

Evaluation of visual stress symptoms in age-matched dyslexic, Meares-Irlen syndrome and normal adults

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Abstract

• **AIM:** To examine the prevalence of dyslexia and Meares-Irlen syndrome (MIS) among female students and determine their level of visual stress in comparison with normal subjects.

• **METHODS:** A random sample of 450 female medical students of King Saud University Riyadh (age range, 18–30y) responded to a wide range of questions designed to accomplish the aims of this study. The detailed questionnaire consisted of 54 questions with 12 questions enquiring on ocular history and demography of participants while 42 questions were on visual symptoms. Items were categorized into critical and non-critical questions (CQ and NCQ) and were rated on four point Likert scale. Based on the responses obtained, the subjects were grouped into normal (control), dyslexic with or without MIS (Group 1) and subjects with MIS only (Group 2). Responses were analysed as averages and mean scores were calculated and compared between groups using one way analysis of variance to evaluate total visual stress score (TVSS=NCQ+CQ), critical and non-critical visual stress scores. The relationship between categorical variables such as age, handedness and condition were assessed with Chi-square test.

• **RESULTS:** The completion rate was 97.6% and majority of the respondents (92%) were normal readers, 2% dyslexic and 6% had MIS. They were age-matched. More than half of the participants had visited an eye care practitioner in the last 2y. About 13% were recommended

eye exercises and one participant experienced pattern glare. Hand preference was not associated with any condition but Group 1 subjects (3/9, 33%) were significantly more likely to be diagnosed of lazy eye than Group 2 (2/27, 7%) and control (27/414, 7%) subjects. The mean±SD of TVSS responses were 63±14 and it was 44±9 for CQ and 19±5 for NCQ. Responses from all three variables were normally distributed but the CQ responses were on the average more positive (82%) in Group 2 and less positive (46%) in Group 1 than control. With NCQ, the responses were equally less positive in Group 1 and 2 than control. Group 2 subjects showed significantly higher TVSS ($P=0.002$), NCQ ($P=0.006$) and CQ ($P=0.008$) visual stress scores than control but no difference between Group 1 and control subjects, was observed for all scores ($P>0.05$, for all comparisons).

• **CONCLUSION:** The prevalence of dyslexia and MIS among Saudi female students was 2% and 6%, respectively. Critical questions performed best for assessing visual stress symptoms in dyslexic and MIS subjects. Generally, students with MIS were more sensitive to visual stress than normal students but dyslexics were more likely to present with a lazy eye than MIS and normal readers.

• **KEYWORDS:** dyslexia; visual stress symptoms; critical questions; non-critical questions; Meares-Irlen syndrome; questionnaire

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INTRODUCTION

Dyslexia describes a specific disability in learning to read despite normal intelligence and opportunity [1]. An unequivocal definition of dyslexia is difficult and can vary according to the discipline [2]. Among practitioners, the diagnosis of dyslexia depends on showing that an individual's phonological, reading and spelling skills are well below what one would expect for their age and other aspects of basic intelligence [3-4]. However, dyslexia is much more than this. It is considered a neurological "syndrome" that involves much more than just reading and writing [5]. Dyslexic individuals may experience significant visual symptoms while reading.

These symptoms may or may not be consistent with binocular visual anomalies but they may impede the desire to read and write, and perhaps ultimately handicap the learning process. The visual stress symptoms include perceptual distortion, asthenopia and headache, diplopia, blurred vision, visual confusion^[2,6] (suggested to be as a result of poor binocular control causing reading and spelling errors)^[7]. Although dyslexia is a lifelong condition^[8-10], most dyslexic persons are able to adapt to their condition by developing coping strategies (e.g. try to avoid reading) that help them to overcome their reading difficulties.

There are no specific causes of dyslexia, but it is widely believed that about 10% to 15% percent of the population with dyslexia are due to a subtle neuro-developmental syndrome^[11-13] or disorder thought to have a hereditary component^[2,14]. Dyslexia with such hereditary, neurodevelopmental aspects has been described as developmental dyslexia. Individuals with developmental dyslexia present difficulties with decoding while comprehension is more intact^[13].

The connection between visual processes and dyslexia has gained much publicity through the claims made by Irlen^[15-17], who reported that many children with dyslexia suffer from a perceptual dysfunction she called Scotopic Sensitivity Syndrome. This condition is currently referred to as Meares-Irlen syndrome (MIS)^[15,18]. MIS is often seen in children with dyslexia^[19] but no clear definition has been given^[3]. It is characterized by visual perceptual distortion such as illusion of images, colour and motion effects, and symptoms of visual stress such as asthenopia in the form of eye strain, tired eyes, headache and photophobia. Treatment of this condition involves the use of proprietary coloured^[17] and precision^[20] overlays.

The involvement of visual stress in MIS is quite obvious but the nature of the relationship between visual stress and dyslexia is still unclear. Among children and adults with and without dyslexia, evidence of a link between MIS and reading difficulties has been established^[21-22]. Singleton and Henderson^[21] investigated visual stress in dyslexic and non-dyslexic children using a bespoke, computerized visual stress screening test and found that the incidence of high level visual stress in dyslexic children was almost twice that in control children. They observed that dyslexic children who showed high visual stress scores reported more than 20% improvement in reading speed with colour overlay in Wilkins Rate Reading Test as compared with control children with high visual stress who showed between 5% and 10% improvement. For children with lower visual stress scores, those with dyslexia showed at least 5% improvement compared with <5% in controls when using coloured overlays^[21]. This indicates that predominance or incidence of visual stress in dyslexics is higher than non-dyslexics.

Till date, many studies on dyslexia and its visual correlates have focused on children with only a few studies in adults^[22-24] even with the identification of an urgent need to support dyslexic adults in higher education^[25]. Also, because the symptoms of MIS and visual stress are non-specific, the need for a differentially diagnosis of the condition from other ophthalmology conditions, such as refractive error, binocular vision anomalies, and accommodative anomalies has been identified^[26]. Adults particularly students are constantly involved in tasks that require a lot of reading and writing. These increases their risk of experiencing visual stress symptoms and in the presence of dyslexia, affects their workplace or studies^[27]. In a literate society, it becomes more disadvantageous and is compounded by racism^[5]. This study aims to examine the prevalence of dyslexia and MIS in a population of literate individuals^[28] and whose field of study demand a high level of study time. The strict admission policy of the prestigious medical schools is sufficient guarantee of a generally high level of knowledge. Given that a common support strategy at undergraduate university level is the provision of extra time in examinations, this study will also subjectively evaluate visual stress levels that are inferred from reading associated symptoms scores among these students, determine the appropriateness of questions to be used in identifying higher levels of visual stress associated with reading, and compare visual stress levels among dyslexic, MIS and normal subjects in order to identify which group of adults are more sensitive to visual stress.

SUBJECTS AND METHODS

Subjects A total of 450 female medical students of King Saud University aged between 18 to 30y were recruited over a 2-month period. All participants gave consent to participate in the study after the protocol has been fully explained. Ethical approval was obtained from King Saud University Ethical Committee and all procedures followed the tenets of the Declaration of Helsinki and the participants were required to complete an extended set of survey questions. Contact details for investigators were available on the survey.

Questionnaire Design A paper version of a validated questionnaire with a wide range of questions was randomly distributed among medical students of the university who were recruited by oral invitation from the investigators. The survey was designed to subjectively identify the type and the degree of symptoms associated with reading, and whether those symptoms hinder the learning process or are associated with a specific reading and/ or spelling difficulty. The detailed questionnaire consisted of 54 questions with 12 questions enquiring on participants' ocular history and demography while 42 questions were on visual symptoms including: symptoms related to visual distortion at near and distance, binocular visual dysfunction and reading or writing

Table 1 Result of analysis of responses on participants' characteristics n (%)

Responses of questions enquiring about oneself	Counts of responses			Total
	Yes	No	Not response	
Use prescription glasses	211 (46.9)	237 (52.7)	2 (0.4)	450 (100)
Use prescription contact lenses	153 (34.0)	296 (65.8)	1 (0.2)	450 (100)
Handedness				
Right-handed	409 (90.9)	-	-	450 (100)
Left-handed	41 (9.1)	-	-	450 (100)
Visited optometrists in the last 2a	263 (58.4)	187 (41.6)	-	450 (100)
Previously diagnosed of lazy eye	32 (7.1)	418 (92.9)	-	450 (100)
Previously wore eye patch	56 (12.4)	394 (87.6)	-	450 (100)
Eye exercises previously recommended	57 (12.7)	393 (87.3)	-	450 (100)
Previously diagnosed with dyslexia	9 (2.0)	441 (98.0)	-	450 (100)
Sensitivity to light	3 (0.7)	447 (99.3)	-	450 (100)
Used coloured overlays/tinted glasses for reading	30 (6.7)	420 (93.3)	-	450 (100)
Sensitivity to pattern glare	1 (0.2)	449 (99.8)	-	450 (100)

errors experienced by the participants. Survey items were derived from previous studies on dyslexia, MIS and visual discomfort [21,26,29-31]. Students who responded positively to previous diagnoses of dyslexia and MIS were contacted at the end of data collection and the diagnosis was confirmed in all subjects.

Statistical Analysis The results were entered into a Microsoft Excel spreadsheet (Microsoft, Redmond, WA, USA), overlaid to eliminate data errors and corrected. Data was analysed using SPSS version 16 (SPSS Inc. Chicago, Illinois, USA). Besides the questions on demography and ocular history which were close end questions (requiring yes/no answer), all other items in the questionnaire were rated on four point Likert scales from 1 (never) to 4 (always) and a neutral response was scored as zero.

Differences were considered significance at $P < 0.05$. Analysis was to assess the construct validity by studying the correlation between the final subjects' questionnaire scoring with the case condition for all subjects using Tukey's post hoc analysis of one way ANOVA. Questionnaire items were divided into two classes of questions: critical and non-critical questions. Critical questions (CQ) were those that purely relate to the reading and/or writing errors and to the visual stress symptom associated with reading while the non-critical questions (NCQ) describe visual symptoms that are attributed to binocular vision dysfunctions rather than the underlying issue or topic. Total visual stress score (TVSS) is the sum of both CQ and NCQ scores. Based on the responses obtained from the categorical questions, the subjects were grouped into normal (control), dyslexic with or without MIS (Group 1) and subjects with MIS only (Group 2). Chi-square test were conducted with continuity correction to relate independent categorical items such as age, handedness, presence of refractive error, sensitivity to the light, history of eye

exercises and sensitivity to pattern glare to case condition (dyslexia or MIS). The average responses for each group of participant were also presented graphically. To evaluate total, critical and non-critical visual stress scores amongst the subject, ANOVA and post hoc test were conducted.

RESULTS

Subjects' Characteristics Initially, 461 students agreed to participate. Six students withdrew from the study due to the length of the survey and 5 failed to respond to most of the questions. Only data from 450 participants (97.6%) who responded to majority of the survey questions were included in the analysis. Of these students, 92% (414/450) were normal subjects (age range, 18-30y) and 8% (36/450; age range 18-26y) had previously been diagnosed with reading difficulties. Of these subjects, 2% were dyslexic with or without MIS (9/450) and 6% (27/450) had MIS only and were using colour filters for reading. The subjects were matched in age. Percentage analysis of the responses elicited by questions on demography and characteristics of the subjects is shown in Table 1. More than half of the participants had visited an eye care practitioner in the last 2y and about 47% and 34% use prescription glasses and contact lenses, respectively. About 13% had been recommended eye exercises and only one participant responded positively to experiencing pattern glare.

Cross tabulation on Chi-square analysis showed no significant association ($P > 0.05$) between all categorical measures (age, handedness, history of eye exercises etc) and case condition (dyslexia with/without MIS or MIS) except previous diagnosis of lazy eye which was significant associated (Chi-square, $\chi^2=9.6$, $P=0.008$) with dyslexia (Group 1). The subjects in Group 1 (3/9, 33%) were more likely to receive a diagnosis of lazy eye than Group 2 (2/27, 7%) and control (27/414, 7%) subjects.

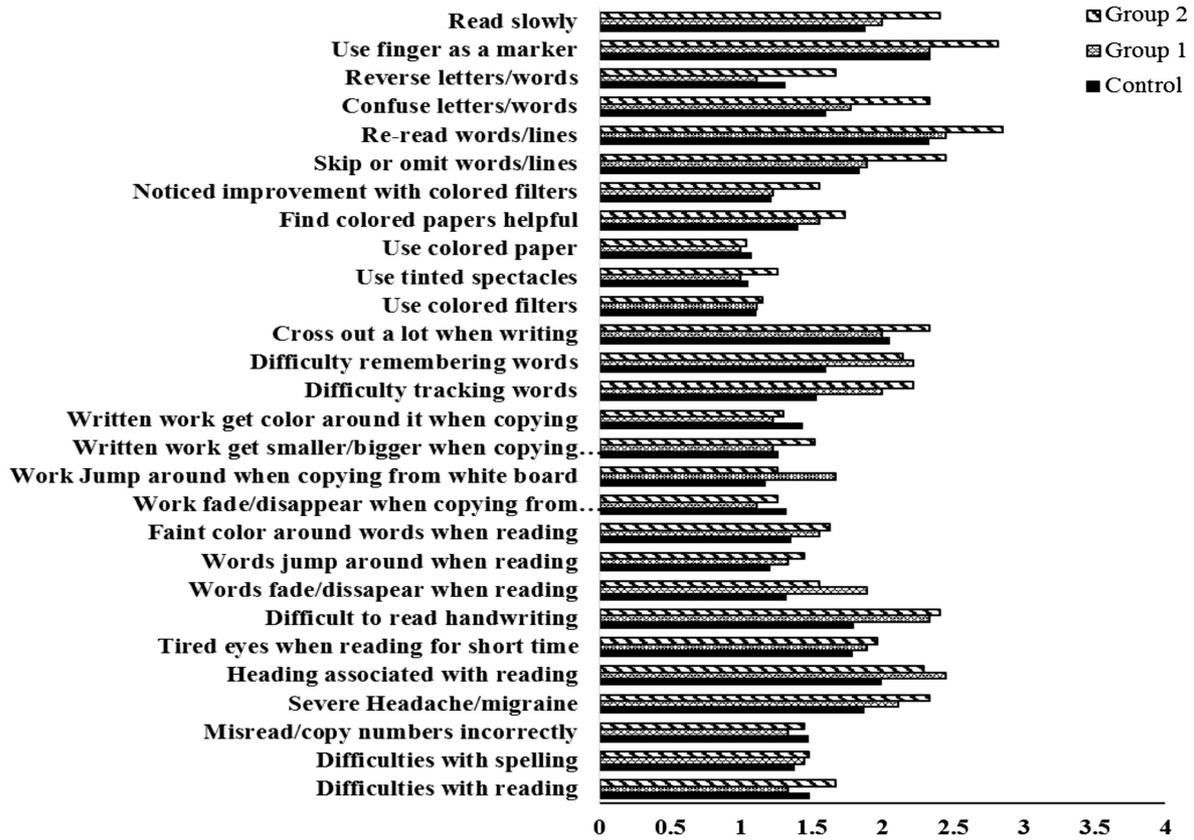


Figure 1 Analysis of average responses on visual stress symptoms using critical questions in dyslexics with or without Meares–Irlen syndrome MIS (Group 1) and Meares–Irlen syndrome subjects (Group 2).

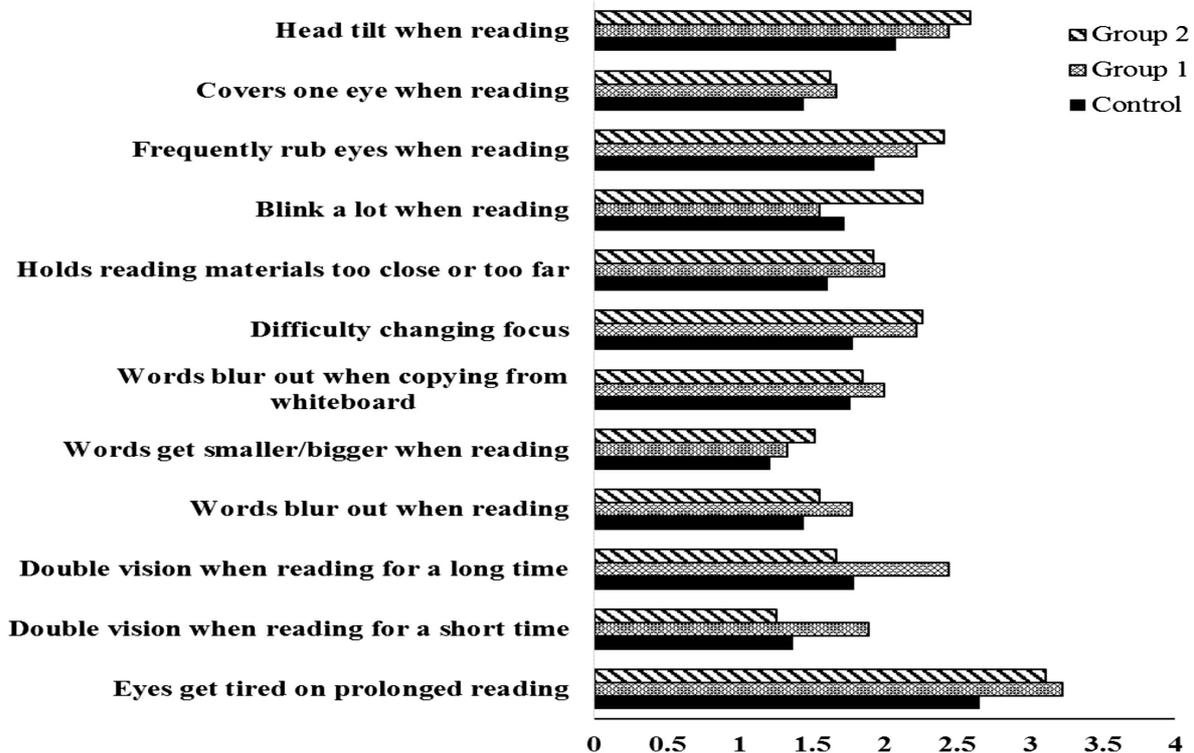


Figure 2 Analysis of average responses on visual stress symptoms using non-critical questions (NCQ) in dyslexics with or without Meares–Irlen syndrome (Group 1) and Meares–Irlen syndrome subjects (Group 2).

Result of Analysis on Responses from Critical and Non-critical Questions The visual stress scores from all three variables were normally distributed. The mean \pm SD of the responses for TVSS was 63 ± 14 and it was 44 ± 9 for CQ and

19 ± 5 for NCQ. The average responses from CQ and NCQ are shown in Figures 1 and 2 respectively for control, Group 1 and Group 2 subjects. With respect to the use of CQ, the response was on the average more positive (82%) for Group

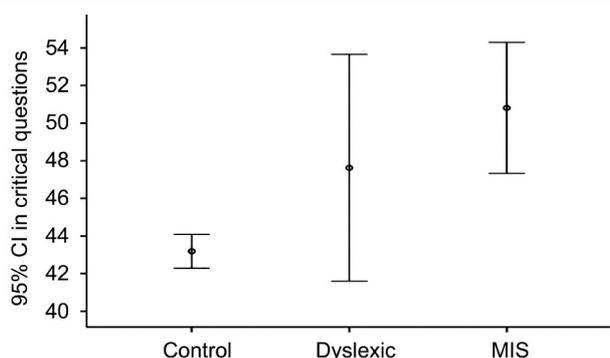


Figure 3 Mean visual stress scores with 95% limits of confidence intervals (CI) for critical questions in control, dyslexic with or without MIS and MIS subjects The subjects with MIS are those who did not receive a diagnosis of dyslexia but use coloured filters to help in reading; dyslexic without MIS are subjects who have been diagnosed as dyslexic but do not use coloured filters to help in reading while dyslexics with MIS are subjects who have been diagnosed as dyslexic and use coloured filters to help in reading.

2 subjects and less positive (46%) for Group 1 subjects compared with the response from the control. Group 2 subjects (*i.e.* MIS subjects who did not receive a diagnosis of dyslexia but used coloured filters while reading) scored the highest when CQ was used to assess visual stress followed by Group 1 (dyslexic with MIS or without MIS) and control subjects (Figure 3).

Concerning NCQ visual stress measure, the responses were on average equally positive in Groups 1 and 2 but more positive than control (Figure 2). On analysis, the mean score was highest for Group 1 followed by Group 2 and control (Figure 4) and the TVSS was highest for Group 2 subjects than Group 1 and control (Figure 5). Tukey's homogenous test showed that the sample size in each group did not influence the results of statistical analysis when total TVSS ($P=0.085$), CQ ($P=0.148$), NCQ ($P=0.080$) were used as measure variables. Analysis using one way ANOVA showed no statistical significant differences in mean score of subjects within groups for TVSS, CQ and NCQ ($P>0.05$, for all) but between groups, the TVSS score ($P=0.003$), the CQs ($P=0.012$) and NCQs ($P=0.002$) visual stress scores were statistically significantly different.

The breakdown of post hoc analysis showing the mean difference in TVSS, CQ and NCQ visual stress scores and the limits of confidence intervals (CI) are shown in Table 2. From the table, Group 2 subjects showed significantly higher TVSS ($P=0.002$), NCQ visual stress scores ($P=0.006$) and CQ visual stress scores ($P=0.008$) than control. In contrast, the TVSS, NCQ and CQ visual stress scores were similar between control and Group 1 subjects ($P>0.05$, for all comparisons). However, when this analysis was performed with Group 1 being split into dyslexic only and dyslexics with MIS, the TVSS (mean difference: -22; 95% CI: -42 to

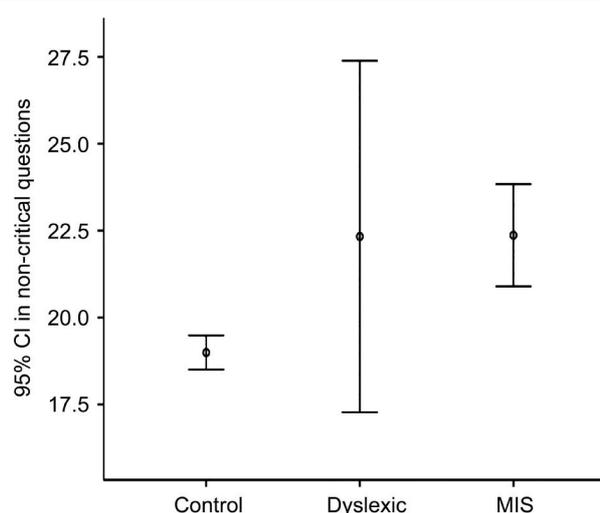


Figure 4 Mean visual stress scores with 95% limits of CI for non-critical questions in control, dyslexic with or without MIS and MIS subjects The subjects with MIS are those who did not receive a diagnosis of dyslexia but use coloured filters to help in reading; dyslexic without MIS are subjects who have been diagnosed as dyslexic but do not use coloured filters to help in reading while dyslexics with MIS are subjects who have been diagnosed as dyslexic and use coloured filters to help in reading.

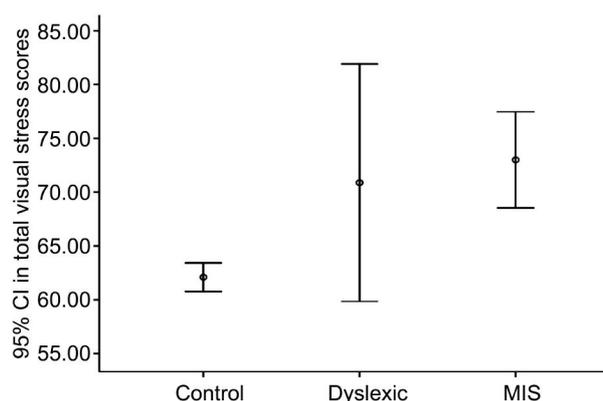


Figure 5 Mean visual stress scores with 95% limits of CI for TVSS in control, dyslexic with or without MIS and MIS subjects The subjects with MIS are those who did not receive a diagnosis of dyslexia but use coloured filters to help in reading; dyslexic without MIS are subjects who have been diagnosed as dyslexic but do not use coloured filters to help in reading while dyslexics with MIS are subjects who have been diagnosed as dyslexic and use coloured filters to help in reading.

-2; $P=0.024$) and NCQ visual stress scores (mean difference: -11, 95% CI: -18 to -4; $P=0.001$) became significantly higher for dyslexics with MIS than control.

DISCUSSION

Learning and reading disorders are common presentations in the primary care setting^[29] and can have serious consequences on educational achievement of subjects. The need for increased awareness of symptoms and identification of patients has been identified^[30]. In this study we assessed for the first time the frequency of occurrence of dyslexic and MIS among a Saudi literate population. The results show that

Table 2 Mean differences in mean scores between groups and 95% confidence intervals for critical question (CQ), non-critical question (NCQ) and total visual stress symptoms (TVSS)

Dependent variable	Group 1	Group 2	Mean difference	SE	P	95% confidence interval
CQ	Control	Dyslexic with/without MIS	-0.217	3.723	0.998	-8.973, 8.538
		MIS	-6.551	2.195	0.008	-11.712, -1.389
	Dyslexic with/without MIS	Control	0.217	3.723	0.998	-8.538, 8.973
		MIS	-6.333	4.253	0.297	-16.335, 3.669
	MIS	Control	6.551	2.195	0.008	1.389, 11.712
		Dyslexic with/without MIS	6.333	4.253	0.297	-3.668, 16.335
NCQ	Control	Dyslexic with/without MIS	-4.210	2.077	0.107	-9.094, 0.674
		MIS	-3.766	1.224	0.006	-6.645, -0.887
	Dyslexic with/without MIS	Control	4.210	2.077	0.107	-0.674, 9.094
		MIS	0.444	2.373	0.981	-5.135, 6.023
	MIS	Control	3.766	1.224	0.006	0.887, 6.645
		Dyslexic with/without MIS	-0.444	2.372	0.981	-6.023, 5.135
TVSS	Control	Dyslexic with/without MIS	-4.428	5.156	0.667	-16.554, 7.699
		MIS	-10.316	3.040	0.002	-17.465, -3.168
	Dyslexic with/without MIS	Control	4.428	5.157	0.667	-7.699, 16.554
		MIS	-5.889	5.891	0.577	-19.741, 7.963
	MIS	Control	10.316	3.040	0.002	3.168, 17.465
		Dyslexic with/without MIS	5.889	5.891	0.577	-7.963, 19.741

P values are results of post hoc analysis using Tukey's HSD. The mean difference is significant at the 0.05 level.

about 8% of female medical students have reading difficulties. One in every 50 student (2%) is dyslexic and one in every 16 student (6%) has MIS. Although it has been difficult to assess the true prevalence of dyslexia mainly due to the differences in the definition of the condition, prevalence studies estimate that it affects between 4% and 10% of children [31-33] and higher rate of dyslexia has been reported among creative students than non-creative students[34]. In another study the prevalence of MIS in adult population was reported to be as common as in children [35]. Irlen [15] inferred that MIS affects 12% of the general population and the condition coexists in 65% of dyslexic people. In this study, we observed that a smaller proportion of dyslexic subjects (33%) also had MIS. Irlen's observation were not backed up by actual data and as such cannot be compared with the current results. In addition to the subjective confirmation of MIS by the persistent benefit of coloured filters used during reading, or from immediate benefit that is indicated by increased reading rate [19,35], the respondents in this study also self-confirmed the diagnosis of the conditions, at the end of data collection. We included a large number of items to ensure content validity [36] as the study was designed to measure a particular trait in a given group of subjects (dyslexics).

Considering the very high completion rate recorded, it appears that the use of this questionnaire as a measure of visual stress level in dyslexic and MIS subjects was well received by the respondents in this study. It is possible that the high response rate was a reflection of the relevance of the subject being assessed to the respondents' occupation

(medical students faced with greater writing and reading task). Whether this survey will perform equally well in adults particularly with lesser education or of different occupation is subject to future research. Of the questions asked, enquiring on the respondents' history of "pattern glare" (a symptom well known to be attributed to MIS condition) may not have been understood because only one positive response was received even though 27 respondents had MIS. Perhaps, the respondents were not familiar with the term although opportunity was made available for them during data collection to ask questions in order to clear any ambiguous issue, or those with MIS were unaware of this symptom. Pattern glare refers to the description of visual perceptual distortions, *e.g.* motion of the reading material, change in the spacing between letters and coloured halos, which in turn can cause visual discomfort, and asthenopic symptoms, by viewing certain "striped" pattern stimuli with spatial characteristics such as lines of the text on a page [19]. A revision of this term into a more familiar term in future studies may improve the respondents' understanding of the symptom.

Visual stress which is the subjective experience of unpleasant visual symptoms when reading (especially for prolonged duration) and in response to some other visual stimuli [37] affects both dyslexics and non-dyslexic individuals [21]. It can be evaluated using objective and subjective techniques. Subjective assessment of visual stress level requires the use of appropriateness questions and in this study, significantly higher visual stress scores were observed in MIS subjects than control regardless of the questions implored as

measurement tools. But, between the control and dyslexic subjects, we found no significant differences in mean scores when NCQ, CQ and TVSS were implored for assessment of visual stress. Additionally, we found that subjects with MIS were more sensitive to visual stress than normal subjects. More dyslexic adults (22%) than MIS (19%) and normal (11%) adults experienced transient blurring of near vision and about 56% of dyslexics, 18% of MIS and 24% of controls experienced double vision during prolonged reading (none of these symptoms differed between groups). von Károlyi and Winner [23] did not find any difference in the performance of perceptual and spatial tasks between dyslexic and non-dyslexic young adults. It has been reported that about 5% of all children and half of all dyslexic children complain of visual problems when they try to read and in these children, letters appear blurred or move around and go double while reading, making the children unable to see them properly [38]. Obviously, these symptoms will interfere with reading in these subjects [4] and may cause eyestrain and headaches. However, these may be reduced, in some cases, by wearing tinted lenses[39].

Various questionnaires have been used to assess visual stress in dyslexics[34,40-42]. Some have assessed the effects of coloured overlays on symptoms and reading rate [35] or measured the distribution of visual discomfort symptoms in dyslexics during reading[43]. While none of these studies have compared the level of visual stress in both groups (dyslexics and MIS subjects) in relation to controls, the responses from studies on children may have under-reported the symptoms due to a lack of understanding [44]. Children who constantly experience symptoms of visual stress during reading may not identify the symptom as unusual and therefore might accept it as normal, except perhaps if these symptoms are relieved by use of coloured overlays[35,45].

Scientists have searched for connections between hand preference and the presence of disorders that affect reading and language development. However, until now, no convincing evidence has been found. Recently, a genetic variant was discovered that appears to link handedness and reading ability. Children with a particular version of the gene, called PCSK6, have a right hand that is unusually dominant and are also poor at reading [46]. Most of the participants (90.9%) in this study were right handed (90.6% normal, 77.8% dyslexics and all MIS subjects) but this preference for hand and the other categorical variables like age and history of eye exercises were not significantly associated with either dyslexia or MIS. However, dyslexic subjects with or without MIS were significantly more likely to be diagnosed with lazy eyes than other subjects in this study. This is in agreement with a previous report that reduced amplitudes of convergence and accommodation were significantly correlated with dyslexia [47]. The authors also suggested that

the binocular instability they observed in dyslexic subjects was due to the decreased amplitude of accommodation.

As a general drawback to all questionnaires, we could not expand the questions beyond the ones already asked and although we did not clinically examine these subjects in order to confirm actual diagnosis, the participants were contacted at the end of data collection and their self-reported diagnosis were confirmed. The decision to recruit only females in this study was pre-intended due to the high preponderance of visual stress symptom scores in women [48-49]. Although this may limit the generalization of the current results, the study highlights the importance of developing a standard set of questions for use in assessing visual stress among dyslexic and MIS adults as this will aid proper intervention in this group of subjects.

In conclusion, we observed that dyslexia (with or without MIS) and MIS alone were present in 2% and 6% of adult female students in Saudi Arabia, respectively. Subjects with MIS were significantly more sensitive to visual stress than normal subjects but between dyslexic and normal subjects, the sensitivity to visual stress was similar. On the other hand, the dyslexic subjects were more likely to present with lazy eyes than other subjects and the use of critical questions was more appropriate for assessing visual stress levels in adult university students with reading difficulties.

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