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ORIGINAL ARTICLE

SMARTPHONE USAGE AS A RISK FACTOR OF MYOPIA AMONG ELEMENTARY SCHOOL STUDENTS IN KEDIRI

Penggunaan Smartphone Sebagai Faktor Risiko Miopia Pada Anak Sekolah Dasar di Kota Kediri

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ABSTRACT

Background: Myopia is the inability to view distant objects. Most cases of myopia occur in school-age children. Working and studying from home due to the COVID-19 epidemic exacerbates myopia concerns. The Kediri City Health Office reports that school-age myopia cases rose in 2022. **Purpose**: This study aims to identify the risk factors of myopia related to smartphone usage among elementary school students in Kediri City. **Method**: This study is an observational study with a case-control approach. Random sampling is used in the sampling procedure. There were 144 participants: 72 students in the case group and 72 in the control group. Independent variables include smartphone duration, using a smartphone in a low-light environment, using a smartphone before sleep, and using a smartphone at an early age. **Result**: The study's findings revealed all factors were associated with myopia: smartphone duration (p-value = 0.001; OR = 4.5), using smartphone in low-light environment (p-value = 0.001; OR = 3.4), using smartphone before sleep (p-value = 0.001; OR = 3.3), and using smartphone in early age (p-value = 0.000; OR = 12. 4). **Conclusion**: This study shows that the duration of smartphone use of more than 3 hours increases the risk by 4.5 times, using a smartphone in low-light environment increases the risk by 3.4 times, using a smartphone before bed increases the risk by 3.3 times, and the risk of myopia increases 12.4 times for smartphone use at a younger age in elementary school students in Kediri City.

ABSTRAK

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Latar Belakang: *Miopia adalah kondisi penglihatan yang tidak memungkinkan seseorang untuk melihat objek yang jauh dengan jelas. Miopia umumnya terjadi pada anak usia sekolah. Kondisi miopia diperparah oleh Pandemi COVID-19 yang mengharuskan kerja dan belajar di rumah. Berdasarkan data Dinkes Kota Kediri, pada 2022 terjadi peningkatan kasus miopia pada anak sekolah.* ***Tujuan:*** *Penelitian ini bertujuan mengetahui faktor risiko miopia terkait penggunaan smartphone pada anak sekolah dasar di Kota Kediri.* ***Metode:*** *Penelitian ini merupakan penelitian observasional dengan desain case-control. Teknik pengambilan sampel menggunakan random sampling. Subjek berjumlah 144 siswa, 72 kelompok kasus dan 72 kelompok kontrol. Variabel bebas meliputi: durasi penggunaan smartphone, penggunaan smartphone di tempat gelap, penggunaan smartphone sebelum tidur, dan usia awal penggunaan smartphone.* ***Hasil:*** *Hasil penelitian menunjukkan semua variabel berhubungan dengan miopia; durasi penggunaan smartphone (p-value = 0,001; OR = 4,5), penggunaan smartphone di tempat gelap (p-value = 0,001; OR = 3,4), penggunaan smartphone sebelum tidur (p-value = 0,001; OR = 3,3), dan usia awal penggunaan rutin smartphone (p-value = 0,000; OR = 12,4).* ***Simpulan:*** *Penelitian ini menunjukkan durasi penggunaan smartphone lebih dari tiga jam meningkat resiko miopia hingga 4,5 kali lipat, penggunaan smartphone di tempat gelap menaikkan risiko miopia 3,4 kali, penggunaan smartphone sebelum tidur meningkatkan risiko miopia 3,3 kali, dan risiko miopia meningkat 12,4 kali lipat untuk penggunaan smartphone di usia yang lebih muda pada anak sekolah dasar di Kota Kediri.*

INTRODUCTION

Myopia, commonly called nearsighted, is an eye disorder in which distant objects appear blurry (1). Myopia occurs when light entering the eye is brought to focus in front of the retina due to an overly curved cornea (2). A curved cornea makes light that enters the eye be unfocused properly and distant objects appear blurry. Myopia is usually detected in children before 10 years old. Still, its onset can vary from 3–4 years to late adolescence or early adulthood depending on ethnic, family, environmental, lifestyle, and geographic factors (3). Uncorrected myopia can continue to progress (4). Myopia not only affects education, but the disadvantages of myopia also extend to quality of life and psychological conditions, especially when individuals develop high myopia. Studies from high-income countries have shown that adults with high myopia report psychological, practical, and financial conditions specifically related to myopia that affect their quality of life. High myopia increases the risk of other eye diseases such as cataracts, glaucoma, retinal detachment, and myopic macular degeneration (MMD), leading to irreversible vision loss (5). The increasing myopia epidemic will have far-reaching consequences for both individuals and society (3).

The number of people with myopia in 2020 was estimated to be 2.6 billion globally and is expected to increase to 4.9 billion by 2050 (6). Between 2001 - 2015, the prevalence of myopia among adults (≥40 years) in area urban in China increased from 22.9% to 31.5% (7). In Korea, between 2008 - 2011, the prevalence of myopia among 20 - 29 years old was 78.9% and increased in 2013 - 2014 (81.3%). In Japan, myopia among adults (≥40 years) increased from 37.7% in 2005 to 45.8% in 2017 (8). In Indonesia, the prevalence of refractive disorders ranked first in the eye disease category, covering 25% of the population, around 55 million people. The prevalence of myopia in Indonesia with more than -0.5 D among young adults (>21 years) is 48.1% (9).

The COVID-19 pandemic has exacerbated the global burden of myopia among children due to lockdowns and increased screen time (e-learning). Studies have shown a 1.4 to 3.6-fold increase in myopia progression during the COVID-19 pandemic lockdown, especially in younger ages (10). The United Nations Educational, Scientific and Cultural Organization (UNESCO) reported that 1.1 billion children in more than 140 countries had been exposed to digital devices due to social distancing and online schooling as of May 2020 (11). A meta-analysis compared myopia

progression in elementary schools in China before and during the COVID-19 pandemic. The results showed that the rate of myopia development in elementary schools in China was higher during the COVID-19 period compared to the period before the lockdown (12). Based on reports of myopia cases by the Kediri City Health Office throughout 2021, there was a spike in myopia cases in the 0-14-year age group at the end of 2021 during the implementation of social restrictions. With a population of 64,732 aged 0-14 years, the prevalence of myopia in this age group reached 0.28% in 2021.

Common risk factors for myopia associated with smartphone usage that are commonly found in many cases include duration of smartphone use (12,13), smartphone use in low-light environment (14), smartphone use before bedtime (15), and age of initial smartphone use (12). Studies have shown a complex interaction between genetic, environmental, and behavioral factors that cause the onset of myopia.

Computers, smartphones, and tablets are used in schools and at home at an early age. The age group which has the fastest growth in using smartphones is children (12). Based on studies, myopic students use nearly twice as much data on their smartphones per day than those without myopia (12). Digital screen time has been linked to myopia or an increase in the eye's axial length. The strongest correlation between screen time and myopia was seen in a northern Indian study of people aged 5 to 15. Over two hours of smartphone use per day was associated with an 8.33 times greater risk of myopia compared to less than two hours per day (13).

The eye's accommodation system is most likely the cause of myopia development related to smartphone use. Near-work and small screen sizes lead to excessive accommodation. Because of this overaccommodation, intraocular pressure subsequently rises. Lens thickening and anterior chamber narrowing cause the anterior chamber depth to decrease after this intraocular pressure. Myopia can develop as a result of changes in the axial length of the eye caused by intense and sustained intraocular pressure (14).

Teenagers and even young children spend more time on computers, smartphones, and other devices, which frequently leads to sleep issues. A child's development depends on sleep, and sleep deprivation can lead to several problems. Fatigue and a lack of focus are direct symptoms. Using smartphones right before bed might worsens the sleep cycle disruption brought on by blue light exposure, which can result in transient smartphone blindness (TSB) (15).

Changes in the length and quality of sleep impact the risk of myopia, while further research is needed to determine the direct relationship. One hypothesis is that using a smartphone reduces sleep time. An increase in the eye's accommodation mechanism, which also raises intraocular pressure, results from increased smartphone use. This is exacerbated by the dark sleeping environment, leading to mechanisms of increased pupil diameter and iris thickening that contribute to intraocular pressure (16). Furthermore, smartphone ownership has increased dramatically among younger age groups in both developed and developing countries, with younger age groups spending more time using smartphones than older students (12).

Although the COVID-19 pandemic has not had a direct impact on myopia, home quarantine and online schooling have increased the use of electronic devices, especially smartphones, which increases myopia risk factors. Recent studies have also found a significant relationship between the development of myopia and government policies during the pandemic (17). According to a survey, 71.40% of 3254 participants reported increased smartphone usage after the COVID-19 pandemic (18). Based on the problems, case data, and risk factors described, the researchers conducted this study to analyze the risk factors for myopia associated with smartphone use in elementary school children in Kediri City.

METHODS

This study is an analytical observational study with a case-control study design. The target population in this study was all public elementary school students in Kediri City, East Java. The study was conducted from December 2023 to April 2024. The number of public elementary school students in Kediri City was 17,988 students. The accessible population in this study was 5th-grade public elementary school students in Kediri City. A total of 11 elementary schools were selected using the stratified random sampling method, including Bangsal 3 Public Elementary School, Pakunden 3 Public Elementary School, Bawang 2 Public Elementary School, Blabak 4 Public Elementary School, Pesantren 1 Public Elementary School, Rejomulyo Public Elementary School, Kampungdalem 6 Public Elementary School, Mojoroto 2 Public Elementary School, Bujel 3 Public Elementary School, Sukorame 3 Public Elementary School, and Bandar Lor 2 Public

Elementary School. The independent variables are daily smartphone usage duration, smartphone usage in low-light environment, smartphone usage before bedtime, and the initial smartphone usage. The dependent variable is myopia.

An eye test is performed using a Snellen diagram or Snellen chart, which measures the vision of the eye or visual acuity, the results of which are written as a fraction, for example, 20/40. The numerator is the standard distance the test is performed (20 feet or 6 meters). The denominator indicates the size of the letters being read. Someone with 20/40 means that the person must be within 20 feet to identify a letter that can be seen clearly at 40 feet with "normal" eyes. Normal visual acuity is 20/20 (3). Snellen diagram test was carried out to determine the case and control group samples. The case group was students who had their vision checked and got myopia results. The control group was students who had their vision checked and got normal results. The ratio for the case and the control group is 1:1, with 72 samples in each group.

Data on smartphone usage were obtained through interviews. The interviewees were students' parents. The questionnaire was created after reviewing questionnaires from previous studies. After developing the questionnaire, a preliminary study was conducted to ensure the questionnaire passed the validity and reliability tests.

Researchers assessed the daily smartphone usage duration, smartphone usage in low-light environment, smartphone usage before bedtime, and the initial smartphone usage. Daily smartphone usage duration is divided into two categories: less than three hours and more than three hours. Smartphone usage in low-light environments is classified as “Yes” for light intensity less than 100 lux and “No” for light intensity more than 100 lux. Smartphone usage before bedtime is classified as either “Yes” or “No.” The initial smartphone usage is divided into two categories: using a smartphone before the COVID-19 epidemic and using a smartphone when the pandemic began. To complete the data on the room's light intensity, measurements were collected using a luxmeter in the room where students spend a lot of time playing with smartphones.

A computer program will be used to process the data that have been obtained. The coding can categorize and make data entry and analysis easier. Data cleaning was conducted after coding to ensure the accuracy and completeness of the data. Computer software was implemented to display and analyze the data. The Chi-square test, with a 95% confidence level, was utilized to determine the OR and p-value. Applying the Chi-square test, bivariate analysis was conducted to determine the relationship between the variables and the myopia.

This study has obtained an ethical clearance certificate approved by the Research Ethics Committee of the Faculty of Public Health, Diponegoro University, with the ethical certificate number 117/EA/KEPK-FKM/2024.

RESULTS

The results of the variable analysis showed that the variables of the duration of smartphone usage, smartphone usage in low-light environment, smartphone usage before bedtime, and early age of smartphone use had a significant relationship with the incidence of myopia in elementary school children in Kediri City (Table 1).

DISCUSSION

Duration of Smartphone Usage

This study shows a significant relationship between smartphone usage duration and myopia incidence in elementary school children in Kediri City ($p = 0.001$). Children who use smartphones for more than three hours are at a 4.5 times greater risk of developing myopia than children who use smartphones for less than three hours.

Along with the development of technology, smartphones have become an important object in life. Children and young adults are now exposed to new environmental risk factors that may be related to myopia, namely digital devices. Smartphones, tablets, and computers are used at a very early age, both at home and school. Children are the fastest-growing population of smartphone users (12). This study shows a significant relationship between the duration of smartphone use and myopia.

This result aligns with the research of McCrann et al. (12) on 418 students. Statistically, myopia is significantly related to increasing smartphone data usage in a day. Another study conducted by Foreman et al. (13) found that the usage of digital screens is linked to myopia or an increase in the axial length. The study revealed that smartphone use for more than two hours per day increases the risk of myopia by 8.33 times compared to less than two hours per day.

Table 1
Statistical Analysis of Independent Variables and Myopia in Elementary School Children in Kediri City

Variable	Myopia	Non-myopia	*p-value*	OR	95 % CI	
	n= 72	n= 72			Lower	Upper
Daily Smartphone Usage Duration						
> 3 Hours	64 (89.89%)	46 (63.89%)	0.001	4.5	1.879	10.883
< 3 Hours	8 (10.11%)	26 (36.11%)				
Smartphone Usage in Low-light Environment						
Yes	42 (58.33%)	21 (29.16%)	0.001	3.4	1.703	6.787
No	30 (41.67%)	51 (70.84%)				
Smartphone Usage Before Bedtime						
Yes	45 (62.50%)	24 (33.33%)	0.001	3.3	1.682	6.605
No	27 (37.50%)	48 (66.67%)				
Initial Smartphone Usage						
Before COVID-19	54 (75%)	14 (19.38%)	0.000	12.4	5.637	27.404
During COVID-19	18 (25%)	58 (80.62%)				

Smartphone Usage in Low-light Environment

The eyes experience changes in anatomical characteristics, such as increased pupil diameter and thickening of the iris in a dark room. Changes in eye structure and high contrast between the smartphone screen and the surrounding environment in dim lighting contribute to increased intraocular pressure. Numerous studies have also identified that a low-light environment can lead to several eye problems, including glaucoma. This study found that smartphone use in low-light environment is a risk factor for myopia in elementary school children in Kediri City (OR = 3.4; CI: 1.703 - 6.787; p = 0.001). Children who use smartphones in low-light environments are at 3.4 times greater risk of developing myopia than children who do not use smartphones in low-light environments. This result is in line with Zhang et al. (19), the review showing a relationship between increased intraocular pressure and increased axial length of the eyeball in people with high levels of myopia compared to people with moderate or low levels. The contrast between the device screen and the environment influences increased intraocular pressure. However, the results of this study contradict the research conducted by Ahmad et al., which found no relationship between the degree of myopia and intraocular pressure (20).

Smartphone Usage Before Bedtime

Sleep is key in child development, and a lack of sleep can cause many disorders. Teenagers and young children spend more time with smartphones, computers, and the like, which often causes sleep problems (15). This study found that smartphone use before bed is a risk factor for myopia in elementary school children in Kediri City (OR = 3.3; CI: 1.682 - 6.605; p = 0.001). Children who use smartphones before bedtime are at risk of developing myopia, 3.3 times greater than children who do not use smartphones before bed. Lidia Puchalska-Niedbał et al.'s study (15) on smartphones and vision said that young children who spend more time with smartphones often experience sleep problems. Direct symptoms include fatigue and impaired concentration. Sleep cycle disorders caused by exposure to blue light from smartphones can be exacerbated by smartphone use before bed, which can cause transient smartphone blindness.

Early Age of Smartphone Usage

This study shows that early-age smartphone usage is associated with the incidence of myopia in elementary school children in Kediri City (OR= 12.4; CI: 5.637 - 27.404; p= 0.000). Children with early smartphone use before the COVID-19 pandemic have a 12.4 greater risk of developing myopia compared to children who started using smartphones during the COVID-19 pandemic. Research by McCrann et al. (12) shows that smartphone ownership has increased drastically in younger age groups. Younger age groups spend more time using smartphones than older students. Research shows that the onset of myopia has also shifted to a younger age (13). Research by Verkicharla et al. (21) on 6984 individuals who visited at least one eye center located in India showed that the earlier the age of onset of myopia

can lead to a greater risk of developing high myopia in adulthood.

Research Limitation

The case-control study may have recall bias. The parents of students have difficulty remembering when their children used a smartphone for the first time, and how long the children spent in outdoor activities. To reduce this, researchers used a confirmation technique by checking smartphone devices to determine the duration of use. This action was taken after obtaining permission from the respondents. However, there are limitations to assessing the duration of smartphone use, which should be done by checking the device directly. Some parents did not bring the device because it was being carried by another family member. As a solution, the researcher asked further questions regarding the time of use and the type of activity that uses the smartphone to estimate the duration of smartphone usage.

In this study, an ophthalmologist did not carry out the examination of visual acuity due to limited resources. As a solution, the researcher conducted training on visual acuity examination using a Snellen chart with an ophthalmologist.

CONCLUSIONS

This study concluded that the duration of smartphone use, usage in low-light environments, usage before bedtime, and the initial age of smartphone exposure are significant risk factors for myopia in elementary school children in Kediri City. Parents of students have an important role in controlling myopia in children. Research by Ali and Alma'aytah (22) shows parental knowledge of smartphones has the potential to limit smartphone use among children. Parents are encouraged to utilize features that lock smartphones after 3-4 hours of usage, adjust screen brightness or activate night mode in low-light settings, and lock devices during bedtime. Parents can change the room's lighting, where children do a lot of reading, writing, and using smartphones. Proper lighting prevents the eyes from getting tired quickly when reading or doing work that requires proximity to the eyes. Additionally, campaigns and parental awareness of smartphone exposure, along with providing good nutrition like vitamin A, are essential in supporting eye health.

The rising trend of myopia cases and smartphone ownership among underage users from year to year emphasizes the need for further research on this relationship. Further research on the initial age of smartphone exposure and myopia cases needs to be conducted in more depth and with a follow-up method. Research on these variables is still rarely conducted, especially in Indonesia.

Based on the results of this study, the researcher expects the local government health office to implement a screening program or eye examination, especially for students, considering that most respondents reported never having undergone an eye examination. Early eye examinations could help prevent myopia from developing in children at a young age.

CONFLICT OF INTEREST

There are no conflicts of interest in this paper.

AUTHOR CONTRIBUTIONS

LAS: Writing, data collecting, and analysing. AU: Reviewing and supervision. DS: Reviewing and supervision. MAW: Reviewing

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