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Cross-Sectional Study on Physical Activity and Auditory Reaction Time in Elementary School Students

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Abstract

Introduction: The rapid advancement of information and communication technologies has significantly influenced children's lifestyle behaviors, particularly reducing their levels of physical activity. Physical activity plays a vital role in enhancing cognitive and motor functions, including reaction time. Auditory reaction time refers to the time interval between the perception of an auditory stimulus and the execution of a motor response, which is critical for learning processes and classroom responsiveness in school-aged children. This study aimed to investigate the relationship between physical activity levels and auditory reaction time among students at SD Negeri 5 Peguyangan Denpasar.
Methods: This analytical observational study employed a cross-sectional design and purposive sampling technique. A total of 38 students who met the inclusion and exclusion criteria were enrolled. Physical activity levels were measured using the *Physical Activity Questionnaire for Children (PAQ-C)*, while auditory reaction time was assessed using Millisecond Software. Data were analyzed using the non-parametric Spearman's rho test to determine the correlation between variables.
Results: The analysis revealed a statistically significant negative correlation between physical activity levels and auditory reaction time ($p = 0.017$, $p < 0.05$), with a correlation coefficient of $r = –0.384$. This finding indicates that higher physical activity levels are associated with faster auditory reaction times.
Conclusion: The study concludes that there is a weak but significant inverse relationship between physical activity and auditory reaction time in elementary school students. Promoting physical activity may contribute to improved cognitive-motor responsiveness in children, which is essential for their academic performance and daily activities.

Keywords: physical activity, auditory reaction time, children, elementary school, cross-sectional study

Introduction

The rapid advancement of information and communication technology has brought numerous conveniences to modern human life. Today, daily activities are increasingly inseparable from the use of digital devices. From work involving extensive computer use to easily accessible entertainment via smartphones and even voice-activated smart robots capable of cleaning entire rooms, technology permeates nearly every aspect of life. However, these conveniences have also led to a decline in physical activity, as people become more sedentary. According to the 2018 Basic Health Research (Riset Kesehatan Dasar) conducted by the Indonesian Ministry of Health, approximately 33.5% of the Indonesian population engages in insufficient physical activity. In Bali Province, about 26% of the population is classified as physically inactive.[1]

Technological development has indirectly changed how people engage in daily activities and consume entertainment, particularly among children. A 2017 survey conducted by the Indonesian Ministry of Communication and Information reported that 65.34% of children aged 9–19 years in Indonesia own a smartphone, and 51.52% of those children use their smartphones for more than three hours per day. Furthermore, 65.29% of them primarily access entertainment applications such as video streaming and games while connected to the internet.[2] These habits indicate that most Indonesian children spend a significant amount of time on smartphones, which can reduce their daily physical activity levels.

Physical activity refers to any bodily movement generated by skeletal muscles that results in energy expenditure.[3] It is typically categorized by intensity and caloric demand into light, moderate, and vigorous activity.[4] Physical activity provides numerous physiological benefits, including enhanced cerebral blood flow, which in turn improves cognitive function and reaction time.[5]

Reaction time is defined as the interval between the presentation of a stimulus and the initiation of a voluntary motor response to that stimulus.[6] There are three types of stimuli that can elicit reaction time: visual, auditory, and tactile.[7] Auditory reaction time specifically refers to the time required for an individual to perceive an auditory stimulus and consciously respond with a motor action.[5] Internal factors that influence reaction time include age, sex, fatigue,

intelligence level, and underlying health conditions. External factors include the type of stimulus, prior training, stimulus anticipation, and the consumption of drugs or food substances.[8]

Engaging in regular physical activity improves cardiovascular fitness. Individuals who participate in moderate to vigorous physical activity tend to have better cardiovascular function than those who engage in light activity.[9] Cardiovascular fitness directly affects cerebral circulation; greater cardiovascular capacity enhances blood flow to the brain.[10] This increased blood flow improves the delivery of essential nutrients such as oxygen and glucose, thereby enhancing cognitive performance, including the speed of processing auditory stimuli.[5,11]

Quick reaction time plays a vital role in everyday life, particularly in academic settings. Faster auditory reaction times can enhance students' academic performance and their ability to solve problems.[12] Despite the relevance of this topic, limited research has explored the relationship between physical activity and auditory reaction time in children, especially those of primary school age. This study therefore aims to examine the relationship between physical activity and auditory reaction time in students at SD Negeri 5 Peguyangan Denpasar. The authors hypothesize that higher levels of physical activity are associated with faster auditory reaction times in children.

Methods

This study employed an observational analytic design with a cross-sectional approach. The independent variable was physical activity, while the dependent variable was auditory reaction time. The study was reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Udayana University/Sanglah General Hospital, Denpasar (Approval Number: 1657/UN 14.2.2.VII.14/LT/2022), and received ethical clearance.

Data collection was conducted on September 17 and 24, 2022, at SD Negeri 5 Peguyangan, North Denpasar. The study sample consisted of students aged 10–11 years selected through purposive sampling who met both inclusion and exclusion criteria. The inclusion criteria were: students at SD Negeri 5 Peguyangan aged 10–11 years, in normal vital sign range, and willing to participate in the study with written parental or guardian consent. The exclusion criteria included known hearing impairments (determined through a whisper test) and any illness during the study period as assessed by a physiotherapist through examination and interview. Dropout criteria included inability to follow instructions, voluntary withdrawal, absence during data collection, and illness during the research period.

The sample size was calculated using Notoatmodjo's formula for cross-sectional studies, with a 10% confidence level, a proportion of 90% from previous studies, and a 10% margin of error. Based on these parameters, a minimum sample size of 38 participants was determined. The research procedure began with obtaining approval from the school principal and providing information to the school and study population regarding participant selection. Eligible participants were given an informed consent form to be signed by their parent or guardian. Participants were then informed about the study procedures in advance.

Physical activity was assessed using the Physical Activity Questionnaire for Children (PAQ-C), which generates a physical activity score ranging from 1 to 5, with higher scores indicating greater physical activity. Auditory reaction time was then measured using the Millisecond Software application (Simple Auditory Reaction Time), which is widely used in national and international studies to assess auditory response time in milliseconds.[11,12] During the test, participants were instructed to press the spacebar on a keyboard as quickly as possible upon hearing a sound stimulus. Each participant received 50 auditory stimuli, and the average reaction time was recorded in milliseconds.

Data were analyzed using SPSS version 25.0. Three types of analysis were performed. First, univariate analysis was conducted to describe the characteristics of age, grade level, gender, physical activity, and auditory reaction time. Second, normality was tested using the Kolmogorov–Smirnov test. Third, bivariate analysis was performed using Spearman's rho to assess the strength and direction of the relationship between the independent and dependent variables.

To minimize bias, all data analysis and processing were performed solely by the researcher. Auditory reaction time was measured using standardized earphones, and the laptop volume was kept constant across all devices to reduce potential confounding factors. The PAQ-C questionnaire used in this study had been previously validated and tested for reliability. Additionally, the researcher supervised and provided instructions during the administration of the PAQ-C and auditory reaction time measurements to prevent misinterpretation and ensure consistency. A whisper test was conducted prior to testing to exclude participants with potential hearing impairments that might introduce bias into the study.

Results

This study involved 38 students aged 10–11 years from SD Negeri 5 Peguyangan who met the predetermined inclusion and exclusion criteria. Subjects were selected through purposive sampling. The following section presents the flow of the study and the characteristics of the subjects based on age, gender, grade level, physical activity scores, auditory reaction times, and their statistical relationships. The flow of participant selection and study procedures is summarized in the following diagram (Figure 1).

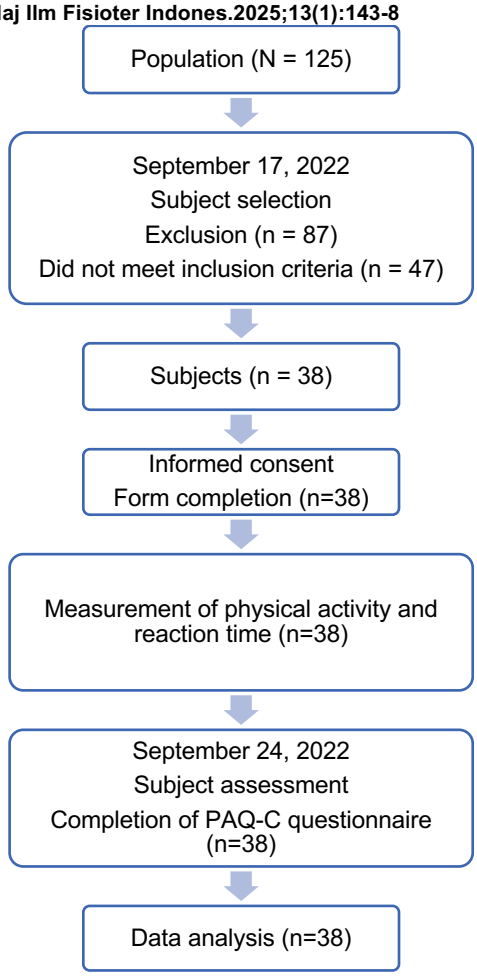

Figure 1. Flow Diagram of the Study

The descriptive data of study participants, including age distribution, gender, grade level, and physical activity scores, are presented in Table 1. These data provide a general overview of the demographic and physical activity characteristics of the subjects.

Table 1. Frequency Distribution of Subject Characteristics

Variable	Frequency (n)	Percentage (%)
Age:		
10 years	18	47.4
11 years	20	52.6
Gender:		
Male	21	55.3
Female	17	44.7
Grade Level:		
IV	6	15.8
V	17	44.7
VI	15	39.5
Physical Activity Score (PAQ-C):		
1	1	2.6
2	13	34.2
3	18	47.4
4	6	15.8
5	0	0.0

Table 1 shows that the participants were nearly evenly distributed in terms of age and gender. Most students were in grade V, and the majority had a PAQ-C score of 3, indicating a moderate level of physical activity. To better understand the general trends in physical activity and auditory reaction time, the mean and standard deviation of these variables are summarized in Table 2.

Table 2. Descriptive Statistics of Key Variables

Variable	Mean	Standard Deviation
Physical Activity Score	2.76	0.75
Auditory Reaction Time (ms)	288.69	56.19

Table 2 indicates that the average physical activity score among participants was 2.76, while the average auditory reaction time was 288.69 milliseconds, with relatively high variability among individuals. The following cross-tabulation (Table 3) provides a more detailed breakdown of auditory reaction times according to physical activity score categories. This allows for comparison of auditory reaction performance across different levels of physical activity.

Table 3. Cross-tabulation of Physical Activity Score and Auditory Reaction Time

PAQ-C Score	Frequency	Minimum (ms)	Maximum (ms)	Mean (ms)	Standard Deviation
1	1	306.52	306.52	306.52	0.00
2	13	256.40	382.24	311.35	39.59
3	18	193.90	375.70	294.54	56.99
4	6	188.82	291.72	234.61	42.77
5	0	0.00	0.00	0.00	0.00

As shown in Table 3, students with a PAQ-C score of 4 demonstrated the fastest average auditory reaction time (234.61 milliseconds), while those with lower scores showed slower response times. To determine the significance and strength of the association between physical activity level and auditory reaction time, a Spearman's rho correlation test was performed. The results are displayed in Table 4.

Table 4. Spearman's Rho Correlation between Physical Activity and Auditory Reaction Time

Variable Correlation	Correlation Coefficient	p-value
Physical Activity vs. Auditory Reaction Time	-0.384	0.017

Table 4 demonstrates a statistically significant negative correlation (r = -0.384, p = 0.017) between physical activity level and auditory reaction time among children aged 10–11 years. This suggests that higher levels of physical activity are associated with faster auditory reaction times, although the correlation is considered weak.

Discussion

Subject Characteristics

This study was conducted at SD Negeri 5 Peguyangan, targeting students aged 10–11 years. The sample size was determined using probability sampling with a purposive sampling method, resulting in 38 participants. Data collection was carried out by inviting each eligible subject—those who met the inclusion and exclusion criteria and had obtained parental/guardian consent—to attend the research site in person.

Among the participants, the majority were 11 years old (n=20; 52.6%), followed by 10-year-olds (n=18; 47.4%). In terms of gender distribution, 21 subjects were male (55.3%) and 17 were female (44.7%). The participants were drawn from three different grades: fifth grade (n=17; 44.7%), sixth grade (n=15; 39.5%), and fourth grade (n=6; 15.8%).

The average physical activity score among students at SD Negeri 5 Peguyangan was 2.76, with a minimum score of 1 and a maximum score of 4. These findings suggest that most students were moderately active, as the average score falls between 2 and 3 according to the Physical Activity Questionnaire for Children (PAQ-C).[13] Similar results were observed in a study conducted at SD Negeri 4 Tonja, where 51.9% of 54 students demonstrated good levels of physical activity.[14] This may be attributed to the strong desire of children aged 10–11 to engage in peer play. Additionally, the relatively short school hours afford children in this age group ample free time for physical play or other activities.

Regarding auditory reaction time, the sample showed a wide range of scores. The mean auditory reaction time was 288.69 milliseconds, with the shortest time being 188.82 milliseconds and the longest 382.24 milliseconds. This mean is lower than that reported in a similar study on elementary school children in Baha Village, where the average auditory reaction time was 447.31 milliseconds for boys and 480.17 milliseconds for girls.[15]

Relationship Between Physical Activity and Auditory Reaction Time

Based on Spearman's rho analysis, a significant relationship was found between physical activity and auditory reaction time, with a p-value of 0.017. The Spearman correlation coefficient was −0.341, indicating a significant but weak negative correlation between the two variables. This suggests that increased physical activity is associated with faster auditory reaction time among children aged 10–11 at SD Negeri 5 Peguyangan.

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. It comprises four key components: bodily movement initiated by skeletal muscle activation, energy expenditure, varying intensity from low to high, and a positive correlation with physical fitness.[16] Regular physical activity offers multiple benefits for children, including improvements in physical, mental, and psychosocial health, as well as reductions in the risk of cardiovascular diseases, diabetes, hypertension, obesity, and metabolic syndrome.[17] Factors influencing physical activity include age, gender, social environment, and living conditions.

Physical activity can enhance cardiovascular function, which in turn improves cerebral blood flow.[10] Increased cerebral perfusion delivers more nutrients and oxygen to the brain, enhancing cognitive function. Improved cognition enables faster processing of stimuli, particularly auditory stimuli.[5,11] Moreover, physical activity can improve concentration and alertness, indirectly contributing to faster reaction times.[5]

A study by Zoya et al. (2019) also identified a relationship between physical activity and auditory reaction time in children. The study, which involved 67 students over a two-day period, found significant differences in auditory reaction time between children with high and low physical activity levels. Children with high physical activity had an average auditory reaction time of 158.45 milliseconds, whereas those with low activity averaged 324.33 milliseconds.[18]

One limitation of this study is that it focused solely on the relationship between physical activity and auditory reaction time, without controlling for potential confounding variables such as gender and intelligence level. Future research should address these limitations by incorporating additional variables that may influence this relationship. Researchers are encouraged to include a more diverse and representative sample, employ stronger research designs, and transparently discuss the study's limitations in the conclusions. This would allow for more valid and detailed insights into the relationship between physical activity and auditory reaction time.

The findings of this study suggest that children with higher levels of physical activity tend to exhibit faster auditory reaction times. However, as the study was limited to students at SD Negeri 5 Peguyangan, the results may not be generalizable to children of the same age group in other settings. Factors such as cognitive ability may vary between populations and influence outcomes. Therefore, further studies with broader and more representative samples are recommended to confirm these findings on a larger scale.

Conclusion

Based on the findings of this study, it can be concluded that there is a statistically significant, albeit weak and negative (inverse) correlation between physical activity and auditory reaction time among students at SD Negeri 5 Peguyangan Denpasar. The implications of these findings suggest that, within this specific student population, higher levels of physical activity are associated with faster auditory reaction times, although the relationship is weak.

These results may offer valuable insight for educators and school administrators regarding the importance of incorporating physical activity as a supportive component in the development of auditory skills. When designing educational programs, it is important to consider the integration of physical activity and auditory skill development as part of a holistic approach to fostering student growth. Additionally, these findings may serve as a consideration for parents and students to maintain a balanced lifestyle that promotes both physical activity and the enhancement of auditory processing skills, contributing to improved health and cognitive performance.

However, it is important to note that these implications are specific to the context of this study and may not be generalizable to broader populations. Further research involving more diverse and representative student samples is recommended to confirm these findings on a larger scale.

Author Contribution

I Gusti Agung Paramananda Prajanata: Conceptualization, methodology, data collection, data analysis, and manuscript drafting.

I Made Niko Winaya: Supervision, guidance on research design, and critical review of the manuscript.

I Wayan Sugiritama: Supervision, validation, and manuscript editing.

Ni Made Linawati: Supervision, methodological consultation, and final manuscript review.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this study.

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Ethics Statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was not required as the study involved only non-invasive procedures (blood pressure measurement and questionnaire surveys) and posed minimal risk to participants. Informed consent was obtained from all participants prior to their inclusion in the study, and confidentiality was strictly maintained.

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