ORIGINAL ARTICLE

# Digital eye strain among library users: Prevalence and ROC-derived cut-off point for the DESRIL-27

**Nabilah Ayob, MPH, Mohammad Saffree Jeffree, MComm. Med (OH), Sharina Mohd Shah, MPH, Kamal Lazi, MPH, Edwin de Cruz, MPH, Azizan Omar, DrPH**

Public Health Medicine Department, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia

## ABSTRACT

**Introduction: Digital eye strain (DES), also known as computer vision syndrome, has become a growing public health issue among students due to prolonged screen exposure. Reliable, locally validated screening tools are essential to estimate prevalence and guide prevention. This study aimed to establish a receiver operating characteristic (ROC)-based cut-off for the Digital Eye Strain and Risk Level Questionnaire (DESRIL-27) against the Computer Vision Syndrome Questionnaire (CVS-Q) as the reference standard, and to estimate the prevalence of DES among university library users.**

**Materials and Methods: A cross-sectional study was conducted between June and September 2024 among users of Universiti Malaysia Sabah libraries. Participants completed the DESRIL-27 and CVS-Q via Microsoft Forms. Data were exported to Excel, cleaned, and analysed in RStudio (version 2025.05.1). Reliability was assessed using Cronbach's alpha. ROC analysis determined the optimal DESRIL-27 cut-off, and diagnostic performance was quantified using sensitivity, specificity, predictive values, and likelihood ratios. Prevalence was estimated based on the optimal threshold with 95% confidence intervals (CI). Ethical approval was obtained from the Medical Research Ethics Committee, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah (JKEtika 3/24 (8)).**

**Results: A total of 277 participants were included (mean age 24.2 years, 67% female). Internal consistency was excellent (α=0.964 for symptoms; α=0.921 for risk factors). ROC analysis yielded an area under the curve of 0.982 (95% CI: 0.970, 0.994). The optimal cut-off was ≥14.5, demonstrating sensitivity of 90.9% and specificity of 96.7%, with a positive predictive value of 98.3% and a negative predictive value of 83.8%. The likelihood ratios were LR+ =27.6 and LR– =0.09. At this threshold, the prevalence of DES was 62.1% (95% CI: 56.1, 67.8).**

**Conclusions: The DESRIL-27 demonstrated excellent reliability and diagnostic performance, with an empirically derived cut-off of ≥14.5. These findings support its use as a screening tool for digital eye strain in university settings.**

**KEYWORDS:**
*Asthenopia, digital eye strain, computer vision syndrome, ROC curve, Public Health, Universities, Cross-Sectional Studies, Prevalence*

## INTRODUCTION

Digital eye strain (DES), also known as computer vision syndrome (CVS), is increasingly recognized as a public health issue in the digital era. Prolonged exposure to a Visual Display Terminal (VDT), with as little as two continuous hours, can trigger Digital Eye Strain (DES) symptoms such as eye fatigue, dryness, blurred vision, headaches, and difficulty focusing. A VDT refers to any device that presents visual information including computers, laptops, tablets, smartphones or game console.[1–3] The global prevalence of DES ranges between 50% and 70%, depending on the population studied and the screening tool applied.[4,5] These symptoms can negatively affect productivity, academic performance, and overall quality of life.[2,6]

University students are particularly vulnerable due to prolonged screen exposure in educational and recreational settings. In Malaysia and other Southeast Asian countries, where digital learning environments have expanded rapidly, DES represents an important occupational and educational health concern.[7,8] Despite its burden, standardized and validated cut-off values for DES screening tools remain limited, especially for local populations.

Various questionnaires have been developed to identify DES. The Computer Vision Syndrome Questionnaire (CVS-Q) by Seguí et al., is among the most widely validated tools, serving as a reference standard across different populations.[9] More recently, the Digital Eye Strain and Risk Level 27-item scale (DESRIL-27) developed by a group of ophthalmologists in the Universiti Brunei Darussalam, has been introduced to capture both symptom severity and environmental or ergonomic risk factors.[10] Although DESRIL-27 has demonstrated high internal consistency (Cronbach's alpha >0.88) and acceptable construct validity, no validated cut-off score has been established, limiting its use for diagnostic screening.[10]

Establishing a reliable cut-off point is essential, as it transform a continuous symptoms score into meaningful classification of DES presence or absence. Traditional methods, such as using the mean ± standard deviation or percentile thresholds have used, but they may not accurately reflect diagnostic performance.[11,12] Receiver operating characteristic (ROC) curve analysis is widely recommended as a more robust method for identifying optimal thresholds, balancing sensitivity and specificity.[13]

*This article was accepted: 15 December 2025*
*Corresponding Author: Mohammad Saffree Jeffree*
*Email: saffree@ums.edu.my*

This study therefore aimed to determine the optimal ROC derived cut-off point for the DESRIL-27 symptom score in screening digital eye strain among university library users at the Universiti Malaysia Sabah, using the CVS-Q as the reference standard. The findings provide population-specific evidence to support the use of DESRIL-27 in local research, screening, and preventive practice.

## MATERIALS AND METHODS

This study employed a cross-sectional analytical design and was conducted between June and September 2024 in two academic libraries at the Universiti Malaysia Sabah (UMS): the Main Library and the Medical Library. The Main Library receives approximately 1,000-1,500 visitors daily during regular academic periods, while the Medical Library receives 20-50 visitors. Both libraries provide access to common VDT-based equipment such as personal laptops, smartphones, and library desktop computers.

### Study Instrument

For our study instrument, there are two validated questionnaires were administered through Microsoft Forms:
1.Digital Eye Strain and Risk Level Questionnaire (DESRIL-27) – a 27-item scale. There are two parts questionnaires: DES symptoms severity and Risk Level. The 15 DES symptom items are scored by multiplying frequency (0-2) and intensity (1-2), producing a continuous symptom score where higher values indicate greater severity. The remaining 12 items measure environmental and ergonomic risks, coded on a Likert-type response format and summed into a continuous risk score where higher value indicates higher risk.[10]

2.Computer Vision Syndrome Questionnaire (CVS-Q) developed by Seguí et al., which served as the reference standard for DES classification.9 The CVS-Q consist of 16 ocular symptoms; each rated for both frequency and intensity. Using established CVS-Q scoring Rules, symptoms are combined into a total score that is then dichotomised into DES categories. A total score of <6 indicates no DES, while score ≥6 indicates the presence of DES. This binary classification was used as the gold standard outcome for ROC curve analysis in this study.[9]

Both instruments were distributed in English versions, and informed consent was obtained prior to participation.

### Study Population and Eligibility Criteria

The study population comprised students, staff and visitors who were actively using either of the two library facilities during data collection.
Inclusion criteria:
1. Individual using the library at the time of data collection.
2. Individuals who had engaged for at least two hours or more of continuous VTD use, consistent with recommendations from the American Optometric Association (AOA).[2] A VDT refers to any device that presents visual information including computers, laptops, tablets, smartphones or game console
3. Age ≥18 years.

Exclusion criteria:
1. Individuals with medical conditions affecting vision and requiring regular hospital follow-up.
2. Those declining to provide informed consent.

### Sample Size Estimation

Sample size was calculated using Cochran's formula for a single proportion.1[4] Based on a previous study in Thai university students reporting an 81% prevalence of DES with a 95% confidence level (Z=1.96) and 5% precision (d=0.05), the minimum sample size was 238 participants.[15] After accounting for a 15% non-response rate, the final target sample size was 280 participants.[16]

### Sampling Strategy and Data Collection Procedure and Management

A multistage sampling approach was applied, combining cluster, systematic, and purposive elements. The UMS Main Library and Medical and Hospital Library were divided into approximately 20 functional zones (reading areas, computer sections, discussion rooms, and librarian offices), which served as natural clusters. For the larger research project, these zones were observed repeatedly across different time slots and dates, resulting in 64 sampling occasions. This provides a systematic coverage of both spatial (library areas) and temporal variation (different dates and times), thereby minimizing selection bias. Such an approach ensured balanced recruitment across high- and low-traffic areas as well as different lighting conditions, strengthening the representativeness of the study population. Minimal missing sociodemographic data were addressed using mean substitution to reduce attrition bias. On each sampling occasion, 5-10 participants were purposively approached within the designated zone based on availability. Individuals who had already completed the survey on earlier occasions were excluded to avoid duplication. Eligible participants were given a participant information sheet, and digital informed consent was obtained prior to survey completion.

The questionnaire was completed via a Microsoft Form, accessible through a QR code or direct link. Participants used their own devices (smartphones, tablets, or laptops) to answer the survey while seated in the library. Each session took approximately 3-7 minutes per participant. Researchers remained present during the sessions to clarify queries and to ensure independent completion. All responses were automatically stored in a secure Microsoft database accessible only to the research team

Survey responses were automatically stored in Microsoft Forms and exported in Excel format. Raw data were cleaned and coded in Microsoft Excel during the first stage of data preparation. Statistical analyses were then conducted in RStudio (version 2025.05.1, Build 513; R Foundation for Statistical Computing, Vienna, Austria). Because the Microsoft Form required participants to answer each item before proceeding, the DESRIL-27 and CVS-Q datasets were complete. Only sociodemographic variables (age, height, and weight) had minimal missing values (n=12), which were replaced with mean values.

**Table I: Diagnostic Classification of DESRIL-27 Against CVS-Q (2x2 table)**

| DESRIL-27 (Cut-Off 14.5) | CVS-Q Positive | CVS-Q Negative | Total |
|---|---|---|---|
| Positive (≥14.5) | 169 (TP) | 3 (FP) | 172 |
| Negative (<14.5) | 17 (FN) | 88 (TN) | 105 |
| Total | 186 | 91 | 277 |

**Table II: Diagnostic Performance of DESRIL-27 at Multiple Cut Off Scores**

| Cut-Off Score | Sensitivity | Specificity | PPV | NPV | Youden Index |
|---|---|---|---|---|---|
| 12 | 98.4% | 62.6% | 84.4% | 94.0% | 0.61 |
| 13 | 96.8% | 74.7% | 89.4% | 91.9% | 0.72 |
| 14 | 93.5% | 87.9% | 95.6% | 84.7% | 0.81 |
| 14.5 (Optimal) | 90.9% | 96.7% | 98.3% | 83.8% | 0.88 |
| 15 | 88.2% | 97.8% | 98.8% | 81.5% | 0.86 |
| 16 | 82.8% | 98.9% | 99.2% | 77.2% | 0.82 |
| 17 | 79.0% | 99.0% | 99.2% | 74.8% | 0.78 |

**Table III: Sociodemographic characteristics by DES status and Risk-Level Scores**

| Characteristic | n (%) | DES Present n (%) | DES Absent n (%) | Mean RL Score ± SD |
|---|---|---|---|---|
| Age Group | | | | |
| 18–24 years | 188 (67.9%) | 124 (66.0%) | 64 (34.0%) | 12.3 ± 5.7 |
| 25–34 years | 67 (24.2%) | 39 (58.2%) | 28 (41.8%) | 12.9 ± 6.0 |
| ≥35 years | 22 (8.0%) | 9 (40.9%) | 13 (59.1%) | 13.2 ± 6.4 |
| Sex | | | | |
| Male | 91 (32.9%) | 41 (45.1%) | 50 (54.9%) | 11.7 ± 5.6 |
| Female | 186 (67.1%) | 131 (70.4%) | 55 (29.6%) | 13.0 ± 5.8 |
| Screen Time (VDT hours) | | | | |
| <2 hours/day | 42 (15.2%) | 15 (35.7%) | 27 (64.3%) | 10.8 ± 4.9 |
| 2–4 hours/day | 157 (56.7%) | 102 (65.0%) | 55 (35.0%) | 12.4 ± 5.7 |
| >4 hours/day | 78 (28.2%) | 55 (70.5%) | 23 (29.5%) | 14.5 ± 6.3 |
| Total | 277 (100%) | 172 (62.1%) | 105 (37.9%) | 12.5 ± 5.8 |

### Statistical Analysis

Descriptive statistics were summarised using means, standard deviations (SD), medians, interquartile ranges (IQR), and frequencies where appropriate. Internal consistency reliability of the DESRIL-27 symptom and risk subscales was assessed using Cronbach's alpha. Receiver operating characteristic (ROC) curve analysis was performed using the CVS-Q dichotomous classification as the reference standard. The area under the curve (AUC) and its 95% confidence interval were calculated. Optimal cut-off points were determined using Youden's index and the closest-to-top-left method. Diagnostic performance metrics including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were computed at the optimal threshold. The ROC-derived cut-off was then used to estimate the prevalence of DES in the study population.

### Ethical Approval

This study was approved by the Medical Research Ethics Committee, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah (Approval Code: JKEtika 3/24 (8)). Participation was voluntary, and informed consent was obtained from all participants prior to data collection. Confidentiality and anonymity of responses were assured throughout the study

## RESULTS

### Participant characteristics

A total of 277 participants were included in the analysis. The mean age was 24.2 years (SD 6.3). The majority were female (67%), while 33% were male. The mean body mass index (BMI) was 23.7kg/m² (SD=5.4). All participants reported using at least one digital device during library use, primarily smartphones and laptops with average screen exposure of 6.3 hours per day (SD=2.4)

### DESRIL-27 score distribution

The overall DES score had a mean of 29.9 (SD=27.7), with a median of 21 and an interquartile range (IQR) of 37. Scores ranged widely from 0 to 171, reflecting substantial variability in symptom severity among participants. The RL score had a mean of 12.5 (SD=5.8), with a median of 12, IQR of 4, and a range of 0-33.

When participants were classified using the ROC-derived threshold (≥14.5), the mean DES score among those without DES (n=105) was 6.2 (SD=4.7), compared to 44.5 (SD=25.8) among those with DES (n=172).

### DESRIL-27 scale internal consistency

Internal consistency reliability of the DESRIL-27 was excellent. Cronbach's alpha for the Symptoms subscale was 0.964 (standardized α=0.965), and for the Risk Level subscale

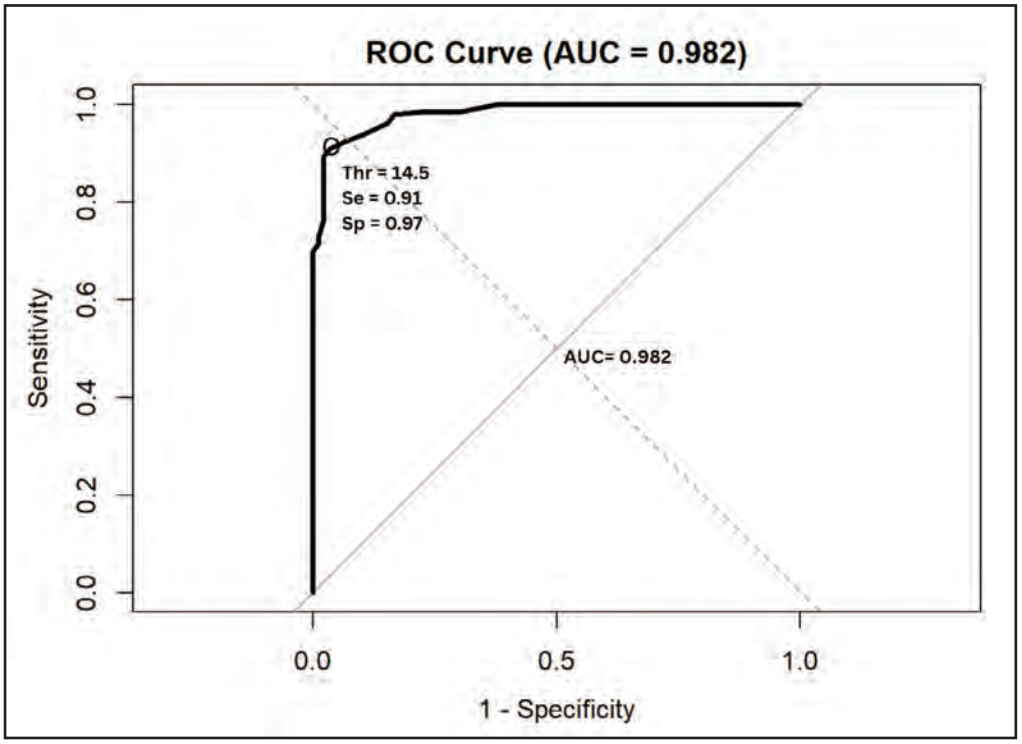


**Fig. 1:** ROC of DES score using CV-Q as reference with threshold value at 14.5.

0.921 (standardised α=0.925). Overall, the DESRIL-27 scale was 0.972 (standardised α=0.973). Although Cronbach's alpha values exceeded 0.90, suggesting strong coherence among items, they may also indicate potential redundancy, where several items measure highly similar construct.

**ROC analysis and diagnostic performance**

Assumption checks confirmed that the DESRIL-27 symptom scores were suitable for non-parametric ROC analysis, with clear distributional separation between CVS-Q groups, appropriate predictor directionality, and fulfilment of the binary outcome requirement.

Visual inspection of histograms showed that DESRIL-27 symptom scores were right-skewed within both CVS-Q–positive and CVS-Q–negative groups; therefore, a non-parametric ROC analysis (DeLong method) was used.

The DESRIL-27 symptoms score showed excellent ability to discriminate CVS-Q–defined DES cases from non-cases. The area under the ROC curve (AUC) was 0.98 (95% CI 0.970, 0.994). Using the CVS-Q classification as the reference standard and applying Youden's index, a cut-off value of ≥14.5 on the DESRIL-27. Figure 1 presents the ROC curve, with the optimal cut-off point (score 14.5) marked on the curve together with its corresponding sensitivity and specificity.

At this threshold (symptom score ≥ 14.5 indicating DES), the diagnostic performance was:

- Sensitivity: 90.9% (169/186; 95% CI 85.8, 94.4)
- Specificity: 96.7% (88/91; 95% CI 90.7, 99.0)
- Positive predictive value (PPV): 98.3% (169/172; 95% CI 94.9, 99.4)
- Negative predictive value (NPV): 83.8% (88/105; 95% CI 75.8, 89.5)

The corresponding 2×2 contingency table comparing DESRIL-27 (cut-off 14.5) with CVS-Q status is shown in Table I. In brief, there were 169 true positives, 88 true negatives, 3 false positives and 17 false negatives. From these estimates, the likelihood ratios were:

- Positive likelihood ratio (LR+): 27.6 (95% CI 9.0, 83.9)
- Negative likelihood ratio (LR–): 0.09 (95% CI 0.06, 0.15)

These values indicate that a positive DESRIL-27 result at ≥14.5 greatly increases the post-test probability of DES, while a negative result substantially reduces it. To allow flexibility in choosing alternative screening thresholds, diagnostic performance at adjacent cut-off values (12, 13, 14, 14.5, 15, 16, and 17) is summarised in Table II. Sensitivity decreased and specificity increased as the cut-off was raised, with the 14.5-15 range providing the best overall balance for screening purposes.

**Prevalence of DES**

Applying the ROC-derived threshold of ≥14.5, the overall prevalence of digital eye strain (DES) among library users was 62.1% (172/277; 95% CI: 56.1, 67.8). Female participants showed a higher proportion of DES cases compared to males (70.4% vs. 45.1%), reflecting their greater representation in the sample. DES was most common among younger users aged 18–24 years (66.0%), and prevalence increased with longer screen exposure, rising from 35.7% among those using

screens for less than 2 hours per day to 70.5% among those exceeding 4 hours. Table III describe the sociodemographic characteristic by DES status and Risk- Level Scores.

## DISCUSSION

This study is among the first in Malaysia to validate and apply the Digital Eye Strain and Risk Level Questionnaire (DESRIL-27) in a university library setting. The DESRIL-27 demonstrated excellent internal consistency, with Cronbach's alpha values well above the conventional threshold of .70 recommended for psychological and health-related instruments.[17] Its discriminative ability against the Computer Vision Syndrome Questionnaire (CVS-Q) reference standard was exceptionally strong, with an AUC of .982. Using ROC analysis, we identified an empirically derived cut-off score of ≥14.5 that produced high sensitivity and specificity, indicating a substantial digital eye strain (DES) prevalence of 62.1% in this population.

The high reliability coefficients observed across both symptom and risk domains suggest that DESRIL-27 is a stable and internally coherent instrument for assessing DES risk. Although Cronbach's alpha values above .90 are often interpreted as excellent consistency, they may also reflect item redundancy, suggesting the possibility of future refinement to shorten the instrument without compromising diagnostic performance. These findings are consistent with earlier validation work on DESRIL-27, which also demonstrated strong internal consistency and robust psychometric characteristics.[10,18] Together, the evidence indicates that DESRIL-27 is well-suited for large epidemiological studies and may have utility as a clinical or occupational screening tool once further implementation pathways are developed.

The observed DES prevalence of 62.1% aligns with global estimates that range from 50-90% among university students and young adults.[1,19,20] It is somewhat lower than the 81% reported among Thai university students during virtual learning, highlighting how prevalence varies with differences in learning modalities, digital workloads, and contextual exposures.[15] Importantly, our data were collected in 2024, after the transition back to hybrid and in-person learning, yet DES remained common suggesting that the increase in digital dependence that occurred during the COVID-19 pandemic has persisted.[18,21,22] This underscores DES as an emerging and ongoing public health concern rather than a transient pandemic-related phenomenon.

The ROC-based cut-off of ≥14.5 demonstrated high diagnostic accuracy. In practical screening contexts, the high positive predictive value (PPV) indicates that most students scoring above this threshold are true DES cases, while the negative predictive value (NPV) suggests that a small proportion of symptomatic individuals may not be detected. These predictive values provide important context for decision-making in university settings: the cut-off can be applied as a first-stage screening tool to identify students requiring targeted ergonomic advice, behavioural interventions, or referral for optometric assessment. The CVS-Q remains a well-established reference standard,[9] but its binary classification system does not capture symptom severity or ergonomic risks. In contrast, DESRIL-27 incorporates symptom frequency, intensity, and environmental factors such as lighting, posture, and viewing distance factors known to influence DES.[23,24]

Although the focus of this paper was on validating the symptom component and establishing a diagnostic cut-off, the risk-level component of DESRIL-27 remains an important part of the instrument. While risk-level data were collected, we did not proceed with full analysis of this component because ergonomic risk evaluation typically requires assessment by a trained and competent ergonomics professional, using standardised ergonomic tools as the gold standard for comparison. Specialised assessment such as workstation observation, lighting measurement, posture scoring, and viewing-distance evaluation was beyond the expertise and scope of the study team.[25,26] Without a recognised gold standard for ergonomic risk assessment in the study setting, it was not methodologically appropriate to validate or compare the DESRIL-27 risk-level scoring system. Future studies incorporating expert ergonomic assessment would allow the risk-level domain to be more rigorously evaluated and interpreted.

This study's multistage sampling approach, which included participants from different library zones at various times of day, provides ecological validity by capturing variation in lighting, seating, device type, and study behaviours. Although zone-specific and temporal analyses were beyond the scope of the present paper, this sampling design establishes a foundation for future work to identify high-risk library environments or peak periods associated with increased DES. Descriptive trends observed in this study for example, higher DES scores among younger students, those with higher BMI, and those with longer screen exposure mirror findings from Jordan, Saudi Arabia, and Malaysia.[27–29] Nonetheless, the cross-sectional design precludes causal inference, and unmeasured factors such as refractive error, sleep quality, and stress may also influence symptom reporting.

Strengths of this study include systematic sampling across 20 library zones, the inclusion of different time periods to reduce temporal bias, and the use of a validated reference tool for ROC analysis. The ROC methodology followed established recommendations for determining optimal thresholds.[11,13] Missing data were minimal and handled by mean replacement, a pragmatic method that may slightly reduce variability but was unlikely to meaningfully affect diagnostic performance. A limitation is that only one university library population was sampled, which may restrict generalisability to other settings such as secondary schools, office workplaces, or clinical populations. Additionally, the ergonomic risk component was not deeply analysed, and observational ergonomic assessments were not conducted, limiting interpretation of risk-level influences.

Despite these limitations, the findings provide strong preliminary evidence that DESRIL-27 is a reliable and valid tool for estimating DES in Malaysian university settings. The high prevalence of DES highlights the need for preventive

strategies rooted in digital health promotion. Universities can incorporate DESRIL-27 into wellness screening initiatives, apply the ≥14.5 threshold to flag students at risk, and deploy targeted interventions such as the 20-20-20 rule, scheduled micro-breaks, visual hygiene education, and ergonomic improvements in study spaces.[30,31] Future studies should analyse the risk-level subscale in detail, conduct stratified and longitudinal analyses, and test integration of the tool into student health services to support early identification and management of DES.

## CONCLUSION

This study provides strong evidence that the DESRIL-27 is a reliable and valid instrument for assessing digital eye strain among Malaysian university students, demonstrating excellent internal consistency and exceptional discriminatory performance against the CVS-Q reference standard. The empirically derived cut-off score of ≥14.5 effectively identified a high prevalence of DES, underscoring the growing public health relevance of digital visual symptoms in post-pandemic academic environments. Although the risk-level component could not be fully evaluated due to the need for expert ergonomic assessment and absence of a gold standard comparison, the findings highlight the potential of DESRIL-27 as a practical screening tool for universities to identify at-risk students and guide early preventive measures. Future research incorporating competent ergonomic evaluation, longitudinal follow-up, and application across diverse settings will further strengthen the instrument's utility and support the development of comprehensive digital eye health strategies.

## ACKNOWLEDGEMENTS

The authors sincerely thank the MPH Class of 2023–2024, the Universiti Malaysia Sabah library staff, and all participants for their kind cooperation and valuable contributions to this study.

## FUNDING

This research was carried out without any external funding support.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

## REFERENCES

1. Sheppard AL, Wolffsohn JS. Digital eye strain: Prevalence, measurement and amelioration. BMJ Open Ophthalmol 2018; 3(1): e000146.
2. AOA. Amerian Optometric Association. Computer vision syndrome. 2024. [cited 2025 June 25]. Available from: https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/computer-vision-syndrome/
3. Portello JK, Rosenfield M, Chu CA. Blink rate, incomplete blinks and computer vision syndrome. Optom Vis Sci 2013; 90(5): 482-7.
4. Reddy SC, Low CK, Lim YP, Low LL, Mardina F, Nursaleha MP. Computer vision syndrome: A study of knowledge and practices in university students. Nepal J Ophthalmol 2013; 5(2): 161-8.
5. Iqbal M, Elzembely H, Elmassry A, Elgharieb M, Assaf A, Ibrahim O, et al. Computer vision syndrome prevalence and ocular sequelae among medical students: A university-wide study on a marginalized visual security issue. Open Ophthalmol J 2021; 15(1): 156-70.
6. Wang C hui, Chang WP, Chen SR, Cheng WJ, Chou KR, Pien LC. Health literacy and exercise to treat frailty in community-dwelling older adults: a national survey study. Int J Environ Res Public Health 2022 17;19: e8711.
7. Ranasinghe P, Wathurapatha WS, Perera YS, Lamabadusuriya DA, Kulatunga S, Jayawardana N, et al. Computer vision syndrome among computer office workers in a developing country: An evaluation of prevalence and risk factors. BMC Res Notes 2016; 9: 150.
8. Alshawawreh MY, Alharbi MT, Albeladi RA, Afandi RA, Alharbi RA, Alrehaili AM, et al. Digital eye strain (DES) among children attending online classes during Covid-19 pandemic in Al-Madinah Region, Saudi Arabia. Med Sci 2022; 26(130): ms572e2638.
9. Seguí MDM, Cabrero-García J, Crespo A, Verdú J, Ronda E. A reliable and valid questionnaire was developed to measure computer vision syndrome at the workplace. J Clin Epidemiol 2015; 68(6): 662-73.
10. Hamid Z, Sharbini S, Abdul Rahman H, Idris FI, Naing L. The development and validation of a questionnaire measuring digital eye strain and risk level (DESRIL-27). Research Square 2023 [PrePrint].
11. Habibzadeh F, Habibzadeh P, Yadollahie M. On determining the most appropriate test cut-off value: the case of tests with continuous results. Biochem Medica 2016; 26(3): 297-307.
12. Sharma B, Jain R. Right choice of a method for determination of cut-off values: A statistical tool for a diagnostic test. Asian J Med Sci 2014; 5(3): 30-4.
13. Hassanzad M, Hajian-Tilaki K. Methods of determining optimal cut-point of diagnostic biomarkers with application of clinical data in ROC analysis: an update review. BMC Med Res Methodol 2024; 24(1): 84.
14. Cochran WG. Sampling techniques. 3rd Edition. Chapter 3; Sampling proportions and percentages New York: John Wiley & Sons; 1977: 50-68
15. Wangsan K, Upaphong P, Assavanopakun P, Sapbamrer R, Sirikul W, Kitro A, et al. Self-reported computer vision syndrome among Thai University students in virtual classrooms during the Covid-19 pandemic: prevalence and associated factors. Int J Environ Res Public Health 2022; 19(7): e3996.
16. Abt G, Boreham C, Davison G, Jackson R, Jobson S, Wallace E, et al. Sample size estimation revisited. J Sports Sci 2025; 43(21): 2511-6.
17. Kline P. Handbook of psychological testing. 2nd ed. London: Routledge; 2013. [cited 2025 Aug 22]. Available from: https://www.taylorfrancis.com/books/9781317798057
18. Hamid Z, Sharbini S, Balalla NBP, Maddess T, Abdullah SNL. Prevalence and risk factors for digital eye strain and musculoskeletal disorders among financial workforce of Brunei Darussalam. Brunei Int Med J 2025; 21: 12-21.
19. Bhatnagar KR. Digital eye strain among medical students associated with shifting to e-learning during Covid-19 pandemic: an online survey. Indian J Ophthalmol 2023; 72(1):98-104.
20. Alqarni AM, Alabdulkader AM, Alghamdi AN, Altayeb J, Jabaan R, Assaf L, et al. Prevalence of digital eye strain among university students and its association with virtual learning during the Covid-19 pandemic. Clin Ophthalmol 2023; 17: 1755-68.
21. Abed Alah M, Abdeen S, Selim N, AlDahnaim L, Bougmiza I. Computer vision syndrome among students during remote learning periods: Harnessing digital solutions for clear vision. Front Public Health 2023; 11: 1106036.
22. Abusamak M, Jaber H, Alrawashdeh HM. The effect of lockdown due to the covid-19 pandemic on digital eye strain symptoms among the general population: A cross-sectional survey. Front Public Health 2022; 10: 923232.

23. Alamri A, Amer K, Aldosari A, S. Althubait B, Alqahtani M, M. Al Mudawi A, et al. Computer vision syndrome: Symptoms, risk factors, and practices. J Fam Med Prim Care 2022; 11(9): 5110-5.
24. Boadi-Kusi SB, Adueming POW, Hammond FA, Antiri EO. Computer vision syndrome and its associated ergonomic factors among bank workers. Int J Occup Saf Ergon 2022; 28(2): 1219-26.
25. DOSH M. Guidelines on occupational safety and health for lighting at workplace 2018. Department of Occupational Safety and Health Malaysia (DOSH), editor. Ministry of Human Resources, Malaysia; 2018.
26. DOSH M. Guidelines on ergonomics risk assessment at workplace 2017. Department of Occupational Safety and Health, editor. Ministry of Human Resource; 2017.
27. Gammoh Y. Digital eye strain and its risk factors among a university student population in Jordan: A Cross-Sectional Study. Cureus 2021; 26(13): e13575.
28. Al-Atawi SK. Risk factors of digital eye strain among computer users at Al-Baha University. Afr Vis Eye Health 2023; 82(1), a815.
29. Chen AH, Rosli SA. Electronic display devices: a study on screen display towards the health issues among malaysian university students. J ICT Educ. 2022:9 (1) 1-9
30. Hayes J r, Sheedy J e, Stelmack J a, Heaney C a. Computer use, symptoms, and quality of life. Optom Vis Sci 2007; 84(8): E738-55.
31. Kaur K, Gurnani B, Nayak S, Deori N, Kaur S, Jethani J, et al. Digital eye strain- a comprehensive review. Ophthalmol Ther 2022; 11(5): 1655-80.