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Relationship of Resting Heart Rate Variability to Physical Fitness Levels in Adolescents

Fatoni[1*], Mohammad Dika Raswadi[2]

[1,2]Department of Physical Education, Health and Recreation, Faculty of Sports Science and Health, Universitas Negeri Makassar, Makassar, Indonesia

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Corresponding author:
Fatoni
E-mail address:
fatoni@unm.ac.id

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ABSTRACT

Introduction. Physical fitness is an important indicator of adolescent health, closely related to cardiovascular function and the body's ability to perform physical activity. One physiological parameter reflecting cardiovascular system regulation is resting heart rate variability, which has the potential to serve as an objective indicator of physical fitness. This study aimed to examine the relationship between resting heart rate variability and physical fitness levels in adolescents. **Methods.** This study used a quantitative approach with a cross-sectional correlational design. Fifty-eight students from SMP Negeri 3 Gowa were selected using a purposive sampling technique. Resting heart rate variability was measured using a digital heart rate monitor, while physical fitness levels were assessed using the Cooper test. Data were analyzed descriptively and inferentially using the Pearson correlation test with SPSS version 25 at a significance level of 0.05. **Results.** The findings revealed a positive and significant relationship between resting heart rate variability and physical fitness levels ($r = 0.462$; $p = 0.001$). Adolescents with better resting heart rate variability tended to demonstrate higher levels of physical fitness. **Conclusion.** Resting heart rate variability is significantly associated with physical fitness levels in adolescents and shows potential as an objective physiological indicator for monitoring physical fitness.

1. Introduction

Physical fitness is an important indicator of adolescent health, supporting physical growth, functional capacity, and readiness for learning and physical activity. During adolescence, various physiological and hormonal changes occur that affect the cardiovascular system and the body's response to physical activity.[1,2] Therefore, monitoring physical fitness in this age group is an important aspect of health promotion and prevention efforts.

One of the physiological parameters increasingly used to describe the condition of the cardiovascular system is resting heart rate variability. Heart rate variability (HRV) is an important physiological parameter for describing the condition of the cardiovascular system. HRV measures fluctuations in the interval between heartbeats, reflecting the ability of the autonomic nervous system (ANS) to regulate the balance between sympathetic and parasympathetic activity. Higher HRV values are generally associated with optimal physiological adaptation capacity and better cardiovascular health.[3,4]

Resting HRV measurement is relatively easy and non-invasive, making it a good physiological indicator for fitness monitoring.[5] Increased parasympathetic activity can be indicated by increased HRV, which is associated with cardiovascular health and physical endurance.[6] The balance between these two components of the ANS is crucial, as an imbalance, particularly a predominance of sympathetic activity, can lead to long-term cardiovascular health problems, including hypertension and the risk of heart disease.[7,8] However, evidence regarding the relationship between resting HRV and physical fitness among Indonesian adolescents remains limited. To date, normative data on HRV parameters in local junior high school populations are still scarce, making it difficult to interpret HRV values within a relevant demographic context. Investigating students at the junior high school level is particularly important, as this developmental stage represents a critical period of cardiovascular and autonomic maturation that may influence long-term health trajectories.

Several studies have reported that HRV can be a valuable indicator for evaluating cardiovascular health risk. Research conducted by Marques et al. demonstrated that alterations in HRV were observed in individuals experiencing cardiorespiratory dysfunction, suggesting that HRV assessment may be useful for monitoring changes in cardiovascular and

autonomic regulation.[3] Decreased HRV is often associated with an increased risk of cardiovascular problems, particularly in the context of hypertension and coronary heart disease.[9]

Low R-R interval variability is associated with elevated levels of C-reactive protein (CRP), a marker of inflammation, in the general population, indicating heart disease risk.[10,11] Given the increasing prevalence of diabetes associated with cardiac autonomic dysfunction, HRV measurement can provide important insights into the diagnosis and management of cardiac autonomic neuropathy.[12] Due to the non-invasive nature of HRV measurement, this method is ideal for use in routine health monitoring, both in healthy populations and in those at risk for heart disease. This approach can be integrated into fitness and rehabilitation programs to monitor individuals' physiological responses to exercise and physical stress.[6,13] HRV analysis can provide valuable information regarding ANS balance and cardiovascular fitness levels, allowing for appropriate interventions to improve performance and prevent overtraining.[14]

Most existing studies have largely emphasized the clinical relevance of HRV, particularly in relation to disease conditions and the assessment of cardiovascular risk. Only a limited number of investigations have explored how resting HRV relates to physical fitness among healthy adolescents, especially within school environments. Consequently, empirical evidence regarding the use of HRV as an objective physiological marker of physical fitness in adolescent populations remains relatively scarce.

In response to this gap, the present study quantitatively investigates the association between resting heart rate variability and physical fitness levels in adolescents. Clarifying this relationship is expected to contribute scientific evidence supporting the use of simple physiological indicators for evaluating physical fitness, as well as providing a practical reference for monitoring and improving adolescent fitness development.

2. Methods

This study used a quantitative approach with a correlational design aimed at analyzing the relationship between resting heart rate variability and physical fitness levels in adolescents. The study subjects were 58 students of SMP Negeri 3 Gowa who were selected using a purposive sampling technique with inclusion criteria including students in good health, no history of cardiovascular disorders, and willingness to participate in the entire study series. Resting heart rate variability was measured using a digital heart rate monitor during a 6-minute resting period under seated resting conditions, while physical fitness levels were measured using the Cooper test. Written informed consent was obtained from all participants and their guardians, and all research procedures were approved by the Universitas Hasanuddin Ethics Committee (Approval Number: 557/H4.8.4.5.31/PP36-KOMETIK). The data obtained were analyzed descriptively to determine the mean value, standard deviation, and data distribution of each variable. A normality test was performed as a prerequisite for inferential analysis. The association between resting heart rate variability and physical fitness levels was examined using the Pearson correlation test when the data met the assumption of normal distribution. The entire statistical analysis process was carried out using the Statistical Package for the Social Sciences (SPSS) version 25 with a significance level of 0.05.

3. Results

The descriptive analysis results show that the data distribution of resting heart rate variability and physical fitness levels in 58 students at SMP Negeri 3 Gowa is relatively varied. Resting heart rate variability values show interindividual differences, reflecting variations in the regulatory state of the autonomic nervous system in the study subjects. Meanwhile, the students' physical fitness levels ranged from low to good, according to the results of the physical fitness tests administered.

Based on descriptive statistical analysis of 58 respondents, the Resting Heart Rate Variability (RHRV) variable had a minimum value of 32.10, a maximum of 78.40, a mean of 54.26, and a standard deviation of 10.87, indicating a moderate level of resting heart rate variability with considerable variation.

Meanwhile, the physical fitness level had a minimum value of 38.00, a maximum of 86.00, a mean of 63.45, and a standard deviation of 11.32, indicating that respondents' physical fitness was moderate to good, with significant differences between respondents.

The analysis results showed that resting heart rate variability had a positive and significant relationship with physical fitness levels in adolescents ($r = 0.462$; $p = 0.001$). This indicates that the better the resting heart rate variability, the higher the students' physical fitness levels tend to be.

Table 1. Descriptive statistics of resting heart rate variability and physical fitness

Variable	N	Minimum	Maximum	Average	Standard Deviation
Resting heart rate variability	58	32.10	78.40	54.26	10.87
Physical fitness level	58	38.00	86.00	63.45	11.32

Table 2. Correlation test results of resting heart rate variability with physical fitness level

Variable	Correlation Coefficient (r)	Sig. (p)	Description
Resting heart rate variability and physical fitness	0.462	0.001	Moderate correlation

4. Discussion

The findings of the study demonstrate a statistically significant positive association between resting heart rate variability and physical fitness among adolescents. This result suggests that adolescents who exhibit better heart rate variability at rest generally show higher levels of physical fitness. Overall, the analysis confirms that HRV is positively related to physical fitness in adolescent populations. These results align with research that suggests adolescents with better HRV tend to have higher physical capacity, suggesting that good cardiovascular regulation is closely linked to an individual's physical ability at a young age.[15,16]

Resting heart rate variability reflects the balance of autonomic nervous system activity, specifically the dominance of parasympathetic activity during rest. The ANS is primarily divided into sympathetic and parasympathetic branches. The parasympathetic system primarily regulates resting heart rate, reflecting relaxation and recovery, while the sympathetic system prepares the body for stress and activity.[17,18] Studies show that greater heart rate variability is associated with increased vagal tone, an important marker of parasympathetic activity.[19,20] Increased HRV, especially during resting states, indicates a well-functioning cardiovascular system capable of adapting efficiently to physical and psychological stress.[21,22]

It has been shown that physical fitness at a young age is important for promoting long-term health benefits.[23] Adolescents who exercise regularly show increased cardiac efficiency, decreased resting heart rate, and improved blood pressure regulation. For example, HIIT has been shown to effectively reduce blood leptin levels. and improve various cardiometabolic variables in adolescent girls, suggesting that physical activity plays a crucial role in combating obesity and related health problems.[24,25] The complex relationship between exercise, body composition, and hormonal responses further underscores the importance of maintaining a physical fitness routine during adolescence.

Endurance training has also been associated with changes in cerebrovascular health, potentially reflecting increased blood flow and adaptations of the cerebral vascular system in response to increased physical demands.[26] These adaptations during youth may underlie cognitive benefits as individuals age. The results of this study suggest that resting HRV has the potential to be a relevant physiological indicator for describing physical fitness in adolescents, as it reflects internal body responses that are not always apparent through observation of physical activity alone.

Practical implications of using non-invasive and easily performed HRV measurements in the context of adolescent health education and fitness monitoring. HRV is recognized as an important indicator of autonomic regulation and overall cardiovascular health, which plays a crucial role in physical education settings. For example, heart rate monitoring is an integral tool that can improve chronic disease management and support healthy physical activity engagement among adolescents, enabling educators and health practitioners to gain objective and actionable insights into students' physiological status.[27,28] Such objective assessments can guide the design of physical activity programs tailored to students' individual fitness levels, potentially mitigating the detrimental effects of sedentary behaviors prevalent in school settings.[29,30]

Furthermore, evidence suggests that integrating HRV assessment into school-based physical education can foster a more informed approach to developing health and fitness interventions aimed at improving students' overall well-being.[31] These practices are highly important in the context of increasing sedentary behavior and lifestyle changes among adolescents, which may adversely affect cardiovascular health and physical fitness. Consequently, the school environment has emerged as a strategic setting for monitoring and promoting cardiovascular fitness through innovative methods that can be integrated into routine educational practices. However, further empirical evidence is still required to comprehensively evaluate the effectiveness of these approaches within this context.[32,33] By utilizing HRV as a monitoring tool, educators and health professionals can ensure a responsive approach to promoting physical fitness that aligns with adolescents' physiological needs and health development, thereby improving their engagement and performance in physical activity. [34]

The present study has several limitations. The use of a cross-sectional correlational approach restricts the ability to infer causal relationships between the variables examined. Heart rate variability was also evaluated solely through the time-domain indicator, namely the root mean square of successive differences (RMSSD), measured under resting conditions, while other HRV metrics, including frequency-domain indicators, were not considered. In addition, several potentially influential factors, such as patterns of daily physical activity, sleep quality, and psychological stress, were not examined in this investigation. Future studies are therefore encouraged to adopt longitudinal or experimental

research designs, incorporate a wider spectrum of HRV indicators, and account for additional relevant variables in order to develop a more comprehensive understanding of the association between autonomic regulation and physical fitness among adolescents.

5. Conclusion

The results of the analysis reveal a significant positive relationship between resting heart rate variability and physical fitness levels in adolescent populations. Adolescents with better resting heart rate variability tended to demonstrate higher levels of physical fitness, suggesting that this physiological parameter may be associated with physical fitness status. The results indicate that resting heart rate variability shows promise as a complementary physiological measure in monitoring physical fitness among adolescents, although it should not be interpreted as a standalone indicator. However, this study employed a correlational design and therefore cannot establish cause-and-effect relationships. Future research is recommended to utilize more robust research designs and incorporate additional relevant variables to achieve a more comprehensive understanding of physical fitness development in adolescents.

6. Author Contribution

The study was conceived and designed by F.F. and M.D.R. The experimental procedures were conducted by F.F. and M.D.R., while F.F. was responsible for the data analysis. The interpretation of the experimental findings was carried out by M.D.R., who also prepared the graphical illustrations. The initial manuscript draft was written by F.F., and both authors contributed to editing and revising the manuscript. The final version of the manuscript was approved by F.F.

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