Increasing Exposure of Digital Devices and Its Impact on Physiological and Psychological Development Among Children: A Systematic Review of Prospective Studies

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Abstract: It is true that technology make our lives very comfortable, but it should not be at the expense of our health. Exposure to radio frequency electromagnetic fields has raised scientific and public concerns. It is necessary to acknowledge the adverse effects on the health among children using digital devices. Innovation in computers and mobile 5G phones, online games and use of social media applications are in a great boom. Study of various reviews give the current exposure effects due to these radiations. Here in this paper, we have included studies published in peer-reviewed journals between 2010 and 2023 which are based on empirical evidence and reviews. We have identified 57 published papers on health effects of digital devices on physiological and psychological aspects of children. Some of the major health related physiological problems are reported in the reviews are musculoskeletal problems, sleep disturbances, headache issues and eyestrain. Whereas Psychological problems highlighted in the reviews are poor concentration, memory loss, stress, depression etc. At present, there is insufficient data to draw firm conclusions about health effects due to the exposure of digital devices which are occurring in the everyday environment. Currently, there is little epidemiological evidence indicating that the use of digital devices causes adverse health effects.

Keywords: Mobile Devices, Digital Devices, Technology, Electromagnetic Radiation, Children.

1. INTRODUCTION

Mobile and digital technology has now become an essential learning platform all over the world. It helps in developing human interaction in all dimensions by supporting mobile and digital collaboration. It provides the educational environment for supporting and improving education and its delivery. It engages learners by connecting to media, educators, peers, experts, and the larger world. User can access information anytime and anywhere. The inclusion of e-learning in the learning process is now becoming widespread as a component of traditional education and has caused positive changes in extend of pedagogical, technological, and economic aspects (Birch & Burnett, 2009). The need to access to the information regardless of time and place has increased the effects of mobile technologies and mobile learning, and it has also brought new strategies to learning process (Uysal & Gazibey,2010). Along with the developments in information technologies, wireless communication and mobile devices have been started to be used to support the traditional learning (Wang at al., 2004). Wireless communication techniques may help student to obtain the necessary information. Besides this, it also helps teachers, and the learning systems can direct students to the information by using these techniques. Therefore, students can use their mobiles or PDAs (Personnel Digital Assistant) to access to the information, they need (Wang, Liu, Horng, & Chen, 2003).

1.1 Digital Around the World

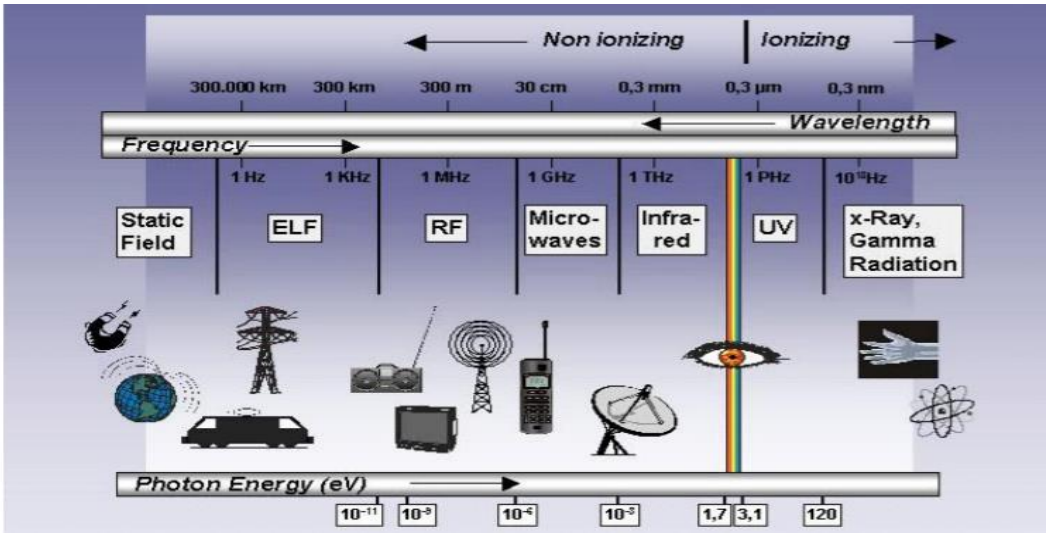
1.1.1 Number of Wireless Subscribers Across India Between June 2010 and December 2020

In the year 2000, there were an estimated 500 million mobile phone users worldwide. Today, there are about 1151 million users. The use of mobile phones among young children and adolescents is also increasing. There has been a phenomenal growth in the telecom sector in terms of total subscribers in India and the total number of Internet users in the country. In 2023, India has over 1.2 billion internet users across the country, showed data by the Telecom

Regulatory Authority of India (TRAI). Social media use continues to grow too, with global users reaching 4.62 billion in January 2022 i.e equal to 58.4 percent of the world population. The number of social media users has increased by 10.1 percent over the past 12 months. 424 million new users joined social media between January 2021 and January 2022, equating to growth of more than 1.1 million new users every day. Social media users are currently growing at a rate of more than 13 new users every single second. Meanwhile, more than two-thirds of the world has a mobile phone, with smartphones accounting for almost 4 in 5 of all the mobile handsets in use today.

1.2 Exposure of Electromagnetic field radiations

1.2.1. Electromagnetic field (EMF) radiation is the flow of photons through space. Different types of radiations are defined by the amount of energy found in the photons. EMFs exist on a spectrum, which is called as electromagnetic spectrum which includes all range of EM radiation. Electric and magnetic fields are part of the spectrum of electromagnetic radiation which extends from static electric and magnetic fields, through radiofrequency and infrared radiation, to X-rays. The field's location on the spectrum depends on its wavelength and frequency.



"Figure 1: *Complete electromagnetic spectrum"*

Note: The image of EMF spectrum was taken from Telecom authority of India. From Information paper on effects of electromagnetic Field radiation from mobile towers and handsets,(2014).Retrieved from https://www.trai.gov.in/sites/default/files/EMF_Information Paper_30.07.2014.pdf.

1.2.2. Classification and Sources of Electromagnetic Radiation Fields

There are four subgroups of electromagnetic radiation fields with frequency and intensity. This electromagnetic spectrum begins at a frequency of 1 Hertz (Hz), which is 1 wave per second.

1.Static Field

2. Extremely low frequency (ELF)

3. Intermediate frequency (IF)

4. Radio frequency (RF)

The RF sources are used in different frequency bands and subdivided in different categories:

i) **Sources operated close to the human body**

One of the examples is mobile phones RF transmitters. In addition to mobile phones, other wireless applications like cordless phones, e.g. DECT, or WLAN systems are very common. The maximum peak power level of a DECT system is 250 mW, of a WLAN system 200 mW.

ii) **Sources operated far away from the human body**

Such sources are fixed installed RF transmitters. An example is base stations that is an essential part of mobile communication networks. The sources of exposure include the FM/AM radio, TV transmission, Mobile phones, tablets, laptops, WLAN, Bluetooth, Wi Fi etc. The effects due to FM, AM and TV transmissions are localized to the areas around the location of towers and the Bluetooth, Zigbee applications operate at low power levels.

Specific Absorption Rate (SAR)

The most important parameter used to assess human exposure to electromagnetic fields is SAR (Specific Absorption Rate). Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed per unit mass by a human body when exposed to a radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg).

1.2.3. Is high or low EMF Radiation Coming Out From Digital Devices Are Responsible For Physiological And Psychological Health Issues?

Numerous articles have been dedicated to refuting theories related to the detrimental effects of Electromagnetic Field (EMF) radiation. These articles collectively underscore the efforts and discussions surrounding the potential health impacts of electromagnetic field (EMF) radiation from mobile towers in India. Officials and experts have consistently emphasized the importance of mobile towers for seamless connectivity while dispelling misinformation about the health risks associated with EMF radiation. International organizations, such as the World Health Organization (WHO), have conducted extensive research, concluding that there is no evidence supporting harmful effects on human health. The regulatory framework in India, including EMF radiation norms and specific absorption rate (SAR) limits, is reported to be stringent, with ongoing monitoring to ensure compliance. In the context of mobile communication, SAR is used to assess the potential health impact of radiofrequency radiation emitted by mobile phones. SAR value of 1.6 watts/kg averaged over a mass of 1-gram human tissue is only permitted to be manufactured or imported in India for the domestic market. Additionally, there have been discussions about 5G standards and potential health risks associated with increased power transmission levels. Committees and authorities have been established to address concerns, conduct checks on mobile towers, and evaluate health-related issues, although no direct link between mobile tower radiation and adverse health effects has been established. The adoption of international standards for electromagnetic field radiation exposure for mobile devices is also highlighted, emphasizing the need for compliance by importers and local manufacturers.

2. METHODS

2.1 Literature Search and Eligibility Criteria

We included studies that were published between 2010 and 2021, few studies before the year 2010. All these studies were based on empirical evidence, published in peer-reviewed journals and conference proceedings. We excluded studies that did not give adequate information about employed countermeasure and those who did not discuss countermeasure efficacy.

Criteria	Inclusion	Exclusion
Population	Adolescents and young people in the age group less than 25 years	Samples based on having specific disorder such as insomnia, diabetes, cancer, and other ill effects which are not the part of physiological and psychological aspects of health.
Exposures	Exposures of EMF due to mobile devices, portable electronic devices such as tablets, laptops, use of social media, games, websites are included in the study.	Studies which referred to screen time without specifying the type of devices used.
Outcomes	All physiological and psychological symptoms which were reported with the help of validated questionnaires are included.	Studies where health outcomes are reported without reference to physiological and psychological symptoms.
Publication type	Peer reviewed journal articles of result reports.	Study protocols, conference abstracts, theses. dissertations, book chapters and any other form of non-peer reviewed publications.

2.2 Data Synthesis Process

Studies were thematically grouped into exposure categories based on the different type of mobile and digital devices use. Summary tables were generated on the various aspects of physiological and psychological symptoms individually. Digital device use category and vote counting approach was used to compare the number of results showing significantly positive or negative association.

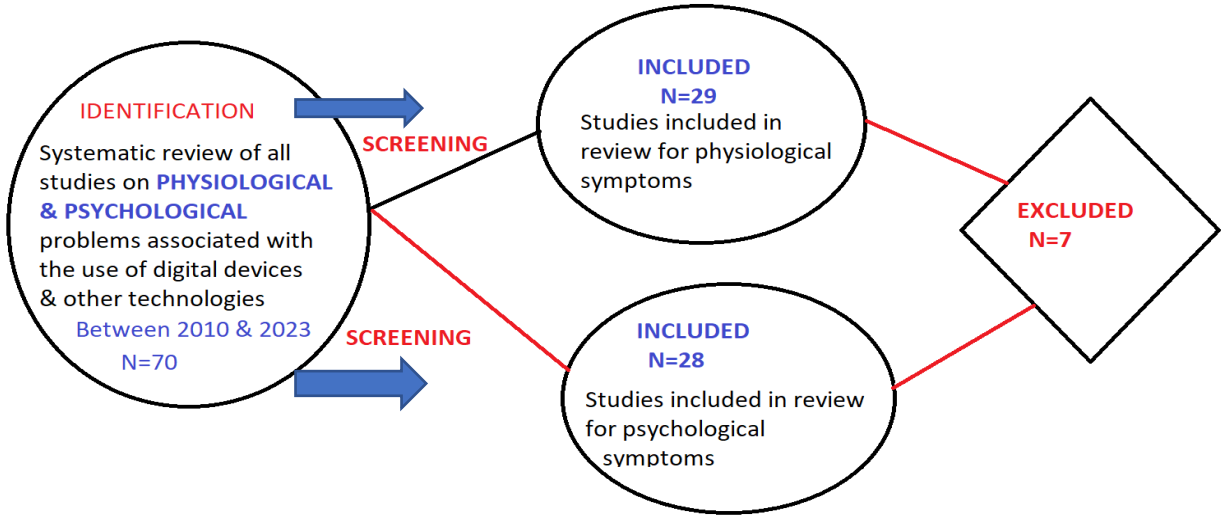


Figure 2: Systematic reviews showing the flow diagram for literature search results.

3. RESULTS

3.1. Literature Search Results

Figure 1 details the study selection process. Total of 57 studies met inclusion criteria. A total of 29 of these studies reported physiological symptoms such as sleep problems, musculoskeletal problems, neurological issues etc whereas 28 of these studies reported psychological symptoms such as depression, stress, anxiety, memory loss etc.

3.1.1. Association Between Digital Device use and Neurological & Musculoskeletal Problems

Warda, Nwakibu & Nourbaksha (2023) found that the use of cell phones among children and young adolescents has led to the emergence of a set of musculoskeletal symptoms that have not been seen before in this age group. **Domoff et al. (2019)** investigated the concerns exist regarding the excessive use and the impact of frequent consumption of mobile media on children such as musculoskeletal outcomes/pain, ocular health, and

migraine/headaches. **Sharma, Lamba & Sharma (2017)** studies indicated symptoms of ill-health such as headache and sleep disturbances among population residing near mobile phone base stations. **Palm et al (2007)** investigated the impact of computer use on the neck and upper-extremity symptoms, headache, and eyestrain for upper secondary school students. They found that students who were using computers greater than 56 hours/week, the prevalence ratios were significantly increased for neck or shoulder symptoms among both the females and the males. **Yuasa et al. (2006)** investigate whether the pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone for 30 min has short-term effects on human somatosensory evoked potentials (SEPs) and concluded that 30 min mobile phone use has no short-term effects on the human sensory cortex. **Meo & Abdul (2005)** studies investigated a link between the use of mobile phones and hearing and vision symptoms in the Saudi population. About 34.59% of problems were related with impaired hearing, earache and/or warmth on the ear, and 5.04% of complaints with the decreased and/or blurred vision.

3.1.2 Mobile and Digital Devices Usage and Poor Sleep Quality

Sakamoto et al. (2022) suggested that the relationship between screen-based media use and children's sleep problem is not simply that media use leads to less sleep but that mental or psychological factors may contribute to the use of media by children with sleep problems.

Akowuah et al.(2021) determined high prevalence of poor sleep quality among undergraduate students in Ghana. **Cyberian, Tendero & Arboledas (2021**) concluded that increase in screen media use was associated with unhealthy habits. **Bhatt et al (2017)** conducted this study to assess the mobile phone dependence level and sleep quality. This study finds out that level of sleep quality was good for 37% students, whereas 63% of students had poor sleep quality.

3.2. Association Between Digital Devices Use and Psychological Development.

3.2.1. Karishma et al. (2023) conducted cross-sectional survey-based study on 100 dental undergraduate students. They found Smartphone addiction reduces the academic knowledge, cognitive, and psychomotor skills of dental students**. Papoutsaki (2022)** studied the effects of electronic media on adolescents where results of the study show that the attention, hyperactivity deficit, and impulsivity were found to have a statistically significant correlation with the social problems. Also found potential addiction to the internet increases rule-breaking, the obsession-compulsion, and the post-traumatic stress. **Blanka Pophof et al. (2021)** conducted this study by systematic review which evaluated the associations between short-term exposure to RF-EMFs and cognitive performance in human experimental studies. **Sultan Ayoub Meo et al. (2019)** investigated the impact of exposure to radiofrequency electromagnetic field (RF-EMF) on cognitive functions. The Mobile phone base stations (MPBSTs) were located within 200 m from the school buildings. In School 1, RF-EMF was 2.010μW/cm2 with a frequency of 925 MHz and in School 2, RF-EMF was 10.021μW/cm2 with a frequency of 925 MHz. In this study, students were exposed to EMFR for 6 hr a day, 5 days a week for a total period of 2 years. Result showed that high exposure to RF-EMF produced by MPBSTs was associated with delayed fine and gross motor skills, spatial working memory, and attention in school adolescents compared to students who were exposed to low RF-EMF. **Xi Mei (2019)** conducted this study to understand the connection between mobile phone use, sleep pattern, and psychological symptoms. Result shows that there was a significant mediation effect of the relationship between mobile phone use before sleep and psychological symptoms by sleep duration. Frequent mobile phone use before sleep was associated with significant adverse effects on multiple sleep parameters and psychological symptoms.

Gadi Lissak (2018) investigated the excessive and addictive use of digital media with physical, psychological, social and neurological adverse consequences. Depressive symptoms and suicidal are associated to screen time induced poor sleep, ADHD-related behavior, Psychoneurological effects: addictive screen time use decreases social coping and involves craving behavior which resembles substance dependence behavior. **Qing -Qi Liu et al. (2017)** conducted the study which revealed that mobile phone addiction would bring about significant adverse impacts on mental health such as depression, anxiety, and even suicidal ideation.

Vernon, Kathryn L. Modecki & Bonnie L. Barber (2017) conducted this study to find out the trajectories of sleep habits and subsequent Adolescent Psychosocial Development. Changes in sleep behaviour mediated the relation between early changes in night-time mobile phone use and later increases in depressed mood and externalizing behaviour and later declines in self-esteem and coping. **Young & Paek (2016)** investigated the relationships among depression, communication competence and level of Smartphone addiction. They found that Depression (r = 0.407, p <0.001) was positively related to smartphone addiction and communication competence (r=-0.281, p<0.001) was negatively related to smartphone addiction. Depression (β=.302, p<0.001), communication competence (β=-0.148, p<.01), daily smartphone using time (β=0.144, p<.01), grade (β=.136, p<0.1), academic achievement (β=.119, p<0.05) and gender (β=.117, p<0.05) were identified as significant predictors of smartphone addiction. **Augner & Hacker (2012)** were conducted this study to address possible associations between excessive or dysfunctional use of mobile phones and certain psychological variables. Statistical analysis of this study indicates that chronic stress, low emotional stability, female gender, young age, depression, and extraversion are associated with problematic phone use. **Khan (2008)** investigated in his study whether the symptoms of ill health reported by young people may be associated with the use of mobile phone (MP). He found out that 16.08% of the subjects complained of headache and 24.48% of fatigue. Impaired concentration was reported by 34.27% of respondents, memory disturbances by 40.56%, sleeplessness by 38.8%, hearing problems by 23.07%, and facial dermatitis by 16.78%. The sensation of warmth within the auricle and behind/around the ear was reported by 28.32%. Research findings indicated that the use of mobile phones may lead to several symptoms such as headache, impaired concentration and memory, and also fatigue.

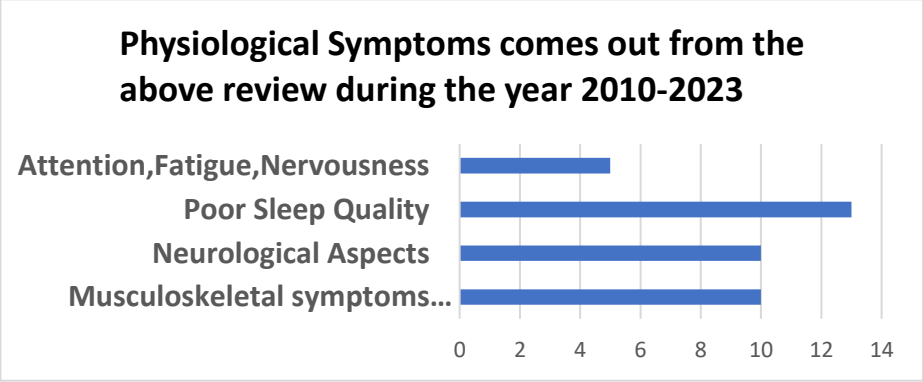
Mortazavi, Ahmadi & Shariati (2007) were investigated the self-reported symptoms such as headache (53.5%), fatigue (35.6%), difficulties in concentration (32.5%), vertigo/dizziness (30.4%), attention disorders (28.8%), nervousness (28.1%), palpitation (14.7%), low back pain (14.3%), myalgia (12.4%), and tinnitus (9.9%) which occurred due to EMF radiations. This finding confirmed the results obtained in provocative studies which indicated the role of psychological factors in electromagnetic hypersensitivity.

4. DISCUSSION

4.1. Findings of the Above Literature Review

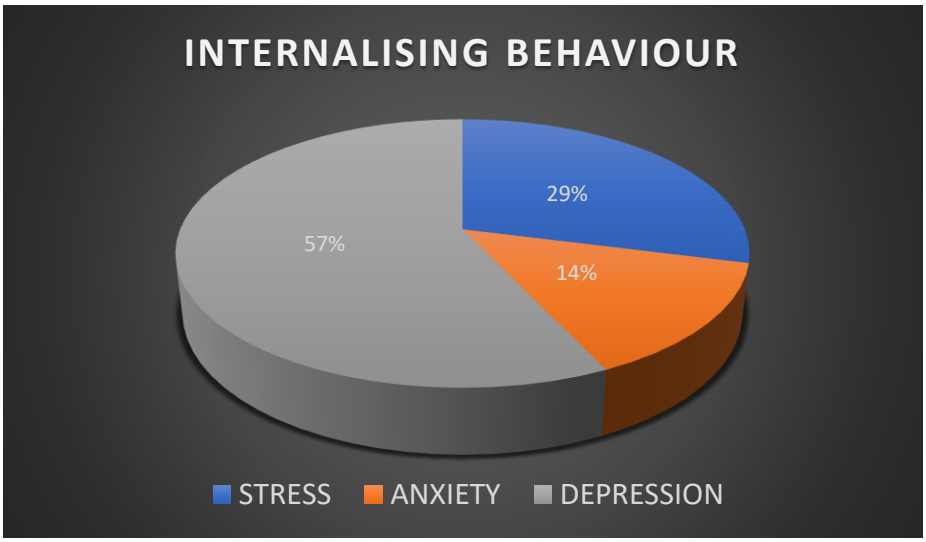
The aim of this systematic review was to summarise the published experimental and longitudinal results for digital device use and its effect on physiological and psychological development among children. There are 57 epidemiological studies that has been reviewed to examine the health effect of exposure of digital devices on physiological and psychological development among children.

1. Reported major Physiological symptoms developing among children and adolescence using mobile and digital devices from the above literature review are musculoskeletal symptoms, neurological issues, poor sleep quality etc. Among all the problems, it can be observed that poor sleep quality was reported many times in the above-mentioned papers.



"Figure 3: Showing the result of review on physiological symptoms".

2. Above studies revealed the fact that there is prolonged effect of mobile and digital devices on psychological development of students. Developed psychological symptoms reported in the above papers were poor concentration, memory, and retention power, internalising and externalising behaviour, electromagnetic hypersensitivity, communication competence etc. In the maximum papers, the impact of digital devices can be seen adversely on mental health. Depression, stress, and anxiety were seen more among students using digital devices excessively.



"Figure 4: Showing the result of review on psychological symptoms".

4.2. Future Research Recommendations

Mobile Services and wireless broadband access are necessary not only for rapid growth and modernization of various sectors of the economy but also for success of key Government initiatives related to education, health, finance and other e-governance services. The EMF Project of World Health Organization, after two decades of extensive research has corroborated that there is no evidence to support the claim that exposure to low-level electromagnetic fields is harmful to human health. WHO said that it is important for citizens to understand today that mobile tower EMF radiation are being strictly monitored and evidence from credible sources have ruled out possibility of health issues emanating from EMF radiations. But besides that, many studies in literature reviews that have been done in the past proclaimed that "physiological" and "psychological" problems are generated due to excess usage of mobile and digital devices. So, it becomes imperative for future interventions including education programmes to reach out to children and youth for increasing awareness of the potential risks of using digital devices.

4.3 Strength and Limitations of the review process

This review includes comprehensive and extensive use of research across various literature searches, the longitudinal and experimental studies, and the categorisation of exposures to consider the different types of difficulties faced by children and youth. Besides that, there are some limitations which includes the exclusion of some reviews which are not published in English, unable to perform meta-analysis, the limitation of methodology of vote counting approach.

CONCLUSION

In India, the EMF radiation norms are 10 times stricter than the limits prescribed by the International Commission on Non-ionizing Radiation Protection (ICNIRP) and is recommended by the World Health Organisation (WHO). The SAR value, which is the radiation emitted by a cell phone, will have to be displayed on mobile handsets. The 1.6 watts/kg averaged over a mass of 1-gram human tissue are only permitted to be manufactured or imported in India for the domestic market. As technology advances, a greater number of people comes under the exposure of EMF.

This literature review summarises 57 studies on the impact of digital devices on physiological and psychological problems among children. Problems such as musculoskeletal problems, neurological issues, poor sleep quality which are developing very fast among children ultimately affecting the academic performance and overall development of children. Result demonstrated that EMF and exposures of Digital devices are one of the reasons for the problems identified, however, more researches need to be done to remove all the doubts and to present the clear picture in front of the public. Children should be provided with adequate environment so they can engage in a broader range of physical activities, adopt healthy eating habits, have proper sleep cycles and nurturing better social environment for their growth and development.

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