

The physiological association between forced vital capacity and reaction time in healthy medical students

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Abstract: Forced vital capacity (FVC) has been proposed as a physiological factor influencing cognitive performance, including reaction time (RT). However, evidence in healthy young adults is limited. This study investigated the association between FVC and RT among medical students. A cross-sectional study was conducted with 34 healthy, non-smoking students at the Medical Students of Hang Tuah University. FVC was measured using a digital spirometer, while simple reaction time (SRT) was assessed with computerized tests. Shapiro–Wilk and Spearman’s correlation were applied for analysis. Males showed slightly higher mean FVC ($93.95 \pm 9.96\%$) compared to females ($92.43 \pm 7.60\%$). Mean SRT was nearly identical (males: 297.83 ± 61.59 ms; females: 298.78 ± 62.73 ms), while CRT was marginally faster in males (437.66 ± 101.12 ms) than in females (445.66 ± 82.39 ms). No significant correlations were found between FVC and SRT ($\rho = 0.138$, $p = 0.437$) or between FVC and CRT ($\rho = 0.292$, $p = 0.094$). In healthy young adults, FVC is not significantly associated with reaction time. Other factors such as physical fitness, neuromuscular coordination, and stress may play a stronger role. Further longitudinal research is needed to clarify the physiological links between lung function and cognitive performance.

Keywords: Cognitive function, Forced vital capacity, Medical students, Reaction time.

1. Introduction

The relationship between forced vital capacity (FVC) and response time (RT) is an increasingly important area of investigation in the study of cognitive function and its physiological underpinnings. Correlations between forced vital capacity (FVC), a measure of pulmonary function, and cognitive performance suggest that respiratory health may influence cognitive processing speed and efficiency. Research indicates that reduced lung function, especially characterized by lower FVC, is associated with cognitive decline and poorer cognitive performance in many populations. Wang et al. [1] study demonstrated a correlation between reduced pulmonary function and accelerated cognitive decline, as well as deficits in specific cognitive domains such as perceptual speed, which has a close connection to reaction time Wang et al. [1]. Cahana-Amitay et al. [2] also found that FVC, but not FEV1, was linked with cognitive impairment in older people. This suggests that restrictive lung patterns may affect cognitive functions, especially reaction time [2]. This aligns with the findings of Xiao et al. [3], who demonstrated that limited lung function correlates with cognitive impairment, hence substantiating the notion that FVC is a crucial indicator of cognitive health [3]. The mechanisms linking FVC and cognitive function, including reaction time, may involve many pathways. A possible mechanism is the effect of oxygenation on cerebral function. Williams et al. [4] showed that cerebral oxygenation levels have a significant effect on cognitive performance in hypoxic conditions. This means that if your lungs do not work well, they may not be able to deliver enough oxygen to your brain, which can affect

cognitive tasks such as reaction time [4]. Studies have shown that chronic obstructive pulmonary disease (COPD), characterized by reduced lung function, influences brain connectivity and cognitive performance, suggesting that changes in brain structure and function may influence the relationship between lung function and cognition [5, 6]. Moreover, genetic and environmental factors may affect the relationship between lung function and cognitive performance. Finkel et al. [7] looked into how genetic factors that affect pulmonary function and cognitive aging may interact with each other. They found that these factors may cause differences in cognitive performance, such as reaction time [7]. Researchers Mohammadi-Nejad et al. [8] found possible genetic links between lung function and cognitive outcomes. This means that genetics may affect both lung and cognitive health [8].

Neuromuscular coordination, forced vital capacity (FVC), and response time (RT) are interrelated elements that significantly influence physical performance and cognitive function. Understanding the relationships among these components is crucial for developing effective training and rehabilitation strategies. Neuromuscular coordination refers to the ability of the nervous system to effectively control muscle movements, which is essential for executing complex motor tasks. Various factors, including respiratory function, influence this coordination. Research indicates that improved neuromuscular synchronization can augment respiratory muscle performance, hence, enhancing FVC. Jabbari and Ghazalian [9] underscored that the coordination of respiratory muscles, particularly the diaphragm, is crucial for optimizing forced vital capacity (FVC) and forced expiratory volume (FEV1). This correlation suggests that interventions aimed at enhancing neuromuscular coordination may yield improved respiratory outcomes, potentially influencing overall physical performance. Research by Rahimi et al. [10] demonstrated that dynamic neuromuscular stabilization breathing exercises significantly improved spirometric parameters, including FVC and FEV1, in sedentary individuals, further supporting the impact of neuromuscular coordination on FVC [10]. Researchers attributed the improvements to enhanced synchronization and activation of the diaphragm and supplementary respiratory muscles, underscoring the significance of neuromuscular training in respiratory health. Researchers have documented the relationship between FVC and cognitive performance, specifically reaction time. Enhanced FVC is associated with superior cognitive results, including accelerated reaction times. Lee et al. [11] found that those with increased FVC had improved information processing speed and fine motor abilities, critical components of cognitive performance [11]. This suggests that maintaining sufficient lung function is vital for preserving cognitive ability, particularly in tasks requiring quick responses. Moreover, systemic factors like oxygen delivery may influence the impact of pulmonary function on cognitive performance. Wang et al. [1] noted that reduced pulmonary function is associated with cognitive decline, influencing both structural brain changes and cognitive processing speed [1]. This association underscores the importance of FVC for physical health and cognitive function, particularly in aging populations where lung function and cognitive abilities may deteriorate. Several physical activities demonstrate the interplay between neuromuscular coordination and reaction time. Improved coordination can lead to faster and more accurate responses to stimuli, which is crucial in athletic and therapeutic settings. An et al. [12] highlighted that cognitive training could enhance joint stiffness management and motor coordination, thereby improving reaction times in individuals recovering from injuries. This study underscores the ability of cognitive therapies to enhance physical training in the improvement of neuromuscular coordination and reaction time.

The impact of lifestyle on forced vital capacity (FVC) and reaction time (RT) among medical students, particularly at Hang Tuah University, encompasses multiple aspects, such as physical activity, stress, and dietary habits. Understanding these connections is crucial for improving health outcomes in this demographic. Physical exercise is a vital lifestyle factor that influences both FVC and RT. Research by Kumar et al. [13], which suggested that yoga practice led to significant increases in FVC and other pulmonary parameters among first-year medical students, has shown that regular exercise improves lung function [13]. The improvement of lung function is essential, as elevated FVC is associated with enhanced oxygen delivery to tissues, improving cognitive performance and reducing reaction times. A study by Jain et al. [14] showed that students engaged in regular physical activity exhibited faster

reaction times compared to their sedentary peers [14]. This suggests that maintaining an active lifestyle can positively affect respiratory health and cognitive processing speed. In addition to physical exercise, stress levels among medical students can significantly affect both FVC and RT. Singh et al. [15] demonstrated that stress-induced tests adversely affected response times in first-year medical students, implying that stress can impair cognitive performance [15]. This aligns with the findings of Laxmi and Saravanan [16] who suggested that neurochemical changes linked to stress may hinder cognitive abilities, including reaction time Laxmi and Saravanan [16]. Saravanan and Wilks [17] highlighted that stressors such as workload and inadequate leisure time are significant predictors of anxiety and depression, which may exacerbate cognitive deficiencies and affect respiratory function. Thus, managing stress through lifestyle changes, such as mindfulness and relaxation techniques, may improve both FVC and RT. Dietary habits considerably influence FVC and RT [17]. While Liang et al. [18] underscored the importance of lifestyle behaviors in reducing non-communicable diseases, their study did not specifically investigate the relationship between fruit and vegetable consumption and pulmonary function [18]. A balanced diet rich in antioxidants and essential nutrients might enhance lung health and cognitive function, perhaps boosting FVC and RT. Duan et al. [19] found that interventions promoting physical exercise and healthy nutrition led to increased self-efficacy and better health outcomes in college students, hence strengthening the association between lifestyle choices and physiological health [19].

2. Method

This study used a cross-sectional design to evaluate the relationship between Forced Vital Capacity (FVC) and Reaction Time (RT) in medical students of Hangtuh University.

2.1. Participants

There will be 34 participants in total, including 17 male and 17 female students aged between 19 and 25. All subjects were non-smokers and had no prior history of pulmonary or neurological diseases. The investigation will take place in a controlled laboratory environment, with simultaneous measurements of variables to reduce temporal bias.

2.2. Instruments and Procedure

A more accurate method measures the main variable. We will measure FVC using a digital spirometer, Spirolab II, that adheres to a strict measurement protocol, measuring three times the maximum exhalation after deep inhalation and recording the highest value. We will measure the reaction time (RT) using the Computerized Reaction Time Test software, which can evaluate both the simple visual reaction time (Simple Reaction Time) and the choice reaction time (Choice Reaction Time). We conduct the test under calm environmental conditions to ensure optimal concentration of participants.

This study necessitates that participants complete a series of tests under controlled conditions to guarantee measurement accuracy during the data-gathering process. We instructed participants to rest for 10 minutes prior to the measurement to mitigate fatigue factors that could influence the results. We conducted FVC measurements using a digital spirometer, Spirolab II, instructing each subject to complete three maximum exhalation measurements after deep inhalation, and documented the highest value for analysis. We assessed reaction time using the Simple Reaction Time and Choice Reaction Time tests, which we conducted using computer-based software. We conduct each reaction time assessment twice to ensure consistency in the results, with an interval of approximately 5 minutes between each trial. We conduct the technique in a serene, distraction-free environment to enhance the participant's focus.

2.3. Data Analysis

This study employs SPSS statistical software for data analysis. We performed a normality test using the Shapiro-Wilk method before conducting the correlation analysis to determine if the data followed a normal distribution. We employed Pearson correlation for normally distributed data and Spearman correlation for non-normally distributed data to examine the relationship between FVC and RT. We also conducted descriptive analysis to determine the mean and standard deviation of each variable.

3. Result

The following Table 1 shows the descriptive statistics by gender, and the graph image of the relationship between FVC and reaction time (RT).

Table 1.
Descriptive research data.

Gender	N	FVC (%)	RT Simple (ms)	RT Choice (ms)	P
		Mean $\pm$ Std.	Mean $\pm$ Std.	Mean $\pm$ Std.	
Male	17	93.95 $\pm$ 9.96	297.83 $\pm$ 61.59	437.66 $\pm$ 101.12	.127
Female	17	92.43 $\pm$ 7.60	298.78 $\pm$ 62.73	445.66 $\pm$ 82.39	.352

Remarks: Forced Vital Capacity (FVC), Simple Reaction Time (RTS), Choice Reaction Time (CRT), $p > 0.005$. The average FVC for males was slightly higher (93.95%) than for females (92.43%), but a high standard deviation indicated a variation in the data. The average simple reaction time for both sexes was almost the same, while the preferred reaction time was slightly faster in males than in females.

The Shapiro-Wilk test revealed a non-normal distribution of the data, with p-values of 0.047 for Forced Vital Capacity (FVC), 0.028 for RT Simple (Simple Reaction Time), and 0.017 for RT Choice (Choice Reaction Time). The data are not normally distributed, so Spearman correlation is a more appropriate method to determine the relationship between two variables than Pearson correlation. This is because Spearman only assesses monotonic or non-parametric relationships, which do not require the data to be normally distributed. The graph in Figure 1 below shows the relationship between FVC and reaction time (RT).

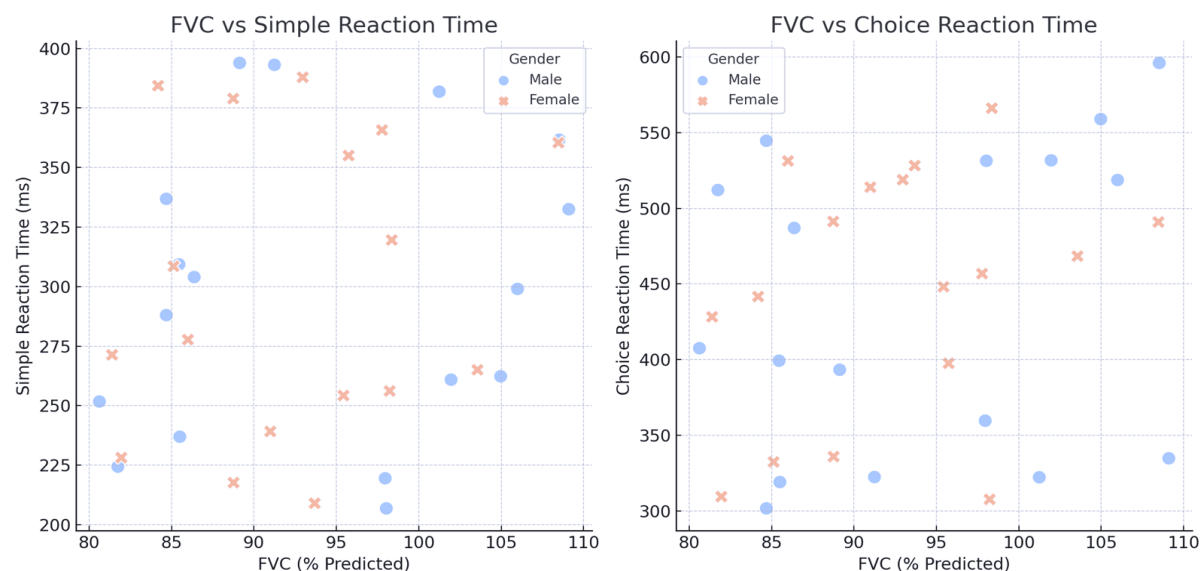


Figure 1.
Graph of the relationship between FVC and reaction time (RT).

Remarks: There was no significant pattern of association between FVC and simple reaction time, for both males and females, and no strong correlation was found between FVC and selective reaction time.

The figure above illustrates the relationship between Forced Vital Capacity (FVC, % predicted) and two types of reaction times: Simple Reaction Time (SRT) on the left panel and Choice Reaction Time (CRT) on the right panel, disaggregated by gender. FVC vs SRT: Overall, the data distribution does not demonstrate a clear linear relationship between lung vital capacity and simple reaction time. Both men and women exhibit a wide range of SRT values across the FVC spectrum (80–110%), with no consistent trend indicating that higher FVC correlates with faster or slower reaction times. This suggests that better lung function, as indicated by a higher FVC, does not necessarily translate to improved simple reaction speed. FVC vs CRT: Similarly, the right graph shows no strong linear relationship between FVC and choice reaction time. Some individuals with high FVC still display slow CRT, while others with lower FVC can have faster CRT. The high variability observed in both genders indicates a weak association between FVC and CRT. Gender Differences: The data distribution for men and women largely overlaps in both graphs, with no clear separation between the sexes regarding the relationship between FVC and reaction time. General Interpretation: These findings support the conclusion that pulmonary function, as measured by FVC, is not a primary predictor of reaction time in young, healthy populations. Reaction time is more likely influenced by other factors such as neural processing speed, neuromuscular coordination, mental state (including stress and fatigue), and physical activity levels, rather than lung capacity itself.

Table 2.

Results of the Spearman correlation test.

Variabel	Korelasi Spearman (ρ)	P
FVC vs RT Simple	0.138	0.437
FVC vs RT Choice	0.292	0.094

Remarks: FVC vs RT Simple (ρ) = 0.138, p = 0.437. There was no significant relationship between FVC and simple reaction time. FVC vs RT Choice (ρ) = 0.292, p = 0.094. There was no significant association, although the positive correlation suggests a potential small association between FVC and choice reaction time.

The correlation between FVC and Simple Reaction Time showed a ρ value of 0.138 with a p value of 0.437 (Table 1), indicating a very weak and non-significant positive relationship. The correlation between FVC and Choice Reaction Time showed a ρ value of 0.292 with a p value of 0.094. This relationship tended to be positive with weak-moderate strength but was still not significant at the 0.05 level (although approaching significance). In general, these results support that vital lung capacity (FVC) is not significantly correlated with reaction speed in young, healthy students, on both simple and complex tasks.

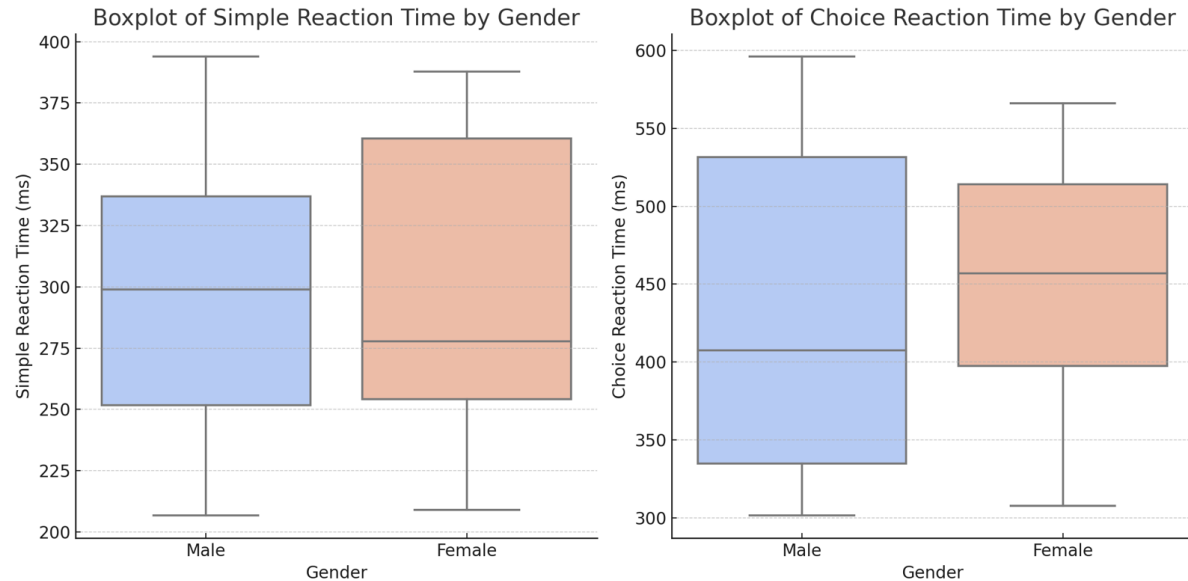


Figure 2.
Boxplot graph of simple reaction time distribution and preferred reaction time by gender.

The boxplot graph in Figure 1 depicts a simple reaction time distribution and a preferred reaction time by gender, showing a comparison of Simple Reaction Time (SRT) and Choice Reaction Time (CRT) between male and female groups. Simple Reaction Time (SRT): The median simple reaction time for males was around 300 ms, while for females it was slightly lower, around 275 ms. The variability (interquartile range) appeared greater in females than in males, indicating a greater diversity in female responses. Although there was overlap, the distribution of extreme values indicated that some females had faster simple reaction times, while others were significantly slower than males. Choice Reaction Time (CRT): The median choice reaction time for males was around 410 ms, while for females it was slightly higher, around 450 ms. The data distribution range for males was relatively wider than for females, as evidenced by the whisker, which reached almost 600 ms. In general, males show greater variation, with some individuals having significantly faster or slower reaction times than females. General Comparison: On the SRT, females show a slightly faster median but with greater variation. On the CRT, males have a lower median (faster) but with a wider range of variance. This indicates that gender may play a role in differences in reaction speed performance, but the observed patterns are also influenced by substantial individual variation.

4. Discussion

The results of this study indicated that there was no significant relationship between reaction time (RT) and forced vital capacity (FVC). A very weak and insignificant relationship is indicated by the Spearman correlation values of $\rho = 0.138$, $p = 0.437$ for RT Simple and $\rho = 0.292$, $p = 0.094$ for RT Choice. These results are pertinent to understanding that, although FVC is a critical metric for lung function, its impact on reaction time may be indirect or negligible.

One statistical method to analyze the relationship between reaction speed and other variables, such as FVC (Forced Vital Capacity), is Pearson correlation analysis. In this context, a Pearson correlation value of -0.134 suggests that the two variables have a very weak relationship, which does not exhibit a distinct pattern. This is consistent with the results of numerous studies, which indicate that the correlation between somatic variables and reaction speed is frequently either negligible or insignificant. For instance, Kurdi and Qomarrullah [20] research indicates that, despite the existence of a correlation between hand reaction speed and service accuracy in tennis, the results show that the correlation is

extremely strong, which contradicts the previous assertion. Sekar Utami et al. [21] conducted a subsequent investigation and determined that the correlation coefficient between the arch's shape and running speed is -0.308 , indicating a relatively low relationship in a negative direction. This implies that factors other than the variable under investigation may significantly influence reaction speed in the context of sports. Furthermore, Fauzi et al. [22] assert that a variety of factors, including muscle strength and coordination, influence reaction speed, a sensorimotor ability associated with stimulus processing and decision-making. Research by Wicaksono et al. [23] demonstrates that traditional games can enhance reaction speed. However, the outcomes are contingent upon the context and methodologies employed. This implies that although we can quantify reaction speed, the correlation with other variables like FVC may not always be consistent or significant. In summary, the low Pearson correlation value between FVC and reaction speed suggests that the relationship between these two variables is extremely feeble and lacks a discernible pattern. Previous research has demonstrated that a variety of factors can affect reaction speed, and this relationship may not always be dependable in a broader context. Consequently, it is crucial to take into account additional variables that may impact the outcomes of this analysis.

In the context of physical performance and health, researchers frequently investigate two variables: lung capacity (FVC) and reaction time. Nevertheless, the evidence indicates that there is no direct correlation between reaction time and FVC. Wu et al. [24] conducted research that indicates that while pollutant exposure results in a decrease in FVC values, this is not always associated with a decrease in reactive speed. This study highlights that environmental factors such as air pollution can influence lung function, but they do not directly impact an individual's response to stimuli. Tsai et al. [25] also suggest that benzodiazepines can shorten reaction times, but there is no proof that lung capacity plays a role in this. In this context, FVC may contribute to general health; however, its impact on reaction speed appears to be negligible. Another study by Pettersson et al. [26], which does not explicitly discuss the relationship between food allergy reactions and lung function, does not support the claim that the body's response to external stimuli is more complex and not solely influenced by lung capacity. Furthermore, Gürsoy's [27] research reveals a correlation between muscle strength and reaction speed, but other variables such as mental state and physiological factors significantly influence this relationship. This suggests that lung capacity has a lesser impact on reaction speed than neurological and physical factors. Therefore, despite the fact that FVC is a critical metric for lung health, there is no evidence to suggest that it has a direct impact on reaction time.

Key discoveries from the investigation: In a healthy student population, there was no significant association between FVC and reaction time, either RT Simple or RT Choice. This implies that other factors, such as physical fitness, stress levels, or neuromuscular coordination, have a greater influence on reaction time. This research supports the claim that lung capacity (FVC) does not directly correlate with reaction time in healthy populations. In contrast, other variables, including tension, neuromuscular coordination, and physical fitness, may exert a more significant impact. Future research may investigate this relationship in conjunction with longitudinal methods to capture long-term dynamics and the broader population.

The relationship between reaction time (RT) and forced vital capacity (FVC) has been examined in the field of athletic performance and health studies. However, the evidence suggests that there is little to no significant direct relationship between these two parameters.

Gürsoy's comparative study found that when controlling for other factors such as height, weight, muscle power, and left eye-hand reaction time, the relationship between FVC and reaction time largely dissipated [27]. This suggests that while FVC may play a role in physiological performance, it may not directly influence reactive capabilities in a meaningful way.

Further research indicates that FVC is more reliably linked to physical activity levels rather than reaction times directly. For example, Wu et al. [28] found that physical activity may act as a mediator, improving FVC and subsequently affecting overall functional performance, but not necessarily reaction times themselves [28].

Additionally, studies have shown that spirometric indices like FVC are often modulated by age, sex, and body metrics, but do not establish a direct link between these indices and cognitive response times [29]. Similarly, Kainu et al. [30] found that the active use of forced expiratory measures like FVC predominantly affects parameters related to bronchodilation rather than reaction time [30].

A meta-analytical approach by Wehrmeister et al. [31] also confirms that associations between various physiological metrics and lung function parameters yield inconsistent results across different populations [31]. This inconsistency further underscores the argument against a direct correlation between FVC and reaction times.

Furthermore, the literature suggests that the relative importance of muscle strength and other physical training parameters tends to overshadow the influence of lung measures like FVC. Alter et al. [32] discuss how pulmonary dysfunction in chronic health conditions spans the breadth of causality rather than resulting in linear relationships across other physiological metrics such as RT [32].

In conclusion, the net evidence indicates that while forced vital capacity is an important metric of respiratory health, its direct relationship with reaction time is not extensively supported. The multifactorial influences, including physical fitness, age, and other demographic variables, complicate the narrative of a simple cause-and-effect relationship between FVC and RT.

5. Conclusion

The results of the study indicated that there was no significant relationship between forced vital capacity (FVC) and reaction time (RT Simple and RT Choice) in the healthy student population. These results suggest that lung capacity, as opposed to neuromuscular coordination, physical fitness levels, or tension, has a greater impact on reaction time. This aligns with previous studies that emphasize the significance of pulmonary function in individuals with health disorders or advanced age. This study underscores the importance of incorporating additional lifestyle and physiological variables into research on reaction time.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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