Impact Of Blue Light on Eye Health: Study The Effects of Blue Light Exposure from Digital Devices on Visual Comfort and Long – Term Eye Health

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***Abstract*—Aim: To analyze the impact of digital devices on human eyes and quality of life.**
Objective: To assess the impact of digital devices on eye, to assess any lifestyle and mental health changes, to assess the quality of life, to gauge the impact of sudden increase in use of digital devices.
Methods: This population based prospective study was done by collecting data of 200 students and working adults in the age group of 18-50 years working and studying using digital devices. Students and working adults who are not willing to participate and suffer from previous eye problems even before the start of the use of computers were excluded from study. Data was collected using a pretested, semi-structured self-administered questionnaire and analyzed by SPSS (Statistical package for social sciences) version 21.0 descriptive statistics was used.
Results: In this study, young adults aged 18–35 dominated (61%), with students comprising 64% and a near-equal gender split (47% male, 53% female), mostly from urban areas (59%). Nearly 58% reported over 4 hours of daily screen time, primarily on smartphones and laptops, with 58.54% using devices past 9 PM heightening risks from blue light, reduced blinking, short viewing distances, and scrolling. Common symptoms included eye dryness, headaches, sleep disruptions, and mental health issues, signaling widespread Digital Eye Strain (DES) or Computer Vision Syndrome (CVS) due to factors like tear film instability, accommodation strain, glare, and circadian disruption.
Conclusion: Early intervention through structured awareness programs, behavioral modification strategies, ergonomic education, and routine eye screening is essential to reduce symptom burden and prevent long-term ocular complications. A multi-level preventive approach involving individuals, educational institutions, workplaces, and public health systems is necessary to safeguard eye health in the digital era.

I. INTRODUCTION

In the tech-driven 21st century, use of digital devices and gadgets has almost become indispensable in every aspect of life.(4,5) The American Optometric Association defines Computer Vision Syndrome(CVS) as "the complex of eye and vision problems related to the activities that stress the near and that are experienced in relation to or during the use of computer"(1) It is a condition resulting from focusing the eyes on a computer or other digital device from protracted, uninterrupted periods of time and the eye's muscles being unable to recover from the constant tension required to maintain focus on a close object.(4)

Some symptoms of CVS include-

- Headache
- Blurred vision
- Neck pain
- Fatigue
- Eye strain
- Dry eye (4,5)

These symptoms are usually temporary and disappear at the end of the working day even though minority of workers may experience continuity of symptoms after work. If no intervention is initiated, a majority of these symptoms will recur and worsen in the future. (4)

PATHOPHYSIOLOGY OF COMPUTER VISION SYNDROME:

The symptoms experienced in Computer Vision Syndrome are caused by three potential mechanisms:

- Extra Ocular Mechanism
- Accommodative mechanism
- Ocular surface mechanism (4)

Extra ocular mechanism causes musculoskeletal symptoms such as neck stiffness, pain, headache, backache and shoulder pain. These symptoms are well associated with improper placement of computer screen which lead to muscles sprain. (4)

Accommodative mechanism causes blurring of vision, double vision, presbyopia, myopia and slowness of focus change. In a study it was reported that a transient myopia was observed in 20% of computer users at the end of their work shift.(3,4) Many people may have slight accommodative problem or binocular problems which do not usually cause symptoms when they are doing ordinary less strenuous visual task, but these problems are worsened in prolonged period of computer usage.

Ocular surface mechanism causes symptoms such as dryness of the eyes, redness, gritty sensation and burning after extended period of computer usage.(4) These symptoms may be multifactorial, among the common factors found to be related to dryness and redness of the eyes are cornea dryness, reduction in blink rate, increased surface of cornea exposure caused by horizontal gaze at the computer screen, reduction of tear production due to ageing process, contact lens usage, medication such as anti-histamines and systemic medical illnesses such as auto-immune connective tissue disease.(4)

VISUAL DEMANDS WHILE WORKING WITH COMPUTER

There is a difference in visual demand when one is viewing the display on the computer screen compare to reading a printed text.(4) An image which is produced on the screen is made up of thousands of timing spots or pixels and resters which collectively form the image. The margin of the image or a word is usually not sharp and this is worsening if the image or word is formed by minimal pixels, or what is known as low resolution. As the resolution goes down the image become poor in quality and the visual demand of a reader has to be increased. In order to appreciate well the wording or image. The contrast (intensity of the light) of the word to the background, the glare of the computer screen and the reflection from the glass screen are all important factors determining the amount of visual demand one must put in order to perceive the image well.

Refresh rate refers to the no of times (per min) the computer screen is repainted to produce an image. When the refresh rate is to low it causes a flickering screen. studies have proven that a higher refresh rate is associated with less flickering dust decreases ocular symptoms and more user friendliness. Extremely low refresh rates (high flickering) are known to be associated with headache, fatigue, irritability and epileptic seizures. (4)

Many people are worried that the computer screen like most electrical appliances emits radiation. Numerous published studies have shown that there is no evidence to support any direct link between the radiation levels emitted and the worker's health problems. Similarly, there is no evidence that computer radiation contributes to significant cataract formation.

PREVENTION OF COMPUTER VISION SYNDROME

The most important approach in the management of computer vision syndrome is eliminating the causative factor leading to the symptoms. Many of the symptoms in computer vision syndrome can be prevented by proper strategies at the workplace. The preventive measures include Environmental factor modification Proper eye care by the worker. (2,4)

FACTORS CONTRIBUTING TO COMPUTER VISION SYNDROME

Personal factor:

- Poor sitting posture
- Improper viewing distances
- Improper viewing angle
- Ocular diseases
- Medical diseases
- Ageing (3,5)

Environmental factor:

- Poor lighting
- Imbalance of light between the computer screen and the surrounding (4)

Computer factor:

- Poor resolution
- Poor contrast
- Glare of the display (4)

ENVIRONMENTAL FACTOR MODIFICATIONS

Among the most important modifiable external environmental factor lighting. Bright light , windows and overhead fluorescent lights often contribute to discomfort glare. These bright light sources need to be control with proper blind, filters, or adjustment of the room adjustment so that an acceptable level of lighting is obtain to minimize visual fatigue. Different age group may require different light intensity to work with, workers over 50 years of age tends to require twice the light levels of young adults to perform the same task.

Imbalance of light between the computer screen and the surrounding is another important factor to be considered. Use of screen filters can reduce glare and reflection of the computer screen, but it should be used as a supplement and not a replacement for poor lighting of the room.

Proper distance from the screen, proper adjustment of the image size and proper height of the seat all are important factors to be considered. It is recommended that the eyes should be about 35-40 inches from the screen and the screen should be placed 10-20 degrees below or that the middle of the screen 5-6 inches below eye level.

II. PROPER EYE CARE

Taking a short break, stretching the muscles, change of scenery and a quick walk around the office have been shown to improve productivity and reduce ocular symptoms of stress and relax the accommodative system of the eyes preventing ocular strain and visual fatigue.

Working nonstop for more than 4 hours has been associated with eye strain. Workers who have recurrent symptoms of computer vision syndrome are encouraged to get proper optometrist review and assessment.

Dry eye secondary to decreased blink rate can be easily managed by applying lubricating eye drops or artificial tears.

Workers who are using contact lens must be more careful with any ocular symptoms which started acutely such as pain and redness. Complications following prolonged contact lens uses such as corneal ulcer must be excluded by proper ophthalmological assessment.

Use of proper corrective glasses for refractive errors such as myopia, astigmatism and presbyopia is important to prevent further deteriorating of the ocular symptoms which can lead to poor work performance and a poor quality of life.

III. REVIEW OF LITERATURE

1. The introduction of computers and visual display terminals have brought a phenomenal change in our lives and has become an integral part of our daily life. The term computer vision syndrome (CVS) is applied collectively to a set of different symptoms in computer users who are either habitually or on compulsion are using computers for a long time during day and night.(4) With the continuous improvement in the computer-related devices and an enhanced audio-visual experience, even the elderly people are using it with great interest to stay active in this ignorant society. The children and students of any age have very gradually switched on to computer-based learning thinking that it's a better option than classroom teachings. This paradigm change very slowly has penetrated in our youth as well as most of the business-related activity is based on the use of computers. This has led to compulsive use of computers by the employees whose job demands long continued hours of sitting in front of computers. (5)
2. The novel corona virus disease 2019 (COVID-19) pandemic has affected the entire world and led to a variety of measures by governments to mitigate the spread of the virus. Most governments have chosen to primarily rely on the concept of social distancing, thereby suspending flights, closing down schools, mandating work-from-home arrangements, and encouraging social distancing in public spaces. The strict home quarantines necessitated by these measures have forced

people to stay home and rely on their digital devices for work, pleasure, relaxation, and various vocational and non-vocational activities. Remote work and education require electronic digital devices, mainly computers. Because of the mandatory nature of these home quarantines, the COVID-19 pandemic is also transforming the way people work, learn, and socialize, which could have a direct impact on their eyes.

3. Digital eye strain (DES) is defined as the combination of one or more vision- related symptoms as a result of prolonged use of a computer, tablet, e-reader, or cell phone.(2) Symptoms (asthenopia) can be categorized into two groups. The first group are internal symptoms, which include eye strain, eye pain, headache, diplopia, and blurred vision. The second group includes burning sensation, itchiness, tearing, and dryness, which are termed as external symptoms.
4. A recent report in Saudi Arabia showed that 92% of the population owns a smartphone, 57% own a personal computer, and 34% own a tablet. Internet users account for 32% of the total population of the kingdom, with an annual growth of 15%. The cell phone addiction in young adults in Saudi Arabia and reported that 61% of subjects spent 5 hours per day while 27% spent more than 8 hours a day on their smartphones. These results are significantly higher than those reported in the US, where the average duration of use of a smartphone is 2 hours and 55 minutes. Moreover, these studies were conducted during periods when people were living freely without any restrictions, as opposed to the current scenario of mandatory indoor living and restricted indoor activities.
5. A recent Indian study to determine prevalence, symptoms frequency and associated risk factors of digital eye strain (DES) among children attending online classes during COVID-19 pandemic in 217 children showed mean age of children was 13 ± 2.45 years. Mean duration of digital device used during COVID era was 3.9 ± 1.9 h, which is more than pre COVID era (1.9 ± 1.1 h). 36.9% were using digital devices >5 h in COVID era as compared to 1.8% before COVID era. The most common digital device used were smartphones (61.7%). One hundred and eight children (49.8%) were attending online classes for >2 h per day. Prevalence of DES in this cohort is 50.23% (109/217). Of these 26.3% were mild, 12.9% moderate and 11.1% of severe grade. Most common symptoms were itching and headache (53.9%). Multivariate analysis revealed age >14 years, male gender, smartphone use, use of device >5 h and mobile games >1 h/day as independent risk factors for DES in children.
6. Another Indian study to observe pattern of digital device use and the various ocular, visual and systemic symptoms associated with them during the lockdown period of the novel coronavirus disease (COVID-19) pandemic revealed most of the respondents were engaged in more than two digital activities (73.81%) over more than two digital devices (48.50%) for more than six days (65.66%). Maximum respondents were mobile users (97.85%) spending major time on social media (89.70%). Symptoms including watering eyes, dry eyes, shoulder pain, back pain and headache showed positive correlation with hours of digital device use per day during lockdown, while itching eyes and pain behind eyes were the major symptoms in those engaged in a greater number of digital activities. Moreover, red eyes were more prominent in respondents using multiple devices for a greater number of hours.

This study is conducted to find out the prevalence of deteriorating effects of prolonged computer use among the university students and to find out the effect on corrected version eyes and normal vision eyes.

IV. METHODS AND MATERIALS

STUDY SITE:
Mewar University, Chittorgarh, Gangrar, Rajasthan 312901.

STUDY POPULATION:
Records of 200 random working adults and students in the age group of 18 to 50 years who were working online.

STUDY DESIGN:
A prospective, population-based study.

SAMPLE SIZE:
200 eyes

TIME FRAME:
Data collection – 4 months Data analysis – 2months

INCLUSION CRITERIA:
All those students and working adults who were using digital devices in one month preceding the data of the study.

EXCLUSION CRITERIA:
Students and working adults who were not willing to participate and suffered from eye problems even before starting to use computers.

METHODOLOGY:
A random population based study will be conducted among the students and working adults using digital devices in North-East India. Data will be collected using a pre-tested semi structured self- administered questionnaire. Data will be analyzed by using Statistical Package for Social Sciences(SPSS).
Study requires use of readily available resources and hence will not require additional funds.

RESULTS
The study results are shown below

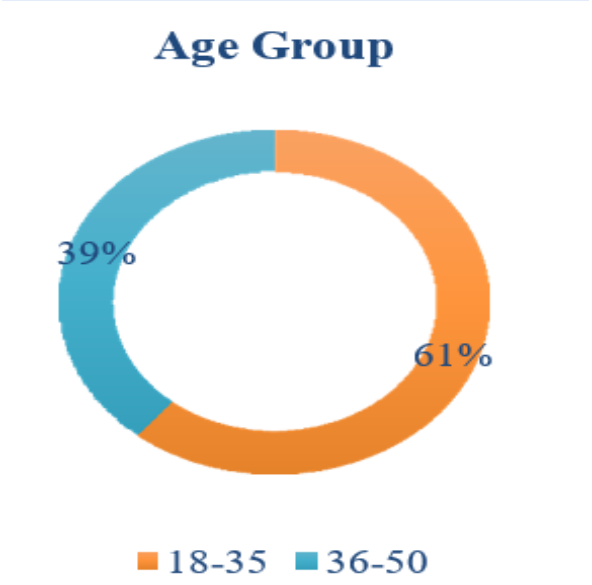

Fig 1: It shows the total No of participants, in which 61% of the population are from 18 to 35 years age group and rest are from 36 to 50 years age group.

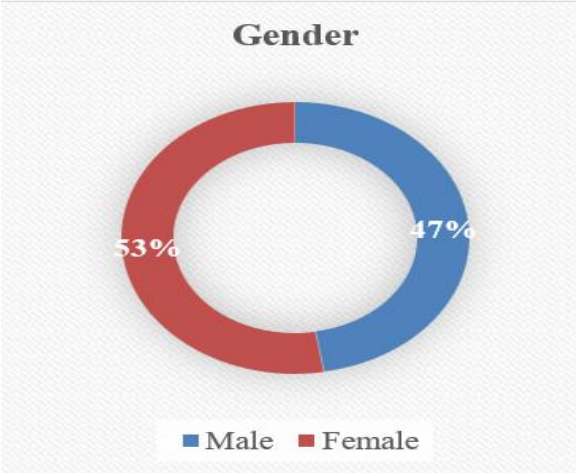

Fig 2: It shows 47% of the population were Male and 53% of the population were female participants

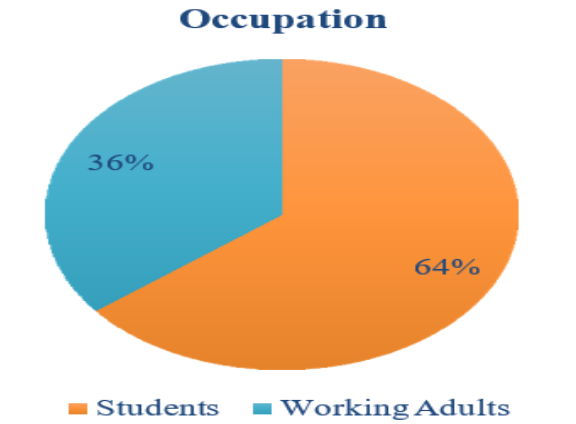

Fig 3: Shows 36% of the participants were “working adults" and 64% of the participants were students

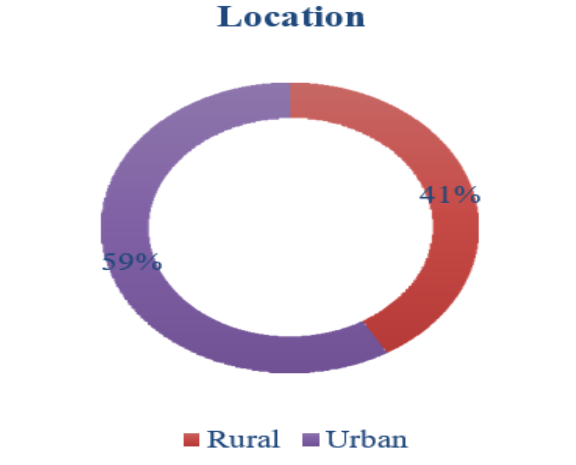

Fig 4: Shows 59% of participants are from urban area and rest 41% from rural area

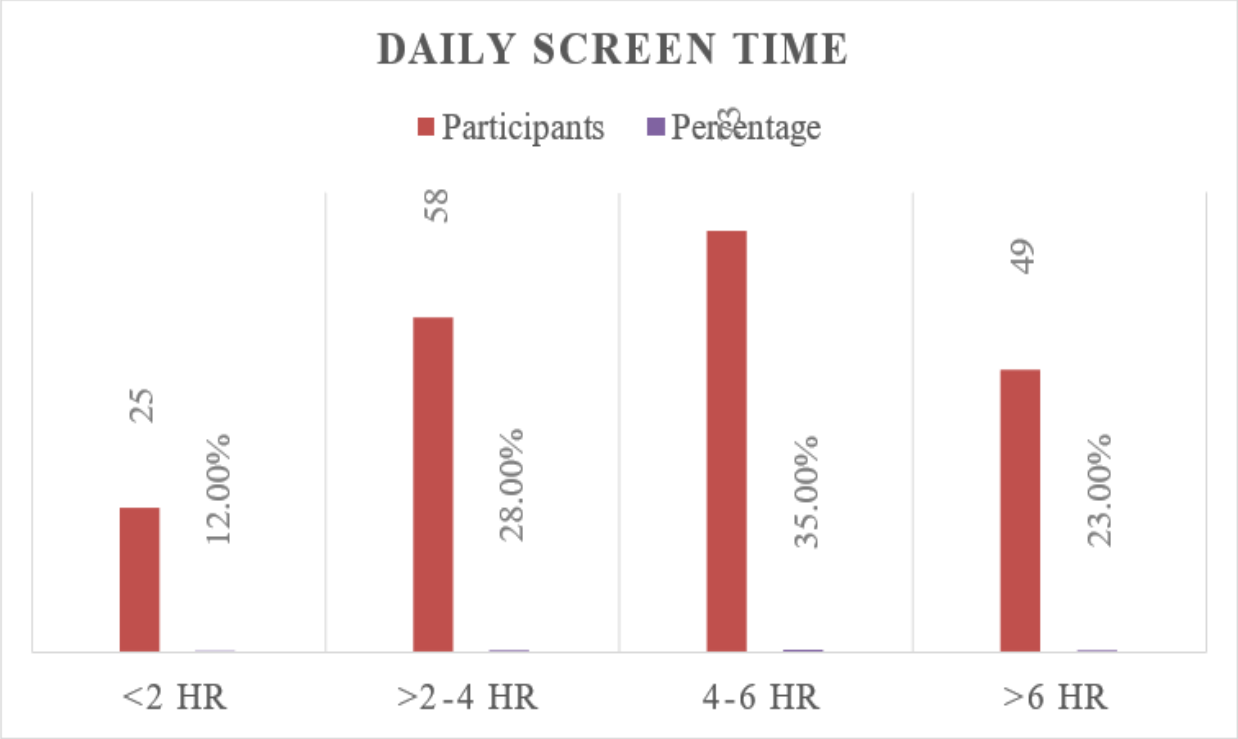

Fig 5: Shows daily screen time use in graphic value

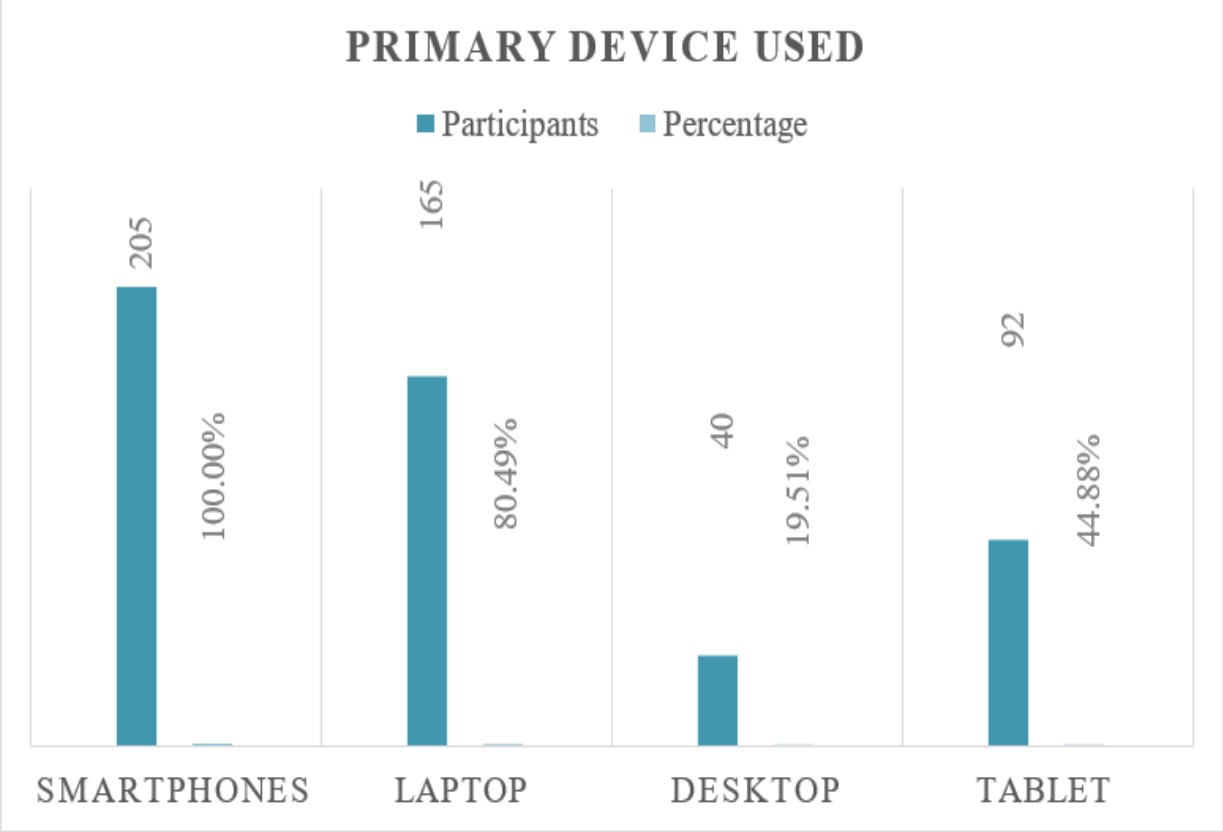

Fig 6: Shows the use of digital devices

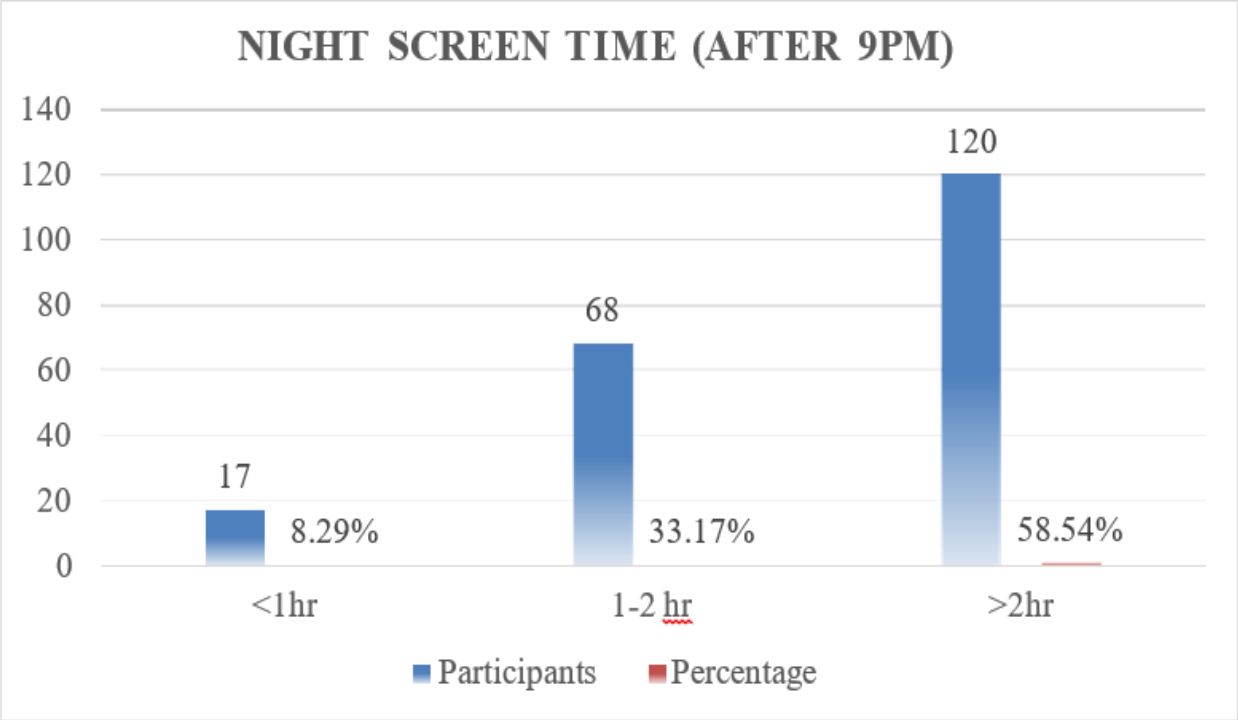

Fig7: Shows most of the participants using digital devices after 9PM

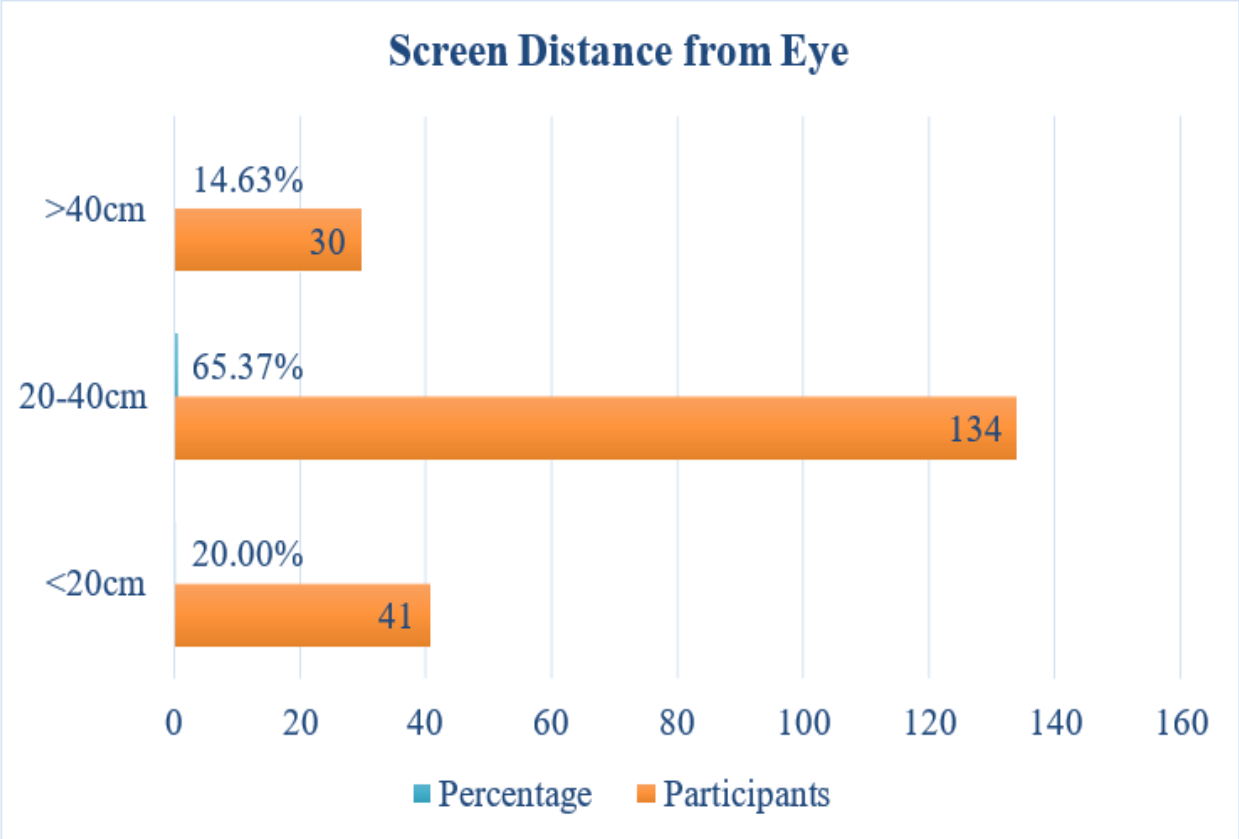

Fig 8: Shows that maximum participants are 20-40cm distance from eyes while using digital devices

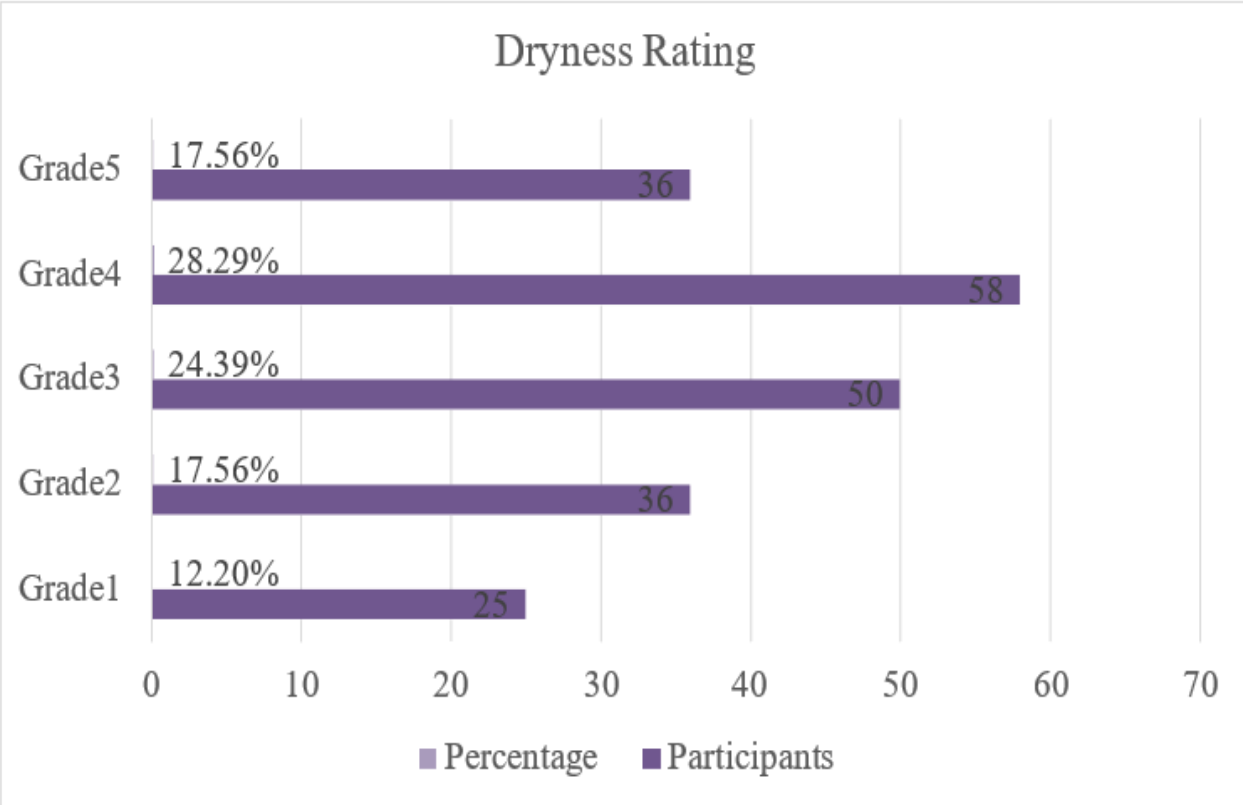

Fig9: Shows the no. of participants having dryness issue due to digital device use

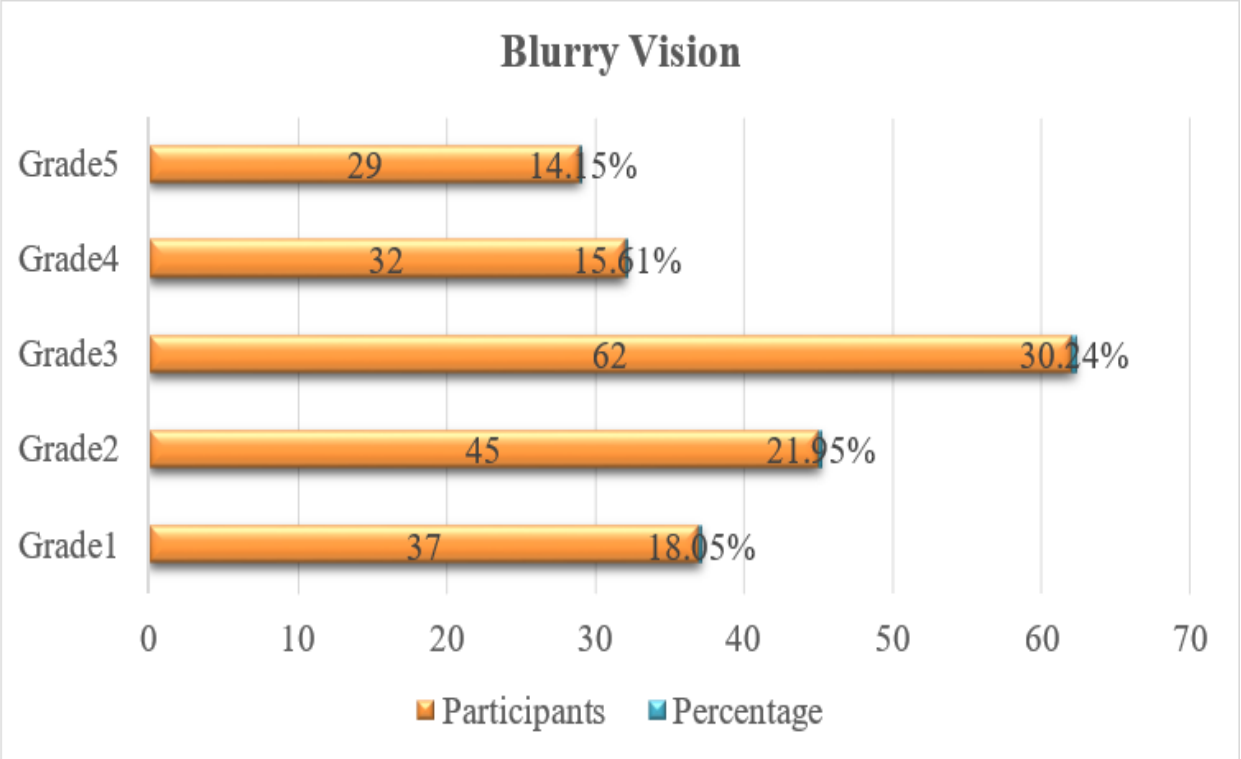

Fig10: Shows person effected blurry vision due to prolonged digital device use

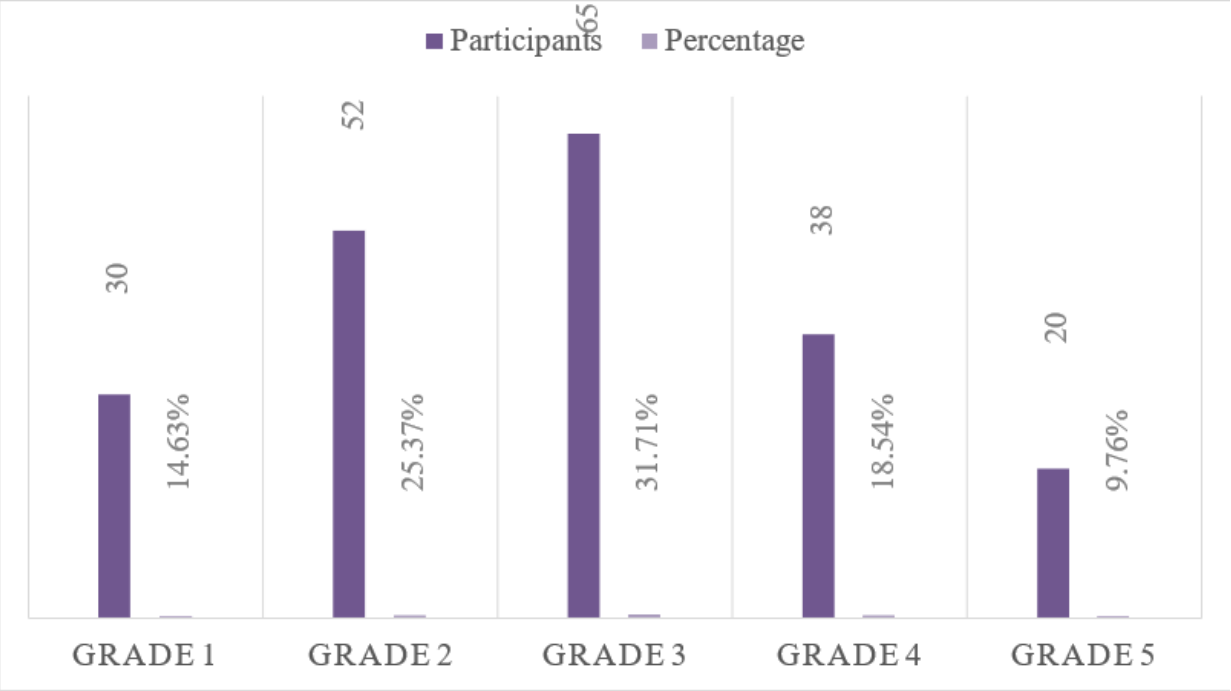

Fig11: It Shows the persons effected with Headache after digital device use.

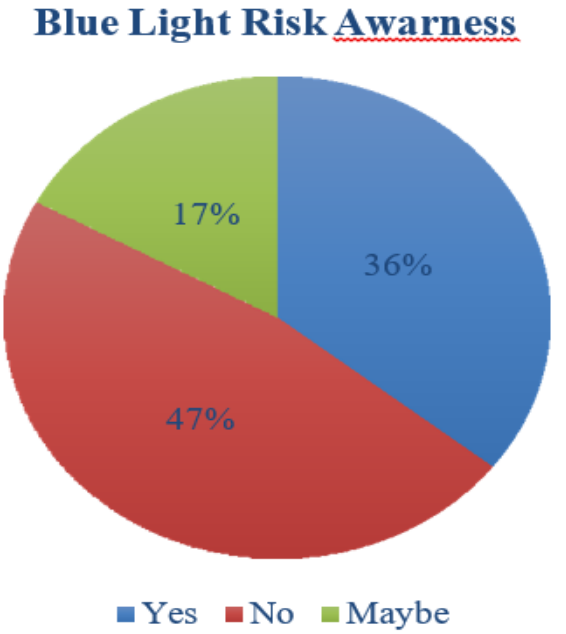

Fig12: Shows the no. of people's awareness of blue light effects

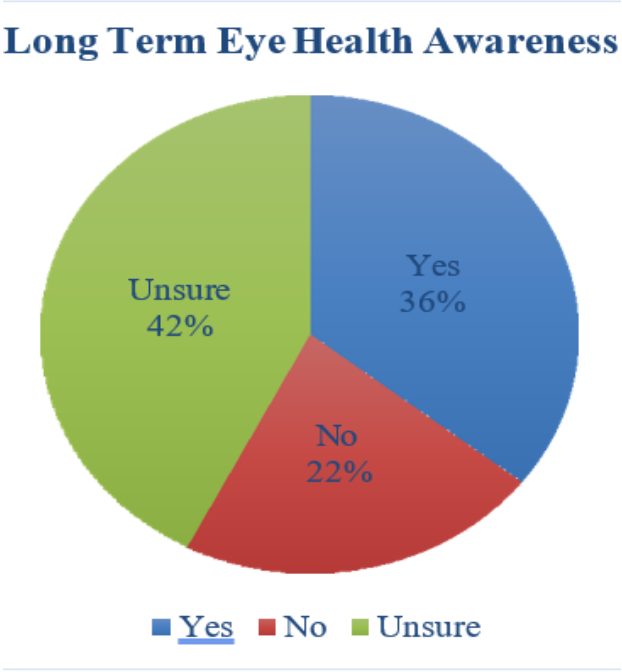

Fig13: Shows the no. of People's awareness regarding long term eye health changes

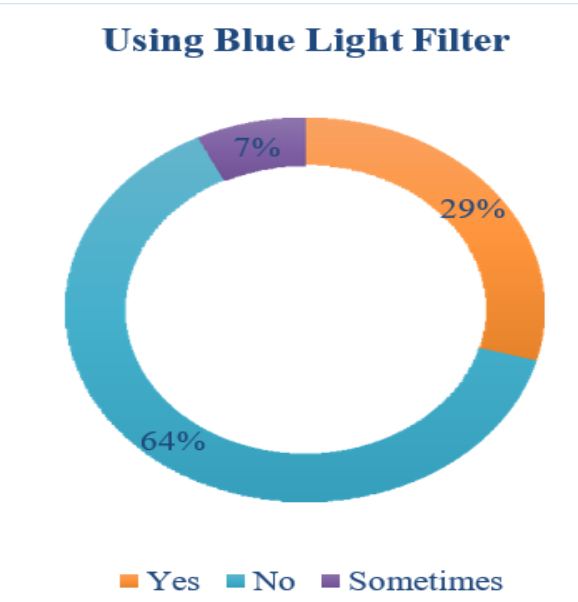

Fig14: Showing the % of blue light filter used by participants

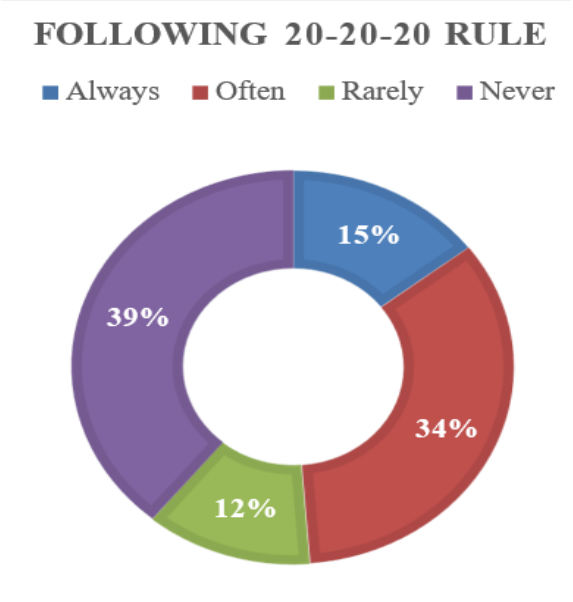

Fig15: Shows the %value of following 20-20-20 rule by the participants

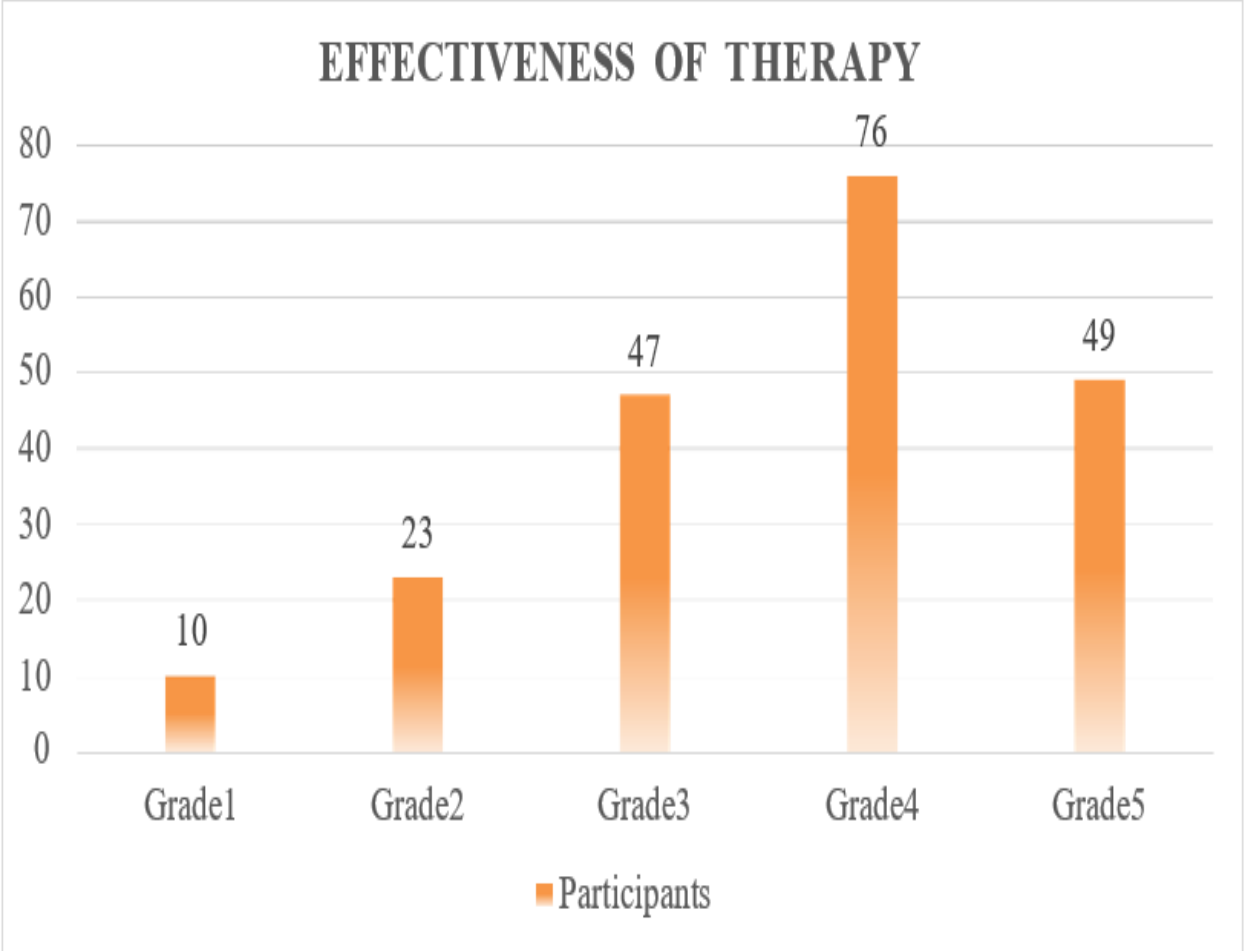

Fig16: Showing the feedback result after following precautions

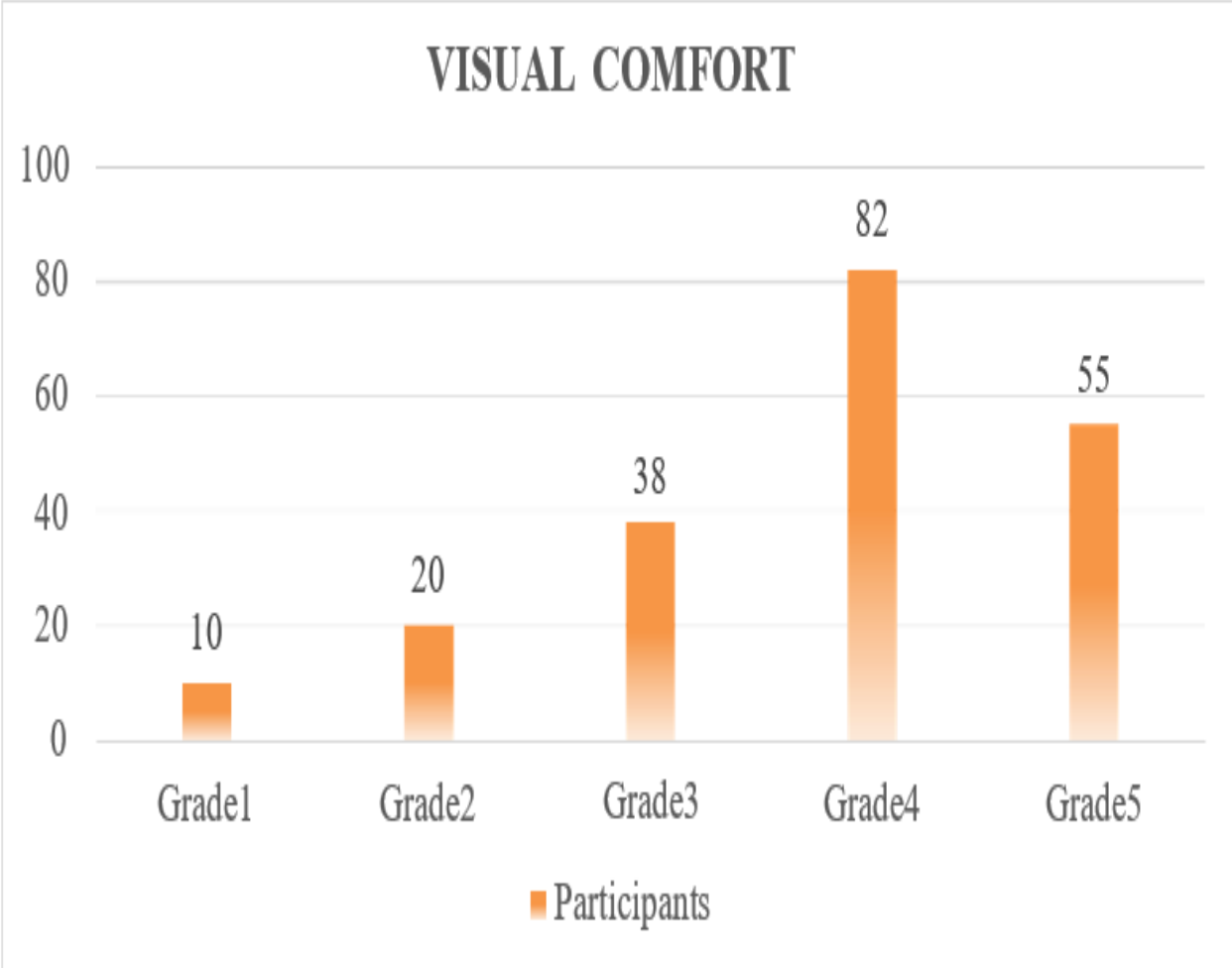

Fig17: Showing Visual comfort of the participants after following the preferred methods of using digital device.

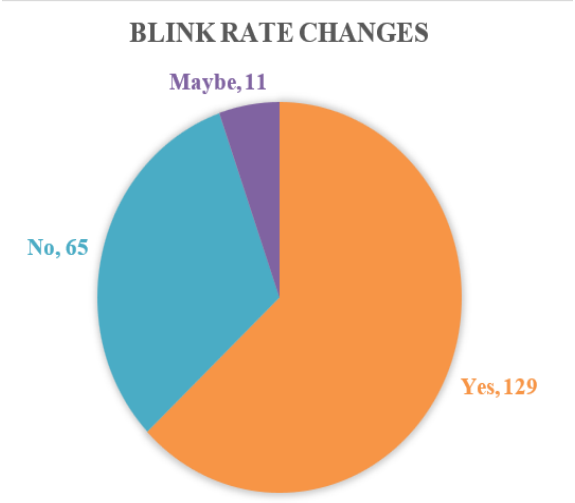

Fig18: Showing the Changes in blinking rate after using digital devices

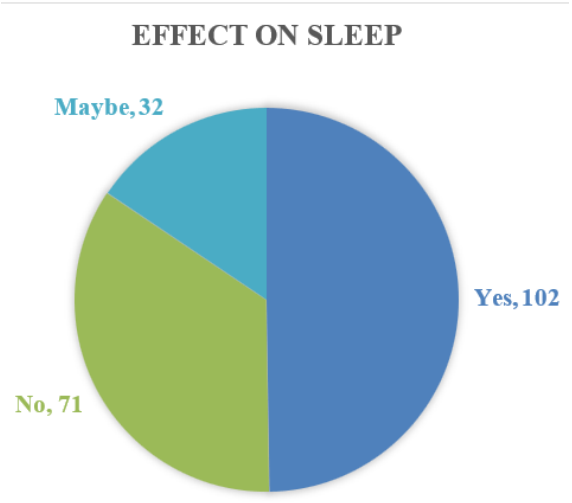

Fig19: Showing the changes in sleeping habits after using digital devices.

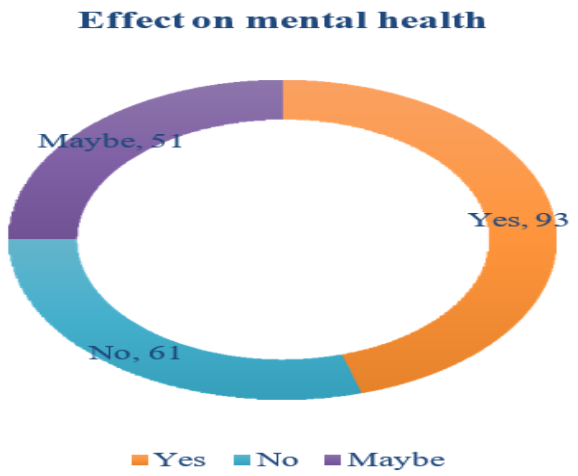

Fig20: Showing changes in mental health after digital device use

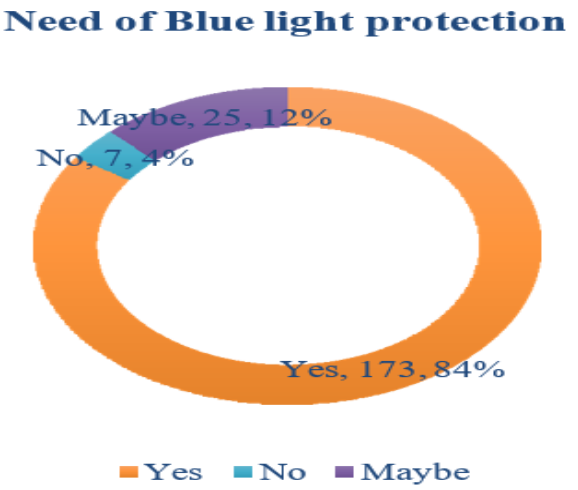

Fig21: Showing preferences of the participants for Blue Light Protection Glasses

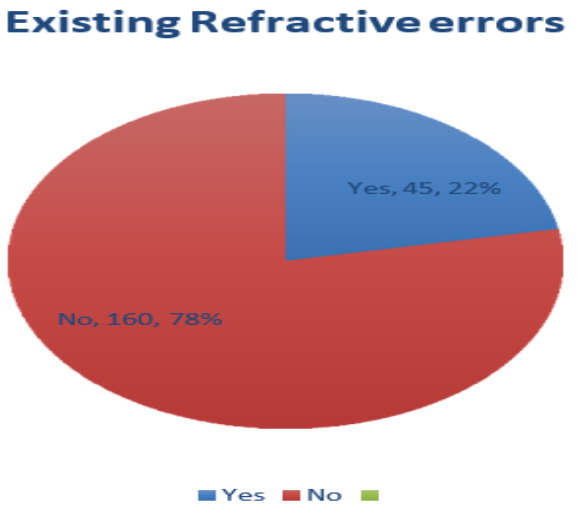

Fig22: Showing the % of participants having Refractive errors.

V. DISCUSSION

In this study, 61% of participants belonged to the 18–35 years age group, indicating that young adults form the majority of digital device users. This finding aligns with global trends showing increased dependency on digital platforms among younger populations for education, communication, and entertainment. (4,5) The predominance of students (64%) further supports this observation, as academic activities increasingly rely on smartphones and laptops. (5)

Additionally, 47% of participants were male and 53% female, suggesting relatively balanced gender representation. A majority (59%) belonged to urban areas, which may reflect greater accessibility to digital infrastructure and internet connectivity in urban settings. (5)

A considerable proportion of participants reported prolonged screen exposure. About 35% used digital devices for 4–6 hours daily, while 23% reported usage exceeding 6 hours per day. This indicates that nearly 58% of the study population is exposed to screens for more than 4 hours daily, which exceeds the recommended safe exposure duration suggested in various ophthalmic guidelines. (2,4)

Smartphones and laptops were identified as the primary devices used. Smartphones, in particular, contribute significantly to ocular strain due to: Short viewing distance, small font sizes, continuous scrolling behavior, blue light emission. (2,4)

Notably, 58.54% of participants reported using digital devices after 9 PM. Night-time exposure to screens is particularly concerning due to blue light emission, which can suppress melatonin production and disrupt circadian rhythm. This may explain the reported changes in sleeping habits among participants. Prolonged night-time exposure may also exacerbate symptoms of digital eye strain and contribute to systemic effects such as mental fatigue and stress. (2)

Participants reported symptoms such as: Dryness of eyes, headaches, changes in sleeping patterns, mental health disturbances. (2,4)

Dryness is a common feature of Computer Vision Syndrome (CVS) and can be attributed to reduced blink rate during prolonged screen use. Studies have shown that blink rate decreases significantly while focusing on digital screens, leading to tear film instability and evaporative dry eye. (4)

Headaches may result from: Continuous

accommodation strain, glare and improper lighting, uncorrected refractive errors, prolonged near work. (3,4)
The high prevalence of these symptoms in the present study indicates a substantial burden of Digital Eye Strain (DES) among participants. (2,4)

Strengths of the Study:

- Inclusion of both students and working adults
- Representation of urban and semi-urban populations
- Evaluation of both ocular and systemic effects

Limitations:

- Self-reported symptoms may introduce reporting bias
- Cross-sectional design limits causal inference
- Lack of clinical ophthalmic examination to objectively confirm dry eye

Awareness and Preventive Practices:
Adoption of the 20-20-20 Rule:
The 20-20-20 rule, recommended by the American Optometric Association, suggests: Every 20 minutes look at something 20 feet away for at least 20 seconds. This helps relax the ciliary muscles and reduce accommodative strain. (1)

Limiting Screen Time
Restrict non-essential digital use to <2 hours/day. Avoid continuous use for >1 hour without a break, encourage "digital detox" periods, especially before bedtime. (2,4)

Night-Time Screen Reduction
Since 58.54% of participants use devices after 9 PM, avoid screens at least 1 hour before sleep, activate night mode / blue light filter, use warm lighting instead of LED white light at night.

Blink Awareness and Dry Eye Prevention
Conscious blinking exercises, use of preservative-free lubricating eye drops (if prescribed), maintain adequate hydration.

Ergonomic Adjustments
Use screen at eye level 40–75 cm viewing distance (laptop/desktop), proper back support, anti-glare screens, adequate ambient lighting. (3,4)
Since 64% of participants are students, colleges and workplaces are ideal intervention points.

School & College Awareness Campaigns

- Conduct annual "Digital Eye Health Week"
- Organize seminars by ophthalmologists.
- Display posters in classrooms about: 20-20-20 rule, proper posture, blue light awareness.

Workplace Interventions
Employers can implement mandatory 5-minute screen breaks every hour, provide ergonomic workstation training and offer routine eye screening camps.

Health Education Campaigns
Public awareness can be increased through social media campaigns, short educational videos, infographics in local language, audio and local TV awareness programs. The World Health Organization emphasizes preventive health education as a key strategy in reducing lifestyle- related disorders.

Primary Health Center (PHC) Screening Programs
Routine screening for digital eye strain, early detection of dry eye syndrome, referral to ophthalmologists when necessary.

Integration into National Health Programs
Digital eye health awareness can be integrated into school health programs, occupational health policies and vision screening initiatives. (1)

Digital Usage Guidelines
Educational boards can limit continuous online class duration, including mandatory screen breaks and encourage printed learning materials.

Blue Light Regulation Awareness
Encourage manufacturers to pre-enable night mode, promote safer display technologies.

Expected Outcomes of Preventive Strategies
If implemented properly, the following improvements can be expected: Reduced dry eye symptoms, decreased headache frequency, improved sleep quality, better academic & work productivity, improved overall quality of life. (1)

VI. CONCLUSION

The study highlights that prolonged digital device use, especially during night-time hours, is associated with ocular discomfort and adverse lifestyle effects. With increasing digital dependency in academic and professional environments, Digital Eye Strain represents an emerging public health concern.

Early intervention through structured awareness programs, behavioral modification strategies, ergonomic education, and routine eye screening is essential to reduce symptom burden and prevent long-term ocular complications. A multi-level preventive approach involving individuals, educational institutions, workplaces, and public health systems is necessary to safeguard eye health in the digital era.

VII. QUESTIONNAIRE

Impact of Blue Light on Eye Health questionnaire:

1. Age:
2. Gender:
   - Male
   - Female
   - Other
3. Occupation:
   - Students
   - Working adults
4. Location:
   - Urban
   - Rural
5. Daily screen time.
   - <2 hr
   - 2-4 hr
   - 4-6 hr
   - >6 hr
6. Primary device used:
   - Smartphone
   - Laptop
   - Desktop
   - Tablet
   - Other
7. Average Evening/Night screen time (after 9 PM)
   - <1 hr
   - 1-2 hr
   - >2 hr
8. Screen Distance from eyes.
   - <20 cm
   - 20-40 cm
   - >40 cm
9. Do you have eye dryness/ irritations in past few weeks, if yes rate it.

   1 2 3 4 5

10. Do you have Blurred vision in past few weeks, if yes rate it.

    1 2 3 4 5

11. Do you having headaches in past few weeks, if yes rate it.

    1 2 3 4 5

12. Do you aware of blue light risks (e.g. retinal damage, myopia).
    - Yes
    - No
    - Maybe
13. Do you worry about long-term eye health from screens.
    - Yes
    - No
    - Unsure
14. Do you use blue light filters/glasses .
    - Yes
    - No
    - Sometimes
15. Do you follow 20-20-20 rule.
    - Always
    - Often
    - Rarely
    - Never
16. How effective these are in reducing eye discomfort.

    1 2 3 4 5

17. Overall visual comfort score.

    1 2 3 4 5

18. Does screen time change your blink rate.
    - Yes
    - No
    - Maybe

19. Does the screen time effect your sleep.
- Yes
- No
- Maybe
20. Does the screen time effect your mental health.
- Yes
- No
- Maybe
21. Do you recommend blue light protection.
- Yes
- No
- Maybe
22. Do you have any existing eye conditions.
- Yes
- No

REFERENCE

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[5] M. Logaraj et al. (2014) – CVS among students.