joaçaba Campus, Brazil, in the following courses: engineering, medicine, dentistry, and pedagogy. Sex and race were included without distinction. The inclusion criteria were the manifestation of the will and authorisation of the participants through free and informed consent. Individuals with visual alterations that could cause acquired dyschromatopsia were excluded. The research was conducted using the Ishihara colour test, and when necessary, the Farnsworth D-15 Test was performed to characterise the type of dyschromatopsia.

The Ishihara colour test⁽¹⁸⁾ was conducted in a calm, well-lit environment, where the participant was presented with an album containing 24 or 38 distinct images, wherein all the plates before those that differentiated the type of dyschromatopsia were read. The examiner had support materials to distinguish whether the students' answers represented normal vision or possible dyschromatopsia. When changes were found in the first plate, subsequent plates (respectively 16 to 17 and 22 to 25) were presented to differentiate the disorder into protanopia or deuteranopia and classify protanopia and deuteranopia as strong or moderate, which are also called protanomalies and deuteranomalies, respectively.

In cases of doubt regarding the answer to the Ishihara test, the Farnsworth D-15 test was performed in person through an online version using a computer. The test is available on the Colorliten website and comprises a series of 15 coloured tablets that vary in similar colour tones with subtle differences between them.⁽¹⁹⁾ Individuals with

dyschromatopsia should organise these tablets in an order of colour gradation.

In the Ishihara test, we noted the plates that the students reported as being outside the normal range and corresponding type of dyschromatopsia. In the Farnsworth D-15 test, the colour axis was confused by the interviewee, with individuals with deuteranopia confusing the green and purple axes, those with protanopia confuse red with the green and blue axes, and those with tritanopia confuse yellow with blue.⁽¹⁹⁾

The participants were approached at the educational institution during class hours, respecting scheduled days, to avoid comprising their academic life. All students were protected by ethical guarantees that allowed for nonparticipation, secrecy, confidentiality, and privacy.

The results were organised into graphs and tables, which helped provide theoretical support and were used in studies, serving as parameters for the municipal and regional identification of the main dyschromatopsia affecting the university population. Categorical data are presented as absolute and relative frequencies. The association between dyschromatopsia and sex was evaluated using the Fisher exact test with JASP software (v. 0.19.3), considering statistical significance $p < 0.05$. Students with visual alterations were referred for complete evaluation and counselling at a specialised private service that was previously prepared for the activity (free of charge for the participant) or according to the preference of the examinee.

RESULTS

The sample consisted of 660 adult students who attended medicine, dentistry, pedagogy, and engineering courses at the Unoesc, Joaçaba Campus, of whom 414 (62.73%) were female ($p = 0.001$; Table 1).

Table 1. Association between sex and dyschromatopsia among students

Sex	Dyschromatopsia		p-value
	Yes	No	
Female	414 (100)	0	< 0.001
Male	238 (96.7)	8 (3.3)	

Results expressed as n (%).

The Ishihara test was used to detect the carriers and types of dyschromatopsia. Six (0.91%) were carriers of dyschromatopsia and seven (1.06%) were inconclusive. For inconclusive cases, the Farnsworth D-15 test was applied, and two (0.3%) were diagnosed with colour

vision deficiency, characterised by strong protanopia and deuteranopia.

In total, eight (1.21%) men with dyschromatopsia were identified, a rate that reached 3.25% when considering only male participants. Among those with dyschromatopsia, five (62.5%) had strong deuteranopia, two (25%) had strong protanopia, and one (12.5%) had a deuteranomaly. The results are summarised in table 2.

Table 2. General prevalence of dyschromatopsia among students

Sex	
Female	414 (62.7)
Male	246 (37.3)
Type of dyschromatopsia	
Strong deuteranopia	8 (1.3)
Strong protanopia	5 (0.8)
Deuteranomaly	2 (0.3)
Course	
Medicine	288 (48)
Dentistry	185 (25.8)
Engineering	131 (21.8)
Pedagogy	56 (9.3)

Results expressed as n (%).

When asked whether they knew they had colour dyschromatopsia, 75% ($n = 6$) were unaware of their colour vision deficiencies (Figure 1).

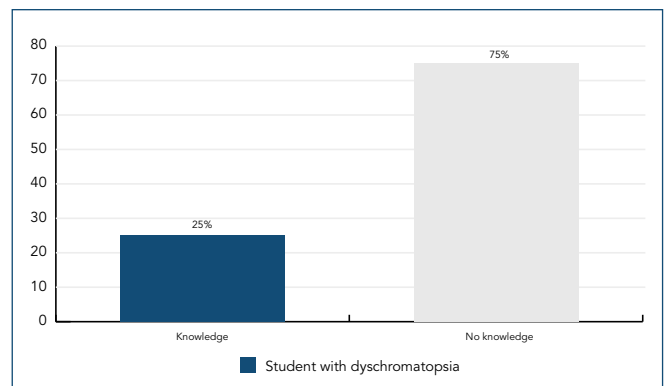


Figure 1. Students' prior knowledge about their dyschromatopsia.

The dentistry course, wherein tests were performed on 185 students (136 females), was the one that presented the highest number of students with dyschromatopsia (4; 50%). Medicine, wherein tests were performed on 288 students (197 females), ranked second (2; 25%). Engineering, wherein tests were performed on 131 students (103 males), came in third place (both at 12.5%; $n = 1$). Pedagogy, wherein tests were performed on 56 students (53 females), came in fourth place. The results are summarised in table 2.

DISCUSSION

This study confirmed a higher prevalence of dyschromatopsia among male students (3.25%), a rate that was below that of most studies conducted in Brazil.^(4,7,20-23) However, the results were similar and had a prevalence higher than some studies^(2,3,24-26) (Table 3). The studies are scattered and almost all of them have a small sample size. This highlights the need for more national studies to improve our understanding of the true prevalence across Brazil.

Table 3. Prevalence of dyschromatopsia in men, nationwide

Author	Location	n Male (total)	Male (dyschromatopsia)
Dalsoglio et al. ⁽²⁾	Luzerna and Erval Velho (SC)	208	4 (1.92)
Adam Netto et al. ⁽³⁾	Tubarão (SC)	836	21 (2.5)
Adam Netto et al. ⁽⁴⁾	Florianópolis (SC)	323	16 (4.95)
Sato et al. ⁽⁷⁾	Curitiba (PR)	523	29 (5.5)
Caroli et al. ⁽²⁰⁾	São Paulo (SP)	121	8 (6.6)
Quarto et al. ⁽²¹⁾	Natividade (RJ)	48	2 (4.16)
Scirea ⁽²²⁾	Bocaiúva do Sul (PR)	475	31 (6.52)
Teixeira et al. ⁽²³⁾	Itaperuna (RJ)	56	5 (8.92)
Cespedes et al. ⁽²⁴⁾	Campo Grande (MS)	66	2 (3.03)
Couto ⁽²⁵⁾	Monte Alegre de Goiás (GO)	60	2 (3.33)
Martins et al. ⁽²⁶⁾	Porto Alegre (RS)	330	10 (3.03)

Results expressed as n or n (%).

None of the participants had colour vision deficiencies. Previous studies conducted in the State of Santa Catarina have shown that the prevalence of dyschromatopsia in the female population varies between 0% and 0.5%.^(2,4,27) Therefore, the percentages found in the present study are in accordance with the values found in the literature. Congenital dyschromatopsia (red-green) is inherited and linked to the X chromosome. In women, two anomalous X chromosomes are necessary for some types of colour vision deficiency, whereas in men, the manifestation appears with only one anomalous X chromosome; hence, its incidence is higher.⁽⁷⁾

Except for a study conducted in Natividade (RJ)⁽²¹⁾, studies conducted in the Southeastern region of Brazil^(20,23) have the highest prevalence. In the South and Central-West regions, most studies conducted in Santa Catarina, Rio Grande do Sul, Goiás, and southern Mato Grosso^(2,3,24-26) revealed results similar to those found in the present study. However, studies in Paraná^(7,21) and Florianópolis⁽⁴⁾ showed higher percentages of participants with dyschromatopsia than that in the current study.

The variability in prevalence associated with colour vision deficiency may occur due to the diversity of races, as Brazil is one of the most mixed-race countries in the world owing to its recent and diverse formation.⁽²⁸⁾ However, there is no clear association, and most studies

were conducted with < 200 participants, which may cause a bias in these results.

At the international level, a meta-analysis conducted by Birch⁽¹⁾ demonstrated, through the analysis of five studies in the populations of Caucasian European men in different regions of Europe (Norway, Germany, France, and Greece), that the prevalence of colour vision deficiency in these locations was high, ranging from 7.8% to 8.01%. However, studies conducted in Sardinia and Reggio Calabria, southern Italy, found that 2.56% and 3.59% of participants, respectively, presented with some type of dyschromatopsia.^(29,30) These results are somewhat like those of the present study, as the region has a high frequency of people with this origin.

Regarding the incidence of dyschromatopsia in African populations, a study conducted in Ethiopia with 2,829 men discovered 106 (3.75%) patients with dyschromatopsia.⁽³¹⁾ Another study, conducted in Nigeria with 769 men reported having discovered 29 (3.8%) participants with some colour vision deficiency.⁽³²⁾ These percentages are similar to that of the present study, although none of these participants were black.

Prior knowledge of dyschromatopsia was observed in only 25% of its carriers. Generally, only the most severe forms of the anomaly are usually identified early, indicating the need for prior diagnostic attention during undergraduate studies.⁽³³⁾ The importance of diagnosing dyschromatopsia is justified by the pedagogical and/or work difficulties faced by carriers.⁽²⁴⁾

Regarding profession, two medical students had dyschromatopsia, one of whom was unaware of their condition. Doctors with dyschromatopsia have difficulties mainly involved in the diagnostic process, such as identifying generalised changes in body colour (cyanosis, pallor, jaundice, and erythema), performing ophthalmoscopy and otoscopy, and differentiating blood or bile in urine and faeces.^(34,35) The greater the severity of dyschromatopsia, the greater the clinical difficulties present in the physical examination performed.⁽⁴⁾

Regarding dentistry, the profession wherein most students have dyschromatopsia, dyschromatopsia reduces the students ability to discriminate colours during procedures to determine the shade of the tooth or prosthesis.⁽³⁶⁾ People with some kind of colour vision deficiency make significantly more errors in terms of selecting hue and chroma when making dental prostheses than do those with normal vision.^(13,37) Knowledge about the underlying causes and consequences of dyschromatopsia can help in making professional decisions within dentistry, especially in relation to dental aesthetics.⁽³⁸⁾

Regarding pedagogues with an affected student, those with dyschromatopsia found it more difficult to perform pedagogical tasks related to colours than their normal counterparts, causing delays in patients that use colours.^(39,40)

Among the engineering students, only one was affected. Future engineers receive the technical knowledge they need at university and in factories to perform their work activities.⁽⁴¹⁾ Engineers with dyschromatopsia may have difficulties in relation to work safety, as the use of colours to signal risks in industries/factories is standardised.⁽³⁾

Building knowledge about the impact of dyschromatopsia is essential to guide early counselling and development of new assistive technologies for those who deal with this sensory condition daily.^(42,43) People with dyschromatopsia may have problems with fundamental activities or dimensions such as occupational performance, education, and social relationships.⁽⁴³⁾

Although this study has the quality of covering courses in which students are most affected by colour vision deficiency, an aspect rarely studied, it has the limitation of having been carried out at a single university, and despite being among the largest in the national literature, the number of male participants is considered low for detecting an anomaly with a low population index.

CONCLUSION

Considering that the participants with dyschromatopsia were in courses that require good colour discrimination, it can be inferred that carrying out the colour test at the beginning of these courses is necessary to allow people with this disability to change their profession, if they wish so, or adapt to their functions, finding specialized guidance to minimize its effects.

AUTHORS' CONTRIBUTION

Arthur Gabriel Duran and Luísa Trucolo contributed to the conception and design of the study, analysis and interpretation of results, writing and critical review of the manuscript's content. Caio Antônio Nhoatto, Gabriel Gardini Fagundes Marafon, Fabricio Salazar Fiorio Marques, and Luiz Henrique Paza da Costa contributed to the performance of the tests, analysis and interpretation of data, writing and critical review of the manuscript's content. Ricardo Alexandre Stock, Antuani Rafael Baptistella and Elcio Luiz Bonamigo contributed to the conception and design of the study, writing and critical review of the manuscript's content. All authors approved the final version

of the manuscript and are responsible for all aspects of the manuscript, including ensuring its accuracy and integrity.

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