Original Article

Assessment Of Digital Eye Strain With The Digital Eye Strain Scoring Index (DESSI)

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Abstract

Purpose: This study aims to assess digital eye strain (DES) with the help of the digital eye strain scoring index (DESSI) in the urban population.

Methods: The subjects were carefully selected with no ocular or systemic problems that may alter the study results and prior written consent was obtained. This study is divided into two phases. Phase 1 consists of reliability testing with Cronbach's alpha and test-retest reliability while phase 2 consists of validity testing with internal validity, sensitivity and specificity. In phase 1 there were two visits, a baseline visit and a retest visit with 24 hours gap. DESSI was implemented on both visits. Phase 2 had two visits on the same day called the pre-task visit and post-task visit separated by one-hour task performance. Pre and post-task assessments were compared for all variables in the DESSI. The smartphone addiction scale (SAS) assessment and disability index (DI) was correlated with the no. of hours of smartphone use. The sensitivity and specificity were also assessed.

Results: In phase 1, Cronbach's alpha value was 0.82 and the co-relation coefficient was found to be acceptable to excellent whereas, in phase 2, the paired sample t-test showed statistically significant differences for all the tests compared. The SAS and DI correlation with the no. of hours of smartphone use was found to be good. The sensitivity and specificity of DESSI were fair, scoring 51% and 53% respectively.

Conclusion: The digital eye strain is a useful tool for clinicians who can accurately analyze digital eye strain with acceptable to excellent test–retest reliability, internal consistency, good validity, fair sensitivity, and specificity.

INTRODUCTION

Digital eye strain (DES), caused by viewing digital devices can lead to glare, defocus, accommodation dysfunction, fixation discrepancy, dryness, discomfort, eyestrain, headaches, impaired vision, dry eyes, and pain in the neck and shoulders (1). Extended use of digital devices strains the musculoskeletal system, eye, and vision-related issues such as blurred vision (1). According to the telecom authority of India's annual report till March 2021, the wireless internet subscribers in India were 1180.96 million making the teledensity at 86.68%. The urban users were 645.20 million while the rural users were 535.75 million (2,3). These numbers demonstrate the extent of utilization of digital viewing devices that inevitably are associated with health concerns; predominantly affecting our eyes, body posture, and mental health (2).

Over the past 20 years, DES has received much-needed attention in the scientific literature (3). A multi-nation European study documented that by the age of three, 68% of kids frequently use digital devices and 54% engage in online activities (4). The average time adults spent viewing digital media per day in the UK was reported to be at 4 hours and 45 minutes (5). In the USA, two-thirds population between the ages of 30-49 were found to spend 5 hours or more daily viewing digital devices (6). Globally, the usage of digital devices has significantly expanded across all age groups, notably with aid of smartphones.

According to US data from 2018, 37% of people aged 60 and older use digital devices daily for 5 or more hours (3). This age group favours laptops and desktop digitals for web browsing, whereas younger adults are more likely to use smartphones and are more likely than older adults to use social media and multitask, with 87% of people in the 20–29 age range using digital devices regularly (4). In another observation made in the US, adult Americans watched digital media for 5.6 hours per day on average in 2016 where mobile phones were viewed for 3.1 hours, personal computers and laptops were viewed for 2.2 hours, and other devices were utilized, including game consoles (0.4 hours). In 2016, 78% of American adults had access to a digital viewing device, 77% had a smartphone, 51% had a tablet, and 22% had an e-reader. The link between increased digital device use and symptoms of DES is well-established (8,9), however, the tools for assessing digital eye strain are scarce.

After the discovery of the novel coronavirus in 2019, social and professional activities shifted to a web-based platform, resulting in a dramatic rise in the utilization of digital devices, in turn increases the total amount of daily screen time for essential work as well as entertainment (7). This includes work from home, personal and social video chats, online

meetings, conferences, webinars, online classes for students, assignments on digital devices, online shopping, leisure, and entertainment (7). A systematic review in India studied the prevalence of DES symptoms (at least 1 symptom present) before and after the COVID- related lockdown (8). Out of 104 studies in total that matched the inclusion criteria, 15 showed positive DES findings. Of all, it was noticed that 93.6% of respondents said they had increased their screen time after the announcement of the lockdown. The prevalence of DES was 64.3% during the pre-lockdown whereas the overall prevalence together pre and post-lockdown of DES was 87.3% (8).

Bhanu P. explains that the human visual system is trained to view far and near objects by focusing on them with the help of pupil size changes and adjustments in focal length. Whereas, this concept does not work while viewing a digital screen where the eyes have to be focused on the focal length of the screen. The disparity between focal length and parallax observed between eyes confuses the brain and eventually the visual system. This confusion gives rise to the symptoms like headaches or blurred vision while viewing digital screens for longer durations (9). Yano S. also supports this line of mechanism and suggests that due to the overuse of smartphones, there is excessive binocular parallax and a conflict between convergence eye movement and the accommodation function (10). The symptoms can be divided into two types, internal and external symptoms. The internal symptoms include visual problems like headache, blurred vision, heaviness of the eyes, accommodative, and vergence. The external symptoms include redness, dryness, burning, itching, and watering along with musculoskeletal discomfort such as neck and shoulder pain from associated poor ergonomics (3).

Prolonged periods of a daily visual display terminal (VDT) and smartphone use have been identified as risk factors for dry eye disease (DED) in children (1,4,11). The International Dry Eye Workshop II (DEWS II) of the Tear Film and Ocular Surface Society (TFOS) defined dry eye as 'Dry eye is a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles' (11). Recent guidelines for diagnostic methods were included in the DEWS-II report and it suggested the use of both subjective and objective measures for the confirmed diagnosis of dry eye, where subjective assessment included ocular surface disease index (OSDI) and dry eye questionnaire (DEQ-5) while objective assessment included at least one positive sign from breakup time (ideally non-invasive), osmolarity, and ocular surface staining with fluorescein and lissamine green (3).
Children with DED aged 7 to 12 who stopped using their smartphones for four weeks saw significant improvements in non-invasive tear break-up time, punctate epithelial erosion, and OSDI scores (1). At the conclusion of the abstinence period, all affected children were no longer considered to have DED (12).

Over the past 10 years, there has been a sharp increase in the use of smartphones worldwide. Smartphones vary in screen sizes, routine usage activities, and viewing distances compared to other digital devices e.g., desktop computers, laptop computers, and smart-watches. The long-term effects of using a smartphone or other portable digital device on the eyes remain unknown. However, using smartphones has been linked to a variety of short-term side effects, such as ocular surface pain, visual discomfort, and asthenopia symptoms (13). Dry eye symptoms increased with mobile phone use and decreased when the use of the phone was discontinued, according to research on Korean primary school students (3). When using smartphones for more than two hours a day, Korean teens had more than a two-fold rise in eye discomfort and vision problems. According to several studies, young adults' eye strain and blur can increase up to five times in just one hour of tablet or smartphone use (3,4,11,15).

It has been observed that smartphone users are drawn to smartphones for long hours of use causing stress. It is suggested that smartphones offer distraction and hence provide comfort and escape from reality (14). In addition, smartphones provide ease of access for day-to-day tasks making them advantageous accessary for smooth modern-day activities. This may lead to feelings of attachment to smartphones among its users. Attachment to smartphones has negative psychological consequences such as separation anxiety (14).

Along with the ocular and musculoskeletal effects, digital devices also affect mental health (13), also called smartphone separation anxiety (or nomophobia) (15,17). The study found that any unavailability of the smartphone feature like unavailable or lack of a phone network, and less battery power of the smartphone was the major cause of anxiety levels (15). Currently, people are heavily dependent on digital devices for internet availability, entertainment, interpersonal relationship, social networking, economic transactions, and overall information and knowledge gathering. Overdependence on smartphones has been found to cause addiction (16).

Any study based on systematic approaches is needed to quantify signs and symptoms associated with the concerned clinical condition. So that the data can be analyzed, and patterns observed for diagnosis and assessing the efficacy of management plans. In the case of DES, the most assessed factor that pre-dominantly is reported in the literature is an assessment of symptoms such as with the help of a computer vision syndrome questionnaire (CVSQ) (17). Other common instruments used include OSDI (18) and Mc Monnies questionnaire (19). While the CVSQ evaluates symptoms of computer vision syndrome, the OSDI and Mc Monnies questionnaires mainly focus on symptoms of dry eyes. Digital device-associated health concerns are multifactorial in their causes, signs, and symptoms. The scientific literature had tried to capture many of these factors in isolation or a combination of a few; however, there is a lack of a validated

comprehensive tool that can be used for accurate diagnosis, classification, and assist in the management of digital eyestrain.
The digital eye strain scoring index (DESSI) is a novel instrument that was created to address the gap left by the lack of a scientifically produced and validated comprehensive tool for the assessment of DES (20). It simplifies the assessment of this multifactorial problem by combining the assessment in segments for ocular muscle balance with the help of accommodation and vergences, ocular surface-related signs, ocular surface-related symptoms with the help of CVSQ (17), disability items and the smartphone addiction scale (SAS)(16) to measure addiction. The 15-item DESSI is a clinical and research tool for eye care professionals that is intended to diagnose DES in viewers of digital screens. DESSI provides a total score, four categories of scores, and a special feature called red flags that, regardless of the final score, indicate a situation that calls for the clinician or examiner to take action. With these inbuilt features, DESSI provides an excellent comprehensive assessment tool. The purpose of the study was to assess DES using a newly developed comprehensive tool.
The objective of the current study is to evaluate the reliability and validity of the DESSI to assess DES in an urban population.

METHODS

This study was conducted based on the protocol of the declaration of Helsinki. Written informed consent was obtained from all the subjects prior to enrollment. The study was approved by the institutional human ethics committee of Chitkara University, Punjab, India. The study design was multi-centred, cross-sectional, experimental and prospective evaluation.

Subjects

The study comprised regular smartphone users over the age of 18. Regular use is defined as using a smartphone on average for a cumulative two hours or longer, at least five days each week. Subjects with distance visual acuities of 0.0 LogMAR or better were included. Functional acuity and contrast sensitivity of 0.0 LogMAR (FACT) or better along with the typical Morgan's values for tropia and phoria, refractive error up to +3.00D, -2.50D, and the cylinder was added (distance positive fusional vergence (PFV): X/7/4 and negative fusional vergence (NFV): 9/19/10, near PFV: 13/21/13 NFV: 17/21/11). In addition, any digital screen use including television, computers, tablets, smartphones or smartwatches at least three hours before the visit was discouraged. However, we understand that occasional viewing could not have been avoided, but care was taken to arrange the visits in the morning hours so the subjects could move on with their digital device-driven regular tasks.
The following conditions were excluded: myopia and hyperopia greater than 3.00D, cylinder greater than 2.50D, binocular vision anomalies, presence of pre-existing ocular surface disorders, history of ocular surgery, pregnancy, smoking, history of ocular or systemic allergies. Additionally, viewing on smartphones for fewer than two hours on average was disallowed. Subjects with chronic systemic illness, including that caused by age, disability, or migraine, were also disqualified.

Study Protocol

Once the subject qualified for the study according to the inclusion/exclusion criteria, written informed consent was obtained. Subjects then underwent the preliminary assessment with the newly developed DESSI.
This study is divided into phases 1 and 2 as shown in figure 1.

Phase 1

In Phase 1, the reliability testing was performed using Cronbach's Alpha on a sample size of 30 participants and test-retest repeatability on a sample size of 15 subjects. There were two visits on each day separated by at least 24 hours for test-retest repeatability. The first is referred to as a baseline visit and the second is a retest visit. Post completion of the pre-assessment sheet, the subject underwent the baseline DESSI assessment which includes an ocular muscle balance assessment (the amplitude of convergence, the amplitude of accommodation, accommodation facility, the accommodation response and the amplitude of fusional vergences), ocular surface assessment (Corneal staining, conjunctival staining, tear film stability, tear film volume and lid wiper epitheliopathy), the DES symptoms assessment (CVSQ and disability index [DI]) and smartphone addiction assessment (SAS). Subjects were instructed to return to the clinic for visit 2 after a minimum wash-out period of 24 hours later to establish test-retest reliability. The individuals got a second evaluation of their visual acuity and DESSI. Here, the pre-assessment questions of DESSI were excluded.

Phase 2

In Phase 2 the internal validity of DESSI was evaluated on the sample size of 85 participants. There were two visits for the internal validity assessment on the same day. After undergoing a pre-task visit similar to reliability testing, the subjects were given 10 to 15 minutes to settle before being asked to undertake a digital viewing task. The subjects were assigned a task known to promote DES. The task performance was a video game for one hour. After the task was completed, the DESSI was re-evaluated in post-task visits excluding the pre-assessment questions.
All of the clinical tests included are well-known and commonly used validated clinical assessments. Since these tests weren't explicitly validated for DES, the purpose of their validation was to see whether they could help assess DES. Since the SAS and DI tasks will not vary within an hour, they were analyzed in relation to the amount of screen time that is used.

DES assessment

In the current investigation, the DES was assessed using DESSI. The presence of accommodation, vergence dysfunction, dry eyes, symptoms of ocular discomfort, and smartphone addiction triggered by smartphone use served as diagnostic indicators. The test used to assess the accommodation and vergence were the amplitude of accommodation, the amplitude of convergence, accommodative facility, accommodative response, and negative and positive fusional vergences. Tear volume, tear stability, and lid wiper epitheliopathy were the tests to assess the ocular surface quality. The symptoms assessment of DES was performed using CVSQ and addiction was assessed using SAS (20). The 15 items of DESSI were scored based on the binary scoring method. The test whose scores were within normal limits was coded as '0', whereas the test whose results were outside the normal limits was coded as '1'. The ocular muscle balance, ocular surface-related symptoms, and disability items categories are highlighted with red flags. If any test from these categories was not within normal limits, they were given special attention by the examiner to counsel/refer the subject for appropriate treatment.
The coded scores were counted and noted at the completion of the scoring index. The total score was then analyzed against normal, mild, moderate and severe categories (20). The cut-off values for the DESSI score are represented in table 1.

Statistical analysis

Mean and standard errors were used for demographic distribution. The normality of the data was tested using SPSS software, with the help of Kolmogorov-Smirnov and Shapiro-Wilk's test. The reliability was tested with test-retest repeatability using a correlation coefficient. Cronbach's alpha was used for the assessment of internal consistency. The internal validity was tested using paired sample t-test which helped to identify statistically significant differences when compared between pre- and post-task measurements where data followed a normal distribution and the Friedman test where data did not follow the normal distribution. The addiction and disability index were correlated with no. of hours of screen time using a correlation coefficient. The sensitivity and specificity were also assessed.

RESULTS

Subject's features

The Phase 1 analysis of Cronbach's alpha was conducted on 30 participants aged 29 ± 1.17 years, of them, 13 were females (43.33%). The average number of hours spent by these participants using digital devices was 4.96 ± 0.13 hours per day. The mean spherical equivalent for the right eye was -0.38 ± 0.18D and for the left eye was -0.72 ± 0.21D. Test-retest reliability was conducted on 15 (Age 24.4 ± 5.24 years) participants of them 4 were males and 11 were females. The average number of hours spent by these using digital devices was 4.4 ± 0.91 hours per day.

Phase 2 of DESSI was conducted on 85 participants (Age 29 ± 0.68 years) where 42 were males and 43 were females. The mean spherical equivalent for the right eye was -0.26 ± 0.08 D and for the left eye was -0.43 ± 0.10D. The average digital viewing hours spent daily were 6.3 ± 0.18 hours per day.

Phase 1

All the tests were normally distributed except post-accommodative facility and response, pre and post-PFV blur, post-PFV recovery, pre and post-NFV blur, pre and post-NFV, pre and post-corneal staining and pre-conjunctival staining. Cronbach's alpha of the overall DESSI was calculated with two factors without replication and the result was 0.82.

Using a correlation coefficient, the test and retest repeatability analysis was carried out, and it was discovered to have acceptable to excellent reliability as shown in Table 2. The tests' amplitude of accommodation, the amplitude of convergence, accommodative response, PFV recovery, NFV blur, tear volume, and tear stability were analyzed for test-retest reliability and achieved excellent reliability. The PFV blur, NFV – break, and accommodative facility, CVSQ tests had good reliability. The tests of PFV break and NFV recovery had acceptable reliability.

Phase 2

All the variables were found to be normally distributed. Paired sample t-test showed that; the amplitude of convergence break, recovery, accommodative facility, accommodative response, positive fusional vergence break and recovery, negative fusional vergence blur, break and recovery, tear stability, lid wiper epitheliopathy, tear volume and computer vision syndrome, positive fusional vergence – break and amplitude of accommodation were all statistically significant differences when compared between pre-task and post-task visits (Table 3).
The internal validation of SAS and DI was conducted. The mean DI was 3.49 ± 1.34, SAS was 35.96 ± 7.03 and no. of hours of screen time was 5.98 ± 1.92. The correlation coefficient of smartphone addiction with no. of hours of screen time was 0.74, the correlation coefficient of disability index with no. of hours of screen time was 0.59 and the correlation coefficient of disability index with smartphone addiction is 0.81. The sensitivity was 0.51, the specificity was 0.53.

DES assessment

At baseline in Phase 2, 63 participants were found to have DES with an average DESSI score of 21.25 +/- 4.35 SD when checked with DESSI criteria. Post-task assessment indicated that all the participants had an increased total score mean of 23.59 +/- 3.66 SD.

DISCUSSION

Similarities were found in the percentage of the adult population exhibiting symptoms of DES in our study done in, India and previously reported statistics from the US, where both countries reported that 87% of the population exhibited signs and symptoms of DES (2,4,5). Slight differences were seen for the average number of hours spend viewing digital devices, individuals use digital devices for roughly 5 hours per day on average in the UK and the respondents in the current study used digital devices for an average of 6 hours a day which is somewhat similar to the data obtained from UK and US.

The current study had some important methodological considerations. To avoid bias, all of the subjects were purposefully chosen to be unrelated to eye care services, carefully excluding optometrists, ophthalmologists, opticians and ophthalmic technicians. The appointments were given to all subjects in the morning, with the instruction to minimize exposure to digital screens beyond necessary before the clinical visit. Morning appointments allowed us to test the ocular muscle balance almost accurately and obtain results with minimal digital screen exposure.

For internal consistency assessment, although the sample size was small, the results were acceptable. According to the test-retest reliability of individual items, responses to the DESSI's test are consistent for repeated readings. For the disability index and addiction scale, test-retest reliability was not conducted as 24 hours was simply not enough time to notice any changes in these questions.

In the absence of an established gold standard as such, that is relatable to the evaluation of DES, internal validity was our best choice to report in this study. The ocular muscle balance, ocular surface-related symptoms and DES symptoms assessment using CVSQ were assessed by DES-inducing task which was performed for one hour (21). The impact of the pre-and post-task on DES was analyzed using paired sample t-test. The amplitude of accommodation showed a lower significance value for pre- and post-task. In the paper by Juanita D. (22), the maximum accommodative lag reported between the symptomatic and non-symptomatic groups is 0.93D among 20 adults with a mean age group of 24 years for a half-hour of sustained laptop work. In the current study, the mean difference between pre-and post-task was 1.2 D on 85 samples with a mean age of 29. Considering the higher significance achieved for other accommodative tests performed in DESSI like accommodative response and accommodative facility, more studies are required to study the accommodative micro fluctuations which will give detailed insights into changes in accommodation and taking into account the sample size and the task duration (4). The break value PFV demonstrated moderate significance emphasizing that inconsistent outcomes have been recorded (3). There has been a slight change, according to the authors who reported the changes in the vergences. Reference here A similar difference was found in our study, which is in line with their findings. Further evaluation is needed on smartphone use because the previously reported vergence studies are primarily computer-based and smartphone use varies with computer use in working distance, screen size, etc. The impact of smartphone use on the health of the ocular surface and tear film was examined in the study by Choi JH (21). While the CVSQ and tear stability both significantly changed, the tear volume did not, in their study (17) which is consistent with the current study. The current study's tear volume data show a mean difference of 0.03 mm. Blink rate is one of the many variables that might cause changes in the tear volume (23). More studies are required to analyze the effects of smartphone use on lid wiper epitheliopathy. In the hour-long DES exposure task, the responses to smartphone addiction and the disability index remained unchanged. More timely observation is needed to detect the shift, which was outside the scope of this study. Similarly, the current study's DES exposure task performance time was insufficient to detect a significant difference between the corneal and conjunctival staining before and after the task.

A sensitivity and specificity value of more than 0.5 is considered to have good predictability and below is considered a poor predictive value. Hence, DESSI can be considered a diagnostic tool. Quartiles were used to establish the severity score cutoff range. The DESSI was created with the intention of giving the examiner a DES score together with the severity range so they could track the development from all angles.

In general, the DESSI has shown to be a useful instrument for evaluating the DES. The symptoms of DES overlap with the symptoms of ocular muscle imbalance, and ocular surface disruption. Objective tests for accommodation and vergences are used to evaluate the ocular muscle imbalance, whilst subjective testing and corneal conjunctival staining tests are used to evaluate the ocular surface quality. Quite a few studies have examined how addiction affects excessive smartphone use (19,26). DESSI is unique in its ability to evaluate DES with both objective and subjective assessments.

In Conclusion, DESSI is a systematic tool that can objectively and subjectively evaluate and measure DES. The DESSI has good sensitivity, specificity and reliability. By offering a quantifiable assessment of DES, it should serve as a useful supplement to clinicians who can effectively analyze DES.

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Tables

Table 1: *The table represents the severity and red flags cut-off values for the digital eye strain scoring index*

	DESSI score
Normal	0 - 12
Mild	13 - 17
Moderate	18 - 22
Severe	23 - 30

Table 2: *The test-retest repeatability of the digital eyestrain scoring index is summarized in the below table. The mean baseline value indicates the values obtained on visit 1 after performing the Digital eyestrain scoring index on subjects. The mean retest value indicates the values obtained on visit 2 after performing the digital eyestrain scoring index. The correlation coefficient between visit 1 and visit 2. A correlation coefficient value of +1 indicates a perfect relationship, 0.8 indicates a fairly strong relationship, 0.6 indicates a moderately positive relationship, 0.4 indicates a weak relationship and 0 indicates no relationship.*

Name of the test	**Baseline (Mean ± SE)**	**Re-test (Mean ± SE)**	**Correlation coefficient**
Amplitude of accommodation	9.93 ± 5.64	9.87 ± 6.57	0.98
Accommodative convergence -break	9.53 ± 4.90	9.67 ± 5.37	0.95
Accommodative convergence – recovery	12.93 ± 4.77	13.73 ± 4.54	0.96
Accommodative facility	6.33 ± 1.59	5.67 ± 1.68	0.87
Accommodative response	-0.57 ± 1.08	-0.50 ± 1.10	0.97
Positive fusional vergence – blur	13.33 ± 2.09	14.00 ± 1.60	0.80
Positive fusional vergence – break	16.00 ± 1.69	16.67 ± 2.02	0.79
Positive fusional vergence – recovery	13.47 ± 3.58	13.07 ± 3.01	0.93
Negative fusional vergence – blur	10.00 ± 2.83	10.93 ± 3.20	0.94
Negative fusional vergence – break	13.60 ± 3.14	13.60 ± 2.41	0.84
Negative fusional vergence – recovery	11.87 ± 3.07	11.33 ± 3.18	0.75
Tear stability	12.07 ± 1.28	12.13 ± 1.41	0.86
Tear volume	25.80 ± 7.18	25.80 ± 6.90	0.97
Computer vision syndrome	2.80 ± 1.32	3.73 ± 1.33	0.81

Table 3: *This table indicates the paired sample t-test values which were used to test the internal validity of the digital eye strain scoring index (DESSI) when compared between pre- and post-task performance. The mean of baseline values indicates the mean of DESSI values obtained during visit 1 and the mean of post-task values indicates the mean of DESSI values obtained during visit 2.*

Name of the test	Mean of pre-task values	Mean of post-task values	P value
Amplitude of accommodation	12.88	11.68	<0.5*
Accommodative convergence -break	8.58	12.21	<0.001***
Accommodative convergence – recovery	11.11	15.30	<0.001***
Accommodative facility	7.91	4.24	<0.001***
Accommodative response	0.03	1.43	<0.001***
Positive fusional vergence – blur	17.27	20.13	<0.001***
Positive fusional vergence – break	20.73	23.94	<0.01**
Positive fusional vergence – recovery	15.52	18.06	<0.001***
Negative fusional vergence – blur	16.55	19.59	<0.001***
Negative fusional vergence – break	20.55	23.64	<0.001***
Negative fusional vergence – recovery	15.04	17.66	<0.001***
Tear stability	10.47	8.76	<0.001***
Lid wiper epitheliopathy	0.10	0.13	<0.001***
Tear volume	0.10	0.13	<0.001***
Computer vision syndrome	6.06	8.41	<0.001***

**p < 0.05, **p < 0.01, ***p < 0.001*

Figures

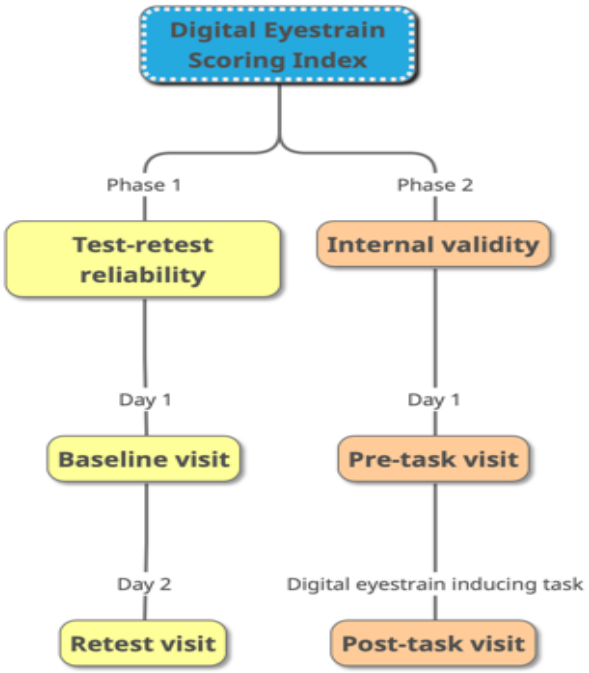


Figure 1: *The flowchart detailing the flow of the study for testing the reliability and validity of the digital eye strain scoring index*

Figure 2: *The flowchart detailing the methods used for testing the reliability and validity of the digital eye strain scoring index*

DESSI
Digital Eye Strain Scoring Index

Summary Diagnosis

Digital eye strain Score	
Total Red flags	

Classification

Normal	0 – 12 score
Mild	13 – 17 score
Moderate	18 – 22 score
Severe	23 – 30 score

Management plan

_____

_____

_____

Referral

Ophthalmologist	
Psychologist	
Others	

Clinician's name

_____

_____

Date:

Demographic data

Patient ID	
Name	
Age (years)	
Gender	
Occupation	
Phone number	
Email ID	

Present glass prescription

	Sph	Cyl	Axis	Vn
OD				
OS				
OU Near Vision				@ ….. cm

Digital use history

Please note the average time you spend viewing your digital devices, e.g., 30 minutes to catch up on news on TV or 2 hours watching your favorite web series on OTT platforms e.g., Netflix, prime videos, etc.

Device type	Number of hours	Red flag (Yes/No)
Smart-phone		
Television		
Tablets		
Desktop computer		
Laptop computer		
Total digital viewing hours		

* Mark as a red flag if > 6 hours

Questions	Responses: Very frequently (VF) / Frequently (F)/ Occasionally (O) / Rarely (R)/ Never (N)
How long do you use your smartphone in a day on average?	
Do you delay your night's sleep because of smartphone use?	
Do you need to modify your smartphone to relieve symptoms of visual disturbances like increasing text size, adjusting brightness, etc?	
Are you wearing any kind of refractive correction like spectacles or contact lenses which are specifically prescribed for use while viewing digital devices?	

* If response is F/VF, it will be considered as red flag

Clinical signs of digital eye strain

Ocular muscle balance assessment

Name of the test and its credit score	Red flag indicator	Acceptable range	Credit score	Patient Score
Amplitude of accommodation		18-1/3 (age) ± 2D*	3	
Accommodative facility		11 - 16 cycles per minute	3	
Accommodative response (Lead/Lag)		-0.50D - 0.75D	3	
Amplitude of convergence		Break: 2.5 - 5.0 Recovery: 4.5 - 7.5	3	
Fusional vergence amplitude – Base Out		Blur: 17 - 22 Break: 21 - 27 Recovery: 11 - 18	1	
Fusional vergence amplitude – Base In		Blur: 13 - 17 Break: 21 - 25 Recovery: 13 - 18		

Total red flags: _____ Total score: _____

Name of the test and its credit score	Red flag indicator	Acceptable range	Credit score	Patient Score
Tear Volume		0.15 or more	1	
Tear film stability		10 seconds or more	2	
Corneal staining		Grade 1 or lower	1	
Conjunctival staining		Grade 1 or lower	1	
Lid wiper epitheliopathy		Grade 1 or lower	1	

Total red flags: _____ Total score: _____

Symptoms of the discomfort of digital eye strain

Name of the test and its credit score	Red flag indicator	Acceptable range	Credit score	Patient Score
Computer vision syndrome questionnaire		≥ 6 points	3	
During the last 7 days have you been prevented from carrying out normal activities like viewing text, e-mails, and comments [8]?		Score 0	1	
Insufficient breaks or pauses (1)?		Score 0	3	
Have you at any time during the last 7 days had trouble such as: ache, pain, and discomfort, numbness in the neck, shoulders or both (2)?		Score 0	2	

Total red flags: _____ Total score: _____

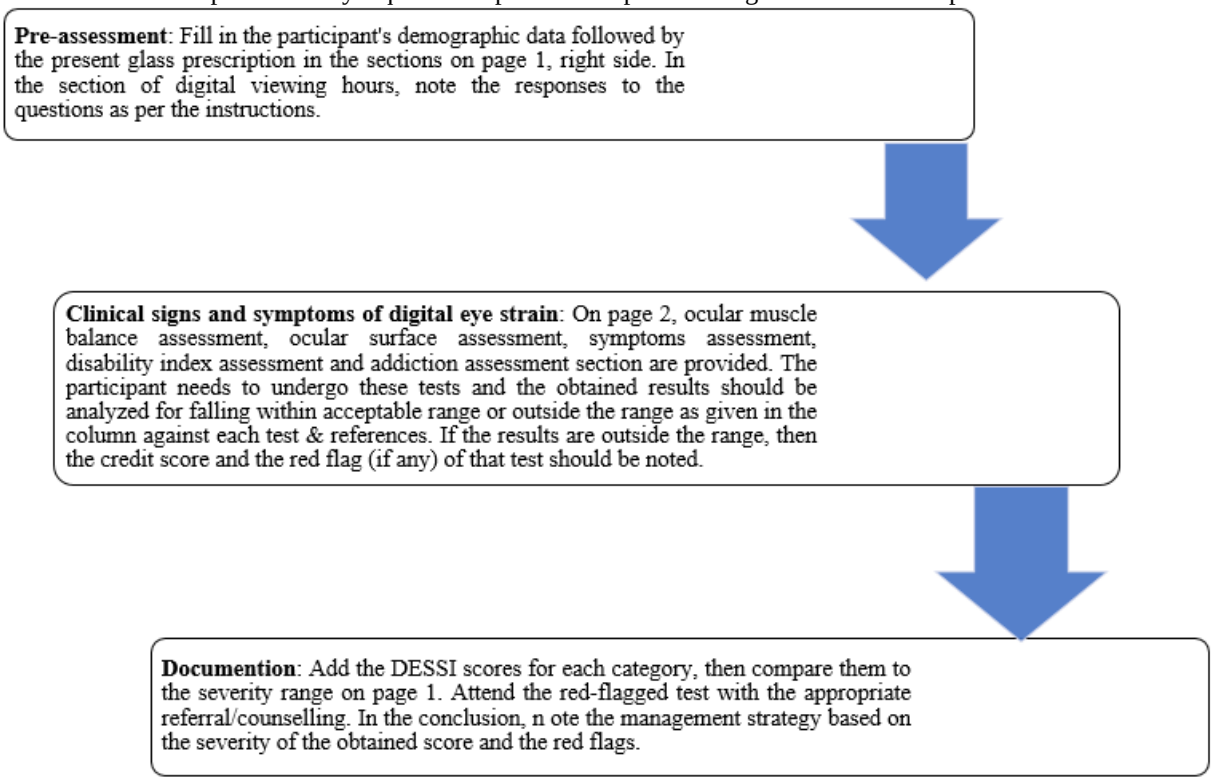
Symptoms of addiction

Name of the test and its credit score	Red flag indicator	Acceptable range	Credit score	Patient Score
Smartphone addiction scale		Till 31 for boys and 33 for girls	2	

Total red flags: _____ Total score: _____

Instruction for use of digital eye strain scoring index

This scoring index contains a series of clinical tests to evaluate the digital eye strain of a smartphone user. All the assessments should be performed by a qualified optometrist/ophthalmologist. Follow the steps of the flow chart:



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