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Smoking Dependence and Cardiovascular Endurance in Late Adolescents: A Study at the Faculty of Engineering, Udayana University

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Abstract

Introduction: Cardiovascular endurance is influenced by various factors, one of which is smoking habits, which can hinder oxygen binding by hemoglobin. Additionally, smoking is a leading cause of cardiovascular disease-related deaths worldwide. This study aims to identify the relationship between smoking dependence levels and cardiovascular endurance in late adolescents at the Faculty of Engineering, Udayana University.

Methods: This cross-sectional study employed a simple random sampling method from June to September 2024. Sixty-five students from the Faculty of Engineering, Udayana University, who met the inclusion and exclusion criteria, participated in the study. Cardiovascular endurance was assessed using the Harvard Step Test while smoking dependence levels were measured using the Fagerström Nicotine Dependence Test (FTND). Data were analyzed using Spearman's rho correlation test.

Results: A moderate negative correlation was found between smoking dependence levels and cardiovascular endurance (r = -0.503, p = 0.001), indicating that higher smoking dependence is associated with lower cardiovascular endurance.

Conclusion: Smoking dependence has a negative relationship with cardiovascular endurance in late adolescents. This study has limitations, including a limited sample size and excluding other lifestyle factors, such as diet and physical activity, which may also influence cardiovascular endurance.

Keywords: smoking, dependence, cardiovascular, adolescents

Introduction

Individuals require good physical fitness as a supporting factor to perform various activities. The ability to carry out daily activities easily is called physical fitness. Physical fitness comprises several components contributing to physical strength, including cardiovascular endurance.

Cardiovascular endurance is the heart's efficiency in sustaining activities involving the entire body at moderate to high intensity.[1] Therefore, every individual should ideally have optimal cardiovascular endurance, as it enhances performance capacity for larger workloads and extended periods.[2] Overall physical performance improves when the body has optimal cardiovascular endurance. However, cardiovascular endurance varies among individuals. It is influenced by internal factors such as age, genetics, and sex, as well as external factors like exercise intensity and daily lifestyle.[3] Genetic factors affect individual heart and lung capacity, with those having a higher capacity receiving a more optimal oxygen supply.[4] Aerobic endurance develops from childhood, peaks between ages 20–30, and then declines, with capacity at age 70 being only half that of a 17-year-old. After puberty, males generally exhibit 15–25% higher endurance levels than females.[5]

One external factor that affects cardiovascular endurance is smoking habits. In the era of globalization, lifestyle changes have significantly influenced smoking behaviors. In Indonesia, smoking is widely regarded as a habitual behavior commonly observed in daily life across various settings.[6]

Tobacco-based products designed for inhalation, burning, or smoking are referred to as cigarettes. Cigarettes contain nicotine, a substance known for its addictive properties.[7] In addition to nicotine, cigarettes contain carbon monoxide (CO), which can reduce cardiovascular endurance. Carbon monoxide binds to hemoglobin more strongly than oxygen, reducing oxygen availability to tissues, including the heart and muscles.[8] Smoking is prevalent across various age groups and is not limited to adults; it is also increasingly common among adolescents. According to the 2021 National Socioeconomic Survey (Susenas), 27.93% of Indonesians aged 15 and older are smokers, a 0.44% increase from 2020.[9]

Adolescence is a crucial phase of growth and development. It is considered a transitional period from childhood to young adulthood.[10] Previous studies indicate that heavy smokers typically begin smoking in their teenage years, with

very few initiating the habit in adulthood. Consequently, adolescence is often regarded as a critical phase determining whether an individual becomes a smoker.[11]

The rising trend of smoking among late adolescents, coupled with the increasing prevalence of adolescent smokers and the potential long-term adverse effects of tobacco, underscores the need for further research. This study aims to analyze the relationship between smoking dependence levels—measured using the Fagerström Nicotine Dependence Test (FTND)—and cardiovascular endurance—assessed using the Harvard Step Test—among students at the Faculty of Engineering, Udayana University. The decision to focus on this population was based on preliminary data collected through a smoking usage questionnaire distributed via Google Forms to students from various study programs at Udayana University. This indicated that smoking prevalence was highest among students in the Faculty of Engineering.

This study hypothesizes that there is a significant relationship between smoking dependence levels and cardiovascular endurance among students at the Faculty of Engineering, Udayana University. Previous studies have demonstrated that smoking reduces aerobic capacity and increases the risk of cardiovascular diseases. A survey by Putra (2022) found that active smokers had lower VO_2 max levels than non-smokers, reinforcing the negative impact of smoking on cardiovascular endurance.[12] However, to date, no studies have specifically examined the relationship between smoking dependence levels and cardiovascular endurance among engineering students at Udayana University.

Method

This study is an analytical observational study using a cross-sectional approach. The cross-sectional design was chosen because it allows researchers to simultaneously assess smoking dependence levels and cardiovascular endurance within a single timeframe. This approach efficiently illustrates the relationship between the two variables without requiring long-term monitoring. Several study programs at the Faculty of Engineering, Udayana University, were selected as research locations, and data collection was conducted from April to October 2024. This study involved 65 respondents as the sample, with the sample size determined based on the smoking prevalence in Bali obtained from previous research. According to Citra, 2020, the prevalence of smokers in Bali is 19%.[13]

Participants' physical activity levels were also controlled by selecting individuals with similar activity levels who were not undergoing intensive exercise programs during the study. By manipulating these three variables, the study could more accurately measure the relationship between nicotine dependence levels and cardiovascular endurance without interference from other factors.

In addition, inclusion and exclusion criteria were considered. The inclusion criteria were as follows: active smokers who regularly use conventional cigarettes for at least one year and were still smoking at the time of the study. This criterion was established to minimize variability and bias that could arise from a non-representative group of conventional active smokers, which is the primary focus of this study. Participants were also required to be in good health, with typical vital signs assessed through blood pressure measurements using a sphygmomanometer, heart rate, and oxygen saturation (SpO2) measurements using an oximeter. They had to be able to walk independently without functional limitations or assistive devices and voluntarily agreed to participate in the study by signing an informed consent form.

The exclusion criteria included students who were athletes or bodybuilders, as these individuals generally have significantly better cardiovascular endurance than the general population. Excluding these participants allowed the study to focus on the relationship between smoking dependence levels and cardiovascular endurance without significant external variable influence. Other exclusion criteria included those currently undergoing smoking cessation therapy, having a history of balance disorders such as vertigo, lower extremity injuries, cardiovascular or respiratory diseases, and those who had consumed alcohol within 24 hours before the assessment, as determined by self-report.

Smoking dependence levels were measured using the Fagerström Test for Nicotine Dependence (FTND), which consists of six questions, each with different scores. The total score is then classified into several categories: mild dependence, mild-to-moderate dependence, moderate dependence, and high dependence. FTND was chosen due to its high validity and reliability, with a Cronbach's alpha value of 0.892, making it a valid and reliable tool for assessing nicotine dependence among adolescents.[14] Cardiovascular endurance was assessed using the Harvard Step Test, which involves stepping up and down on a 50 cm bench or step, the standard height for the test for males, for five minutes. The test could be stopped if the participant felt exhausted and could not maintain the stepping rhythm. After the test, heart rate was measured during the first, second, and third minutes of rest. The final results were calculated using a specific formula and classified into the following categories: inferior, poor, fair, reasonable, and excellent.

The study began with participants signing an informed consent form, which included explanations of the study's purpose, benefits, and procedures. This was followed by interviews and anamnesis, as well as the completion of the Fagerström Test for Nicotine Dependence (FTND). Participants then underwent the Harvard Step Test to assess cardiovascular endurance. Each respondent required approximately 10–12 minutes to complete all measurements in a single session. During data collection, a single-masked method was applied, wherein the research team conducting the Harvard Step Test was unaware of the respondents' nicotine dependence levels. This method minimized bias by preventing preconceived notions from influencing the researchers' assessments. Complete data were available for all study variables without missing or incomplete entries.

Data analysis was conducted using IBM SPSS Statistics v27.0, applying univariate and bivariate approaches. Normality tests were performed using the Kolmogorov-Smirnov test before analysis. The univariate analysis included variables such as smoking dependence level, cardiovascular endurance, and age. Meanwhile, bivariate analysis utilized Spearman's rank correlation test to examine the relationship between smoking dependence level and cardiovascular endurance.

This study received ethical approval from the Research Ethics Committee of the Faculty of Medicine, Udayana University/RSUP Sanglah Denpasar, with approval number 0273/UN14.2.2.VII.14/LT/2024. Additionally, informed consent was obtained from all respondents before the study commenced, and participants had the right to withdraw from the study at any time without consequences or negative impacts.

Results

The following flowchart illustrates the participant selection process in this study. It outlines the progression from the initial target population to the final number of subjects included in the data analysis based on attendance and eligibility criteria. This process can be seen in Figure 1.

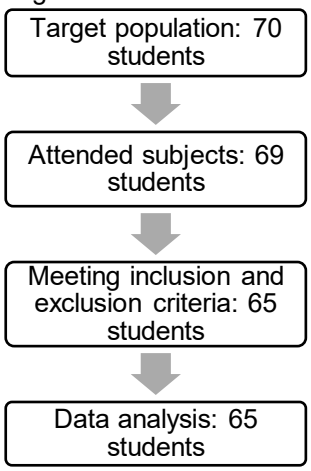

Figure 1. Participant Selection Flowchart

The flowchart represents the selection process of study participants. Initially, the target population consisted of 70 students. Out of these, 69 students attended and participated in the study. After applying the inclusion and exclusion criteria, 65 students met the eligibility requirements. Finally, data analysis was conducted on all 65 eligible students. After data collection and analysis, the results are presented in Table 1.

Table 1. Characteristics of Study Subjects

Variable	Frequency (n)	Percentage (%)
Age		
a. 18 years	3	4.6
b. 19 years	42	64.6
c. 20 years	14	21.5
d. 21 years	6	9.2
Nicotine Dependence Level		
a. Low	15	23.1
b. Low to Moderate	34	52.3
c. Moderate	16	24.6
Cardiovascular Endurance		
a. Very Poor	27	41.5
b. Poor	13	20.0
c. Fair	3	4.6
d. Good	16	24.6
e. Very Good	6	9.2

Based on Table 1, the majority of respondents are aged 19-21 years. According to the WHO classification, ages 10-19 years are included in the adolescent category, while ages 20-24 years are included in the young people group. Thus, the respondents in this study belong to the age group of late adolescence to young adulthood, with the majority dominated by the age of 19 years old (64.6%), while the other age groups had smaller proportions. The most common level of nicotine dependence was in the low to moderate category (52.3%), and no participants exhibited high nicotine dependence. Regarding cardiovascular endurance, most students fell into the inferior category (41.5%), while only a tiny proportion demonstrated excellent endurance (9.2%). These findings suggest that most smoking students had low to moderate nicotine dependence, with generally poor cardiovascular endurance. The relationship between nicotine dependence level and cardiovascular endurance is presented in Table 2.

Table 2. Relationship Between Nicotine Dependence Level and Cardiovascular Endurance

Nicotine Dependence Level	Cardiovascular Endurance					p	r
	Very Poor	Poor	Fair	Good	Very good		
Low	0 (0.0%)	1 (6.7%)	0 (0.0%)	11 (73.3%)	3 (20.0%)	<0.001	-0.503
Low to Moderate	16 (47.1%)	11 (32.4%)	3 (8.8%)	3 (18.8%)	1 (2.9%)		
Moderate	11 (68.8%)	1 (6.3%)	0 (0.0%)	2 (12.5%)	2 (12.5%)		

As shown in Table 2, Spearman's correlation test yielded a p-value of <0.001 ($p < 0.05$), indicating a significant relationship between nicotine dependence level and cardiovascular endurance among late adolescents at the Faculty of Engineering, Udayana University.

The correlation coefficient was also -0.503, with the negative sign (-) indicating an inverse relationship between the two variables. The correlation strength is classified as moderate since it falls within the 0.26–0.50 range.

Overall, these findings suggest that higher nicotine dependence is associated with lower cardiovascular endurance among late adolescents at the Faculty of Engineering, Udayana University. This is further supported by the negative correlation value, which confirms an inverse relationship between the two variables.

Discussion

Subject Characteristics

This study was conducted at the Faculty of Engineering, Udayana University, with 65 student participants aged 18–21 years. The subjects were from three study programs: Industrial Engineering, Information Technology, and Mechanical Engineering. This distribution reflects the variation in the number of students meeting the research criteria across these programs. The study employed a simple random sampling technique, meaning samples were randomly selected from the population. The chosen samples met the inclusion and exclusion criteria previously described.

The study was conducted on-site at the research location. Most participants were 19 years old. This aligns with previous findings indicating that individuals who start smoking before the age of 18 have a higher risk of nicotine dependence than those who start smoking later. Early smoking initiation is associated with an increased likelihood of developing long-term dependence and health issues. Adolescence is often considered a critical period that determines whether an individual will become a smoker. Several factors influence adolescent smoking habits, including social and physical environments, media advertising, individual perceptions (e.g., smoking as a symbol of masculinity, stress relief, or weight control), socio-economic status, and a lack of knowledge or skills to resist peer pressure. Furthermore, the high prevalence of adolescent smoking is supported by factors such as accessibility, availability, and the relatively low cost of cigarettes.[15]

Nicotine Dependence and Cardiovascular Endurance

Nicotine dependence levels were assessed using the Fagerström Test for Nicotine Dependence (FTND). The findings revealed that 15 participants had low dependence, 34 had low to moderate dependence, and 16 had moderate dependence. Nicotine dependence results from the brain's adaptation to substances like nicotine, leading to withdrawal syndrome and neuro adaptation. Withdrawal syndrome triggers feelings of anxiety and depression when an individual does not smoke, while neuroadaptation increases the desire to smoke continuously for pleasure. Cigarettes contain over 4,000 chemicals, including nicotine and carbon monoxide (CO), which pose significant risks to cardiovascular function.[16]

In addition to age and duration of nicotine exposure, the amount of daily cigarette consumption also influenced the level of dependence of respondents. Most respondents in this study only consumed a limited number of cigarettes, less than ten cigarettes per day. This small amount of consumption is not enough to maintain consistently high nicotine levels in the body, so the nervous system has not formed a strong physiological dependence.[17] Considering the relatively young age of the respondents and the limited amount of daily cigarette consumption, it can be concluded that the characteristics of the subjects in this study contributed to the dominance of the cigarette dependence category at the low to moderate level. However, a low level of dependence in a young age group cannot be considered completely safe, as repeated nicotine exposure still has the potential to increase the risk of forming a heavier dependence in the future, especially if the smoking habit continues without intervention.

Cardiovascular endurance was assessed using the Harvard Step Test. The results showed that 27 participants had very poor cardiovascular endurance, 13 had poor endurance, 3 had fair endurance, 16 had good endurance, and 6 had excellent endurance. The Harvard Step Test required participants to step up and down on a 50 cm-high bench at a pace of 120 beats per minute for five minutes or until they could no longer maintain rhythm due to fatigue. Cardiovascular endurance is closely related to an individual's ability to sustain prolonged physical activity without excessive fatigue. It reflects the heart's efficiency in supplying oxygen to the body during physical exertion.[18] Individuals with good cardiovascular endurance can perform repetitive activities for an extended period without experiencing significant fatigue and still have sufficient energy reserves for short bursts of activity.[19]

Relationship Between Nicotine Dependence and Cardiovascular Endurance

A hypothesis test was conducted using Spearman's rho. The analysis (Table 2) showed a significant relationship between nicotine dependence and cardiovascular endurance ($p < 0.001$, $p < 0.05$) among late adolescents at the Faculty of Engineering, Udayana University.

The study found a correlation coefficient of -0.503 between nicotine dependence and cardiovascular endurance. The negative coefficient indicates an inverse relationship: the higher the nicotine dependence, the lower the cardiovascular endurance. This correlation is classified as moderate.

These findings align with Amanati et al. (2021), who examined the effects of smoking on cardiorespiratory fitness. Their cross-sectional study investigated the relationship between smoking habits and fitness levels using questionnaires on smoking duration and cigarette consumption combined with the Harvard Step Test. Their results indicated a significant correlation between smoking habits and reduced fitness levels.[20] Additionally, Kuncoro (2021) conducted a literature review on cardiovascular endurance among smokers and non-smokers, analyzing 10 studies published between 2010 and 2020. The review found a significant difference in cardiovascular endurance between smokers and non-smokers, suggesting that adolescent smokers tend to have lower cardiovascular endurance,

increasing their risk of cardiovascular diseases.[21] These findings are further supported by Kusuma (2023), who compared physical fitness, resting heart rate, and post-exercise heart rate between smoking and non-smoking anesthesiology students using the Six-Minute Walk Test. While no significant differences were observed in resting and post-exercise heart rates, non-smokers covered a greater distance in the test, indicating better physical fitness.[22]

Maintaining good cardiovascular endurance is essential to support students' physical activity in academic and extracurricular settings. The body operates as an integrated system, and improvements in cardiovascular endurance enhance blood circulation efficiency. Increased endurance contributes to higher blood volume and red blood cell counts, ensuring more oxygen is distributed throughout the body.[23]

Smoking habit is one of the indicators that affect a person's cardiovascular endurance. Reduced cardiovascular endurance in smoker individuals can be explained through various biomolecular mechanisms that affect cardiac structure and function. Based on a study from the Global Heart Journal, smoking is associated with increased left ventricular mass and a higher heart mass-to-volume ratio, a condition known as left ventricular hypertrophy (LVH). This hypertrophy is an adaptation of the heart to chronic increased workload due to stimulation of the sympathetic nervous system by nicotine. Nicotine in cigarettes stimulates the release of catecholamines (such as norepinephrine and epinephrine), resulting in an increase in blood pressure and heart rate. Physiologically, this condition causes the heart to work harder, which in the long run leads to morphological changes in the heart muscle. In addition, carbon monoxide (CO) in cigarette smoke also contributes to tissue hypoxia. CO binds to hemoglobin to form carboxyhemoglobin, reducing the blood's capacity to transport oxygen. As a result, the heart muscle and peripheral tissues experience oxygen deprivation, forcing the heart to pump blood at a higher intensity.[24]

In addition to the influence of nicotine on cardiac morphology, other chemicals in cigarette smoke also play a role in damaging the cardiovascular system through different mechanisms. Cigarettes are known to contain more than 7,000 chemicals, most of which are toxic and carcinogenic. Some of the most prominent harmful substances include nicotine, carbon monoxide, tar, formaldehyde, benzene, acrolein, and various types of free radicals. These substances not only adversely affect the respiratory system but also enter the systemic circulation and interact directly with the blood vessel walls. This interaction is a major trigger for oxidative stress, inflammation and endothelial dysfunction, leading to an increased risk of cardiovascular disease. Endothelial dysfunction results from a disturbance in the balance of physiological functions of endothelial cells lining the inner surface of blood vessels.

Normally, the endothelium plays an important role in regulating vascular tone, maintaining blood flow, preventing platelet aggregation, and controlling inflammatory and clotting responses through the release of substances such as nitric oxide (NO). However, when the body is exposed to risk factors such as cigarette smoke, hyperlipidemia, hypertension, or hyperglycemia, endothelial cells experience oxidative stress caused by increased production of reactive oxygen species (ROS). These ROS interfere with the bioavailability of NO by oxidizing or inactivating it, leading to vasoconstriction and decreased vascular dilatation capacity. In addition, oxidative stress also activates inflammatory pathways through the expression of adhesion molecules (such as ICAM-1 and VCAM-1) that trigger leukocyte adhesion to the vessel wall and initiate the process of atherogenesis. This indicates that although the majority of college students have not shown high dependence, exposure to nicotine and other toxic substances remains a potentially significant risk to the subjects' cardiovascular endurance and health in the future.[25]

Study Limitations

This study has several limitations. The sample size was relatively small, and nicotine dependence was measured using a questionnaire, which introduces the potential for information bias if respondents were not entirely truthful about their smoking habits, leading to underreporting or overreporting. Additionally, other factors such as diet and nutritional intake were not fully controlled, which may influence the observed relationship between nicotine dependence and cardiovascular endurance.

Despite these limitations, this study contributes to understanding the association between nicotine dependence and cardiovascular endurance among late adolescents at the Faculty of Engineering, Udayana University. The findings have significant clinical implications for raising student awareness about the health risks associated with smoking. Given that most participants started smoking during adolescence, education plays a crucial role in informing students about the adverse effects of smoking on respiratory function and cardiovascular endurance. Evidence-based approaches, such as presenting data and scientific findings on long-term health risks, can enhance the effectiveness of smoking prevention programs.

Conclusion

There is a significant relationship between the level of smoking dependence and cardiovascular endurance, with a negative correlation (-0.503), categorized as moderate. This relationship indicates that the higher the smoking dependence, the lower the cardiovascular endurance. However, other factors, such as dietary patterns and physical activity, which were not controlled in this study, may also influence this relationship and should be considered further.

The findings of this study can serve as a basis for universities to design more specific educational programs on the dangers of smoking and the importance of cardiovascular health. One proposed initiative is the "Healthy Campus Program", which could include awareness campaigns on the impact of smoking on physical fitness and sports activities that support cardiovascular endurance improvement. Additionally, smoking prevention programs would be more effective if implemented among first-year students before smoking habits become more ingrained. Through this approach, universities can play a role in promoting healthy lifestyles and raising students' awareness of the long-term health risks associated with smoking.

For researchers planning to continue or expand this study, it is recommended to include additional nutrition-related variables using a longitudinal design to observe the long-term effects of smoking habits on cardiovascular

endurance. Furthermore, incorporating objective measurement tools, such as aerobic capacity tests (VO_2 max), could provide a more accurate assessment of cardiovascular endurance.

Additional Information

This research did not receive funding from government agencies, private entities, or nonprofit organizations, and the authors confirm that no financial support influenced the study design, data collection, analysis, interpretation, or manuscript writing. The authors declare no conflicts of interest related to this study. Ethical approval was obtained from the relevant institutional review board, and all participants provided informed consent before participation. The authors also thank all participants and individuals or institutions contributing to the research process.

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