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A Lifestyle with Moderate-to-Vigorous Physical Activity Lowers Resting Heart Rate in Adolescents

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Abstract

Physical activity plays an important role in maintaining cardiovascular health and preventing early cardiometabolic risk. However, global evidence indicates that a large proportion of adolescents do not meet the recommended levels of physical activity, which may negatively influence cardiovascular indicators such as resting heart rate (RHR). Elevated RHR has been widely recognized as an early marker of cardiovascular risk and autonomic imbalance. This study aimed to analyze the association between physical activity levels and resting heart rate among adolescents aged 20–24 years. This research employed an analytic observational design with a cross-sectional approach. A total of 100 participants were recruited using convenience sampling from the Faculty of Medicine, Duta Wacana Christian University, Yogyakarta. Physical activity levels were assessed using the International Physical Activity Questionnaire Long Form (IPAQ-L), while resting heart rate was measured through radial pulse palpation after a five-minute seated rest. Statistical analysis was conducted using SPSS software with Chi-square testing. The results showed that 47% of participants engaged in moderate physical activity, 24% in vigorous activity, and 29% in low activity. Most participants (62%) had a resting heart rate above 80 bpm. A significant inverse association was found between physical activity level and resting heart rate ($p = 0.019$), indicating that adolescents with higher levels of physical activity tended to have lower resting heart rates. In conclusion, moderate-to-vigorous physical activity is associated with healthier resting heart rate values, suggesting improved cardiovascular function in adolescents.

INTRODUCTION

Physical activity (PA) plays a vital role in maintaining overall health and preventing chronic diseases. Regular PA is associated with reduced cardiovascular risk and improved longevity. Meta-analyses have shown that aerobic exercise significantly lowers blood pressure, and moderate-to-high PA levels are linked to decreased mortality among individuals with diabetes (Huai et al., 2013; Sluik et al., 2012). Beyond cardiometabolic benefits, PA enhances musculoskeletal strength and supports healthy body composition (Benedetti et al., 2018).

In addition to insufficient total PA, excessive sedentary behavior has independently been associated with adverse cardiometabolic outcomes in youth, even among those who meet recommended moderate-to-vigorous (MVPA) physical activity levels. Prolonged sedentary time has been linked to impaired vascular function and early markers of cardiovascular risk in adolescents (Carson et al., 2016).

According to the 2020 global guidelines from the World Health Organization, adolescents should accumulate at least 60 minutes of MVPA daily to maintain optimal cardiovascular health World Health Organization, 2020). Nevertheless, pooled analyses across 146 countries show

that 81% of adolescents do not meet these recommendations, with particularly high inactivity levels in Southeast Asia (Guthold et al., 2020).

Resting heart rate (RHR) is a simple and non-invasive physiological indicator that reflects the balance of autonomic nervous system activity. Elevated RHR has been independently associated with increased all-cause and cardiovascular mortality. Zhang et al. reported a linear correlation between RHR and mortality risk, particularly when RHR exceeds 90 bpm (Zhang et al., 2016). Other studies have identified high RHR as a predictor of heart failure, especially among elderly men (Nanchen et al., 2013).

Elevated resting heart rate in young adults has also been associated with subclinical target organ damage, including increased arterial stiffness and reduced endothelial function, suggesting that RHR may reflect early vascular aging processes (Böhm et al., 2018).

Epidemiological studies have emphasized the clinical relevance of resting heart rate as an early cardiovascular risk indicator in young populations. Evidence from large population-based cohorts shows that individuals with higher resting heart rates are more likely to develop hypertension, metabolic syndrome, and future cardiovascular events later in life, indicating that elevated resting heart rate in early adulthood may reflect autonomic imbalance and increased cardiovascular workload. Furthermore, longitudinal analyses suggest that resting heart rate measured during adolescence or early adulthood can predict cardiometabolic risk factors in later life, supporting its use as a simple physiological marker for early identification of individuals who may benefit from preventive lifestyle interventions, particularly those aimed at increasing physical activity levels (Jensen et al., 2014).

While these associations are well documented in older populations, limited research explores the relationship between PA and RHR in younger adults.

Adolescents aged 19 to 24 are typically considered one of the most active age groups (Hallal et al., 2012). However, a 2018 national report found that 87.1% of Indonesian adolescents in this age range were physically inactive (Sawyer et al., 2018). This concerning disparity highlights the need for further investigation into the relationship between PA and cardiovascular markers such as RHR in young populations.

This study examines the association between physical activity levels and resting heart rate among adolescents aged 20–24 years. Understanding this relationship may help clarify how lifestyle behaviors influence early cardiovascular function. The findings could provide a scientific basis for future research exploring health monitoring and intervention approaches in young populations.

RESEARCH METHODS

This study used an analytic observational design with a cross-sectional approach to examine the relationship between physical activity and resting heart rate. The minimum required sample size was 100 participants, calculated based on standard parameters for cross-sectional studies. Data collection occurred from March 14 to April 14, 2021, in the Faculty of Medicine Duta Wacana Christian University, Yogyakarta, Indonesia.

Adolescents aged 20–24 years were recruited via convenience sampling from our faculty's research population. Inclusion criteria required participants to be within this age range and willing to provide informed consent. Exclusion criteria eliminated individuals with chronic

conditions or those taking medications known to affect heart rate, such as cardiovascular drugs, antidepressants, or stimulants.

Physical activity, the independent variable, was assessed as an ordinal-scale measure using the International Physical Activity Questionnaire Long form (IPAQ-L). The IPAQ-L classified activity levels into three ordered categories: low (<600 MET-min/week), moderate (600–3000), and vigorous (>3000) based on standardized metabolic equivalent (MET) thresholds. Resting heart rate, an interval-scale dependent variable, was measured via radial palpation after 5 minutes of seated rest. For analysis, RHR was grouped into <60, 60–70, 71–80, and >80 bpm categories, preserving equal 10-bpm intervals while aligning with cardiovascular risk strata.

Statistical analysis was performed using SPSS version 16.0 software. The data were analyzed using univariate tests to describe baseline characteristics of participants, followed by bivariate analysis to examine their correlation. Data normality was verified using the Kolmogorov-Smirnov test, appropriate for samples larger than 70 participants. Ethical approval was obtained from the Ethical Committee of Duta Wacana Christian University (No.1251/C.16/FK/2021) prior to data collection.

RESULTS AND DISCUSSION

Over a one-month recruitment period, 112 adolescents completed baseline assessments using the validated IPAQ-L. Twelve participants were excluded due to predefined criteria, primarily medication use or chronic conditions affecting heart rate. The final analytic sample included 100 participants aged 20-24 years, meeting the predetermined sample size requirements for cross-sectional analysis.

Table 1 shows the baseline characteristics. The participants included 44 males (44%) and 56 females (56%), with a mean age of 21.68 ± 1.28 years. The average RHR was 84.09 ± 10.72 bpm. Most participants (62%) had an RHR >80 bpm, while only 11% fell in the 60–70 bpm range, and none had an RHR below 60 bpm. Regarding PA levels, 47% reported moderate PA, 24% vigorous, and 29% low. Normality testing indicated that age was not normally distributed ($p < 0.001$), whereas RHR was normally distributed ($p = 0.106$).

Table 2 presents the distribution of RHR by age group. The highest proportion of elevated RHR (>80 bpm) occurred among participants aged 20 (68.4%) and 21 (78.8%) years. In comparison, participants aged 22–24 were more evenly distributed across the 60–80 bpm ranges. No participant in any age group recorded an RHR <60 bpm.

Table 3 demonstrates a clear inverse relationship between PA levels and RHR, with 75.9% of low-PA participants exhibiting elevated RHR (>80 bpm) compared to only 37.5% of vigorous-PA participants. Conversely, moderate and vigorous PA groups showed higher representation in the optimal 60–70 bpm range (14.9% and 12.5%, respectively), while no participants in any PA category had RHR <60 bpm. The Chi-square test confirmed this inverse association as statistically significant (p=0.019), supporting the cardiovascular benefits of higher PA intensity.

Our findings reveal a significant inverse association between PA and RHR ($p = 0.019$), supporting the hypothesis that higher levels of PA are linked to improved cardiovascular function in adolescents. The 2018 RISKESDAS national survey found that physically inactive Indonesian adolescents had 1.9-fold higher odds of elevated RHR (>80 bpm), closely aligning

with our finding that 75.9% of low-PA participants exhibited elevated RHR (Kementerian Kesehatan RI, 2019). These results are further strengthened by independent research from Java, which similarly reported 5-8 bpm lower RHR values among adolescents engaging in moderate-vigorous PA compared to their sedentary counterparts (Wiratama & Hidayat, 2019). These findings reflect well-established physiological relationships observed worldwide. Previous research has consistently shown that increased PA is associated with lower RHR across both sexes (Zanuto et al., 2020).

This physiological relationship is particularly evident in youth, as a 2020 systematic review found that higher-intensity activity produces measurable improvements in cardiovascular outcomes (Carson et al., 2020).

Previous studies involving adolescent populations have also demonstrated that participation in regular sports activities is associated with lower resting heart rate, independent of other factors such as body composition and lifestyle variables. These findings highlight the importance of habitual physical activity in maintaining optimal cardiovascular function during adolescence (Christofaro et al., 2018).

Physiologically, reductions in RHR can be attributed to adaptations in the autonomic nervous system. Regular PA enhances parasympathetic (vagal) activity and reduces sympathetic drive, promoting more efficient heart rate regulation. A 2014 systematic review and meta-analysis of pediatric exercise interventions found significant improvements in heart rate variability following structured physical training, reinforcing the autonomic benefits of regular activity in youth (da Silva et al., 2014). Although the exact mechanisms remain unclear, the predominance of parasympathetic tone following exercise training has been supported by studies investigating the phenomenon of parasympathetic withdrawal (Bahrainy et al., 2016).

Experimental studies have demonstrated that regular moderate-to-vigorous physical activity enhances baroreflex sensitivity, which plays a central role in the short-term regulation of blood pressure and heart rate. Improved baroreflex function contributes to lower resting heart rate and greater cardiovascular stability during physiological stress (Monahan et al., 2017).

Regular physical activity has also been shown to improve heart rate variability (HRV), a widely recognized marker of autonomic nervous system balance and cardiovascular health. Higher HRV reflects stronger parasympathetic modulation and improved adaptability of the cardiovascular system to physiological stressors. Adolescents who engage in regular moderate-to-vigorous physical activity demonstrate significantly higher HRV compared with sedentary peers, suggesting enhanced autonomic regulation and cardiovascular resilience.

The autonomic nervous system is central to heart rate control. Sympathetic activation increases heart rate by influencing calcium levels in cardiac cells, enhancing myocardial contraction. In contrast, parasympathetic stimulation via the vagus nerve reduces heart rate, producing a negative chronotropic effect (Gordan et al., 2015).

These opposing mechanisms allow the heart to adjust efficiently between rest and physical exertion. Additionally, longitudinal studies have shown that during adolescence, autonomic maturation involves increasing vagal modulation and decreasing sympathetic tone, highlighting how developmental changes support more effective heart rate regulation (Gatzke-Kopp & Ram, 2018).

Cardiovascular adaptations to regular PA also contribute to a lower RHR. Repeated muscle contractions during activity increase venous return and stroke volume. According to the

Frank-Starling mechanism, stretching of the heart muscle leads to increased contractile force. The resulting rise in stroke volume reduces the need for a high heart rate to maintain cardiac output, particularly at rest.

These findings support the concept that physical activity contributes not only to short-term autonomic adjustments but also to long-term structural and functional adaptations of the cardiovascular system. Over time, repeated exposure to aerobic exercise improves cardiac output efficiency, allowing the heart to pump a greater volume of blood with fewer beats at rest (Silva et al., 2018).

In addition to autonomic adaptations, regular physical activity has been shown to improve vascular endothelial function, which plays an essential role in maintaining cardiovascular homeostasis. Endothelial cells regulate vascular tone through the release of nitric oxide and other vasoactive substances that influence blood flow and arterial elasticity, and increased physical activity stimulates nitric oxide production, resulting in improved vasodilation and reduced vascular resistance. These vascular adaptations may indirectly contribute to lower resting heart rate by enhancing circulatory efficiency, allowing the cardiovascular system to maintain adequate systemic perfusion with fewer cardiac cycles at rest, thereby supporting the inverse association between physical activity and resting heart rate observed in adolescent populations (Green et al., 2017).

From a public health perspective, adolescence represents a critical window for cardiovascular risk modification, as behavioral patterns established during this period frequently persist into adulthood. Longitudinal evidence indicates that physical activity trajectories during youth strongly predict adult cardiovascular health outcomes (Telama et al., 2014).

Sedentary behavior has increasingly been recognized as an independent risk factor for cardiovascular dysfunction, even among individuals who meet recommended physical activity guidelines. Prolonged sitting or screen-based activities are associated with reduced vascular function, impaired metabolic regulation, and unfavorable autonomic balance, which may contribute to elevated resting heart rate and increased cardiovascular workload in adolescents. Therefore, reducing sedentary time while simultaneously increasing moderate-to-vigorous physical activity may provide synergistic benefits for cardiovascular health, highlighting the importance of interventions that promote active lifestyles in adolescents by encouraging regular exercise and limiting prolonged sedentary behaviors (Saunders et al., 2020).

The findings of this study highlight the importance of promoting moderate-to-vigorous physical activity among adolescents, as regular physical activity is associated with lower resting heart rate, reflecting improved autonomic function and cardiovascular health. Resting heart rate may therefore serve as a practical and non-invasive marker for early identification of cardiovascular risk in youth populations. Although this study provides valuable insights into the relationship between physical activity and resting heart rate in adolescents, future research incorporating additional physiological indicators such as body composition, stress biomarkers, or genetic markers of autonomic regulation, as well as longitudinal study designs, may further clarify the mechanisms linking physical activity to cardiovascular health and support the development of more targeted preventive interventions.

CONCLUSION

This study demonstrates that physical activity level is significantly associated with resting heart rate among adolescents aged 20–24 years. Participants who engaged in moderate-to-vigorous physical activity tended to have lower resting heart rates compared with those who reported low levels of physical activity. The findings support existing evidence that regular physical activity contributes to improved cardiovascular function through autonomic and physiological adaptations, including enhanced parasympathetic activity, improved stroke volume, and greater cardiovascular efficiency. The results also highlight the importance of maintaining an active lifestyle during adolescence, as resting heart rate can serve as a simple and non-invasive indicator for early detection of potential cardiovascular risk. Thus, this study reinforces the role of moderate-to-vigorous physical activity as an important behavioral factor in promoting cardiovascular health among young populations. Despite these findings, several limitations should be acknowledged, including the cross-sectional design, which limits causal interpretation, and the use of convenience sampling from a single institutional population. Therefore, future research is recommended to employ longitudinal or experimental study designs to better understand the causal relationship between physical activity and cardiovascular outcomes in adolescents. In addition, future studies should consider incorporating larger and more diverse populations, as well as additional physiological indicators such as body composition, heart rate variability, stress biomarkers, and genetic or lifestyle factors that may influence cardiovascular regulation. Such approaches would provide a more comprehensive understanding of the mechanisms linking physical activity to cardiovascular health and support the development of more effective preventive strategies for young populations.

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