Original Article

Correlation between Predicted Maximal Oxygen Uptake (VO_2 Max) from the Six-Minute Walk Test with Reaction Time in Male Security Guards

Amira Ismi Noor, Dicky Soehardiman, Feni Fitriani Taufik

Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Indonesia, Persahabatan Hospital, Jakarta, Indonesia

Abstract

Background: Reaction time, the interval between stimulus and motor response, reflects alertness and is critical in professions such as security guards. On the other hand, a measurement of cardiorespiratory fitness using maximal oxygen uptake (VO_2 max) as a standard has been linked to improvements in cognitive performance. Therefore, this study examined the relationship between predicted VO_2 max values from the six-minute walk test and reaction time in security guards.

Methods: A cross-sectional study was conducted among 33 male security guards at Persahabatan National Respiratory Center between October and November 2024. Participants completed physical activity questionnaires, the six-minute walk test, and audio-visual reaction time assessments. Analyzed using Pearson's test if both variables were normally distributed, or Spearman's if both variables were not normally distributed.

Results: The predicted VO_2 max was 17.9 (10.3–24.6) ml/kg/min (metabolic equivalents/METs: 5.2±0.8). Body mass index significantly influenced VO_2 max (P=0.005). Auditory reaction time was considerably faster than visual reaction time (172.6±25.7 ms vs. 199.8±33.1 ms; P<0.001). A weak negative correlation and statistically significant result were found in predicted VO_2 max and visual reaction time (r = –0.340; P=0.048), but not significant with auditory reaction time (r = –0.245; P=0.169).

Conclusion: The predicted VO_2 max was not strongly associated with visual reaction time among security guards.

Keywords: cardiorespiratory fitness, maximal oxygen uptake, reaction time, VO_2 max

Corresponding Author:
Amira Ismi Noor | Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Indonesia, Persahabatan Hospital, Jakarta, Indonesia | amiraisminoor@yahoo.com

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INTRODUCTION

A reaction refers to a deliberate and conscious act triggered by an external stimulus. The duration between the stimulus and the resulting physical action is termed reaction time.[1] It represents the total duration required for an individual to perceive an external stimulus, process the information, make an appropriate decision, and initiate a motor response.[2] Reaction time is critical to everyday functioning and relies on integrated sensory input, cognitive processing, and motor performance.[3]

Reaction time can be deliberately trained. Engaging in physical activity and exercise can enhance the underlying processes that influence reaction time.[4,5] Therefore, it plays a central role in determining one's level of alertness, particularly in professions where rapid response is vital, such as drivers, athletes, pilots, military personnel, doctors, nurses, and security guards.[3] As an example, security guards are trained to assess situations swiftly and accurately and also deliver appropriate responses. Their response speed is often dependent on the urgency of the situation.[6]

Reaction time has been shown to be affected by a wide array of factors to include such as sex, age, physical fitness, mental fatigue, attentional interference, alcohol intake, personality characteristics, the specific limb engaged in testing, circadian fluctuations, and the sensory stimulus (e.g., auditory vs. visual). On the factor of physical fitness, persistent low oxygen levels and systemic inflammation may provoke muscle weakness, cognitive impairment, and neurological abnormalities. This thereby adversely impacts motor

functions such as physical activity, balance, posture, and coordination.[7] The consequence is that reaction time becomes longer and performance decreases.[8,9]

Therefore, oxygen levels in the body must be maximally taken up. Maximal oxygen uptake (VO_2 max) is a measure of the cardiorespiratory system's capacity to take in, transport, and utilize oxygen in the mitochondria of active muscles to meet the energy demands of contraction. It is a key indicator of cardiorespiratory fitness, commonly used across populations ranging from athletes to sedentary individuals and patients with various medical conditions.[10,11]

Furthermore, higher cardiorespiratory fitness has been linked to better cognitive performance in both younger and older adults.[12–14] However, most reaction time tests have low specificity, meaning they often fail to accurately reflect an individual's ability to respond rapidly in profession-specific contexts.[15] While many studies focus on athletes, limited research has explored reaction time in security personnel.

Therefore, the present study aims to investigate the correlation between predicted VO_2 max obtained from the six-minute walk test and reaction time in male security guards.

METHODS

This cross-sectional analytical study was conducted at Persahabatan National Respiratory Center Hospital, Jakarta, from October to November 2024. Ethical approval was obtained from the Health Research Ethics Committee of Persahabatan National Respiratory Center Hospital (Approval No. 0222/KEPK-RSUPP/10/2024). The study involved 33 active male security guards selected based on predefined inclusion and exclusion criteria using a correlation-based sample size calculation.

Eligible participants were male security guards aged 20–55 years currently employed at the hospital who provided written informed consent and agreed to participate fully in the study. Exclusion criteria include a history of cerebral disorders (e.g., head trauma, stroke, encephalitis, meningitis); use of antidepressants, antihistamines, or beta-blockers with anxiolytic effects (e.g., propranolol, bisoprolol); illicit substances; alcohol; stimulants such as caffeine; and a history of myocardial infarction or unstable angina.

Data collection was carried out on non-working days. The researcher introduced the study objectives, benefits, and participant eligibility criteria and obtained written informed consent. Participants completed a demographic data form and the Global Physical Activity Questionnaire (GPAQ) and underwent a physical examination. Reaction time was measured using the L77 Lakassidaya reaction time device, which yields two measurement results are visual reaction time and auditory reaction time. Followed by the six-minute walk test to estimate maximal oxygen uptake (VO2 max). The prediction values for VO_2 max were measured by Nury's formula:[16]

$$(0{,}053\ \text{total distance}_{\text{meter}}) + (0{,}22\ \text{age}_{\text{years}}) + (0{,}032\ \text{height}_{\text{centimeter}}) - (0{,}164\ \text{weight}_{\text{kilogram}}) - (2{,}228\ \text{gender}_{\text{male=0, female=1}}) - 2{,}287.$$

Figure 1. The formula for maximum VO_2

All collected data were analyzed using IBM SPSS Statistics for Windows, Version 26.0. The correlation between predicted VO_2 max and reaction time was assessed using Pearson's test if both variables were normally distributed, or Spearman's rank correlation test if at least one variable was not normally distributed. The hypothesis testing results were reported in terms of values of *P* (with significance set at $P<0.05$) and the correlation coefficient (r), with a 95% confidence interval.

RESULTS

A total of 35 male participants provided written informed consent; however, two were excluded—one due to a history of ischemic stroke and another due to antihistamine use, resulting in 33 subjects participating. Both the six-minute walk test and the reaction time assessment were conducted on non-working days or holidays.

The subjects shared similar baseline characteristics, with a median age of 41 years

(range: 22–51 years). Smoking status was a notable characteristic. The majority of participants were active smokers (90.9%), primarily in the light Brinkman Index category (60.6%), with the rest in the moderate category (30.3%). A small proportion were former smokers (6.1%) or non-smokers (3%).

Based on body mass index (BMI), most participants were classified as overweight (60.6%) or obese (15.2%), while 24.2% had a normal BMI. Physical activity levels, assessed using the GPAQ, indicated that the majority of participants (63.6%) had a moderate level of physical activity, equivalent to 600–1499 metabolic equivalents (MET)-minutes per week. Complete data is provided in Table 1.

Table 1. Sample characteristics (n=33)

Variables	n	%
Age, years (median [min-max])	41 (22–51)	
Level of security training		
Basic	30	90.9
Intermediate	3	9.1
Advanced	0	0.0
Years of service		
New (0–5 years)	30	90.9
Moderate (6–10 years)	1	3.0
Long-term (>10 years)	2	6.1
Smoking status		
Non-smokers	1	3.0
Former smoker	2	6.1
Active smoker	30	90.9
Brinkman Index		
Light	20	60.6
Moderate	10	30.3
Heavy	0	0.0
History of hypertension		
Yes	3	9.1
No	3	90.9
Height, cm (mean±SD)	169.3±3.8	
Weight, kg (median [min-max])	75 (63–110)	
Body Mass Index (BMI), (mean±SD)	27.5±3.7	
Normal (18.5–24.9)	8	24.4
Overweight (25.0–29.9)	20	60.6
Obese (≥30.0)	5	15.2
Physical activity level (GPAQ)		
Low	7	21.2
Moderate	21	63.6
High	5	15.2

The mean six-minute walk distance (6MWD) was 515.3±38.7 meters, translating to a predicted VO_2 max of 17.9 (10.3–24.6) ml/kg/min calculated using Nury's formula. The mean MET value for all subjects was 5.2±0.8. Bivariate analysis was conducted to identify factors associated with predicted VO_2 max (Table 2). Variables showing P<0.20—BMI and physical activity level—were included in the multivariate analysis using linear regression.

Table 2. Bivariate analysis of subjects' characteristics associated with predicted VO_2 max

Variables	Predicted VO_2 max (ml/kg/minute)	*P*
Age	17.9 (10.3–24.6)	0.653[a]
Smoking status		
Non-smokers and former smokers	17.2 (15.4–24.6)	0.977[b]
Active smoker	18 (10.4–22.7)	
History of hypertension		
Yes	20.6 (17.2–21)	0.381[c]
No	17.9 (10.3–24.6)	
Body Mass Index (BMI)		
Normal	19.9±2.4	
Overweight	18.6±2.4	0.001[d]
Obese	14.4±2.6	
Physical activity level (GPAQ)		
Low	17.9 (17–22.4)	
Moderate	17.5 (10.3–24.7)	0.067[b]
High	20.6 (15.4–22.7)	

Note: [a]Spearman test; [b]Mann-Whitney test; [c]ANOVA one-way; [d]Kruskal-Wallis test

Age was retained in the model due to its known biological influence on oxygen uptake. Multivariate analysis (Table 3) revealed that BMI was the only variable significantly associated with predicted VO_2 max (P=0.005).

Table 3. Multivariate analysis of subjects' characteristics associated with predicted VO_2 max

Variables	β	SE	CI 95%	*P*
Constant	25.159	3.658	17.677–32.641	---
Age	0.011	0.058	-0.107−0.130	0.849
BMI	-2.506	0.831	-4.205− -0.807	0.005*
Physical activity level	0.14	0.817	-1.656–1.684	0.986

Note: Linear regression test; *significant if P<0.05; CI 95%=95% Confidence Interval; Adjusted R square = 27.4%

Based on the reaction time measure, both visual reaction time and auditory reaction time were obtained an average visual reaction time for all subjects was 199.8±33.1 ms. Whereas the mean auditory reaction time was 172.6±25.7 ms (Table 4). Pearson's test showed a statistically significant difference between reaction times with auditory versus visual stimuli (P<0.001).

Table 4. Reaction time examination results (n=33)

Reaction Time	Mean±SD	*P*
Visual (ms)	199.8±33.1	<0.001
Auditory (ms)	172.6±25.7	

Table 5 showed a negative correlation between predicted VO_2 max and visual reaction time (r = -0.340; *P*=0.048), with a weak strength, but statistically significant. A negative correlation was also found between predicted VO_2 max and auditory reaction time (r = -0.245), but this result was not statistically significant (*P*=0.169).

Table 5. Correlation between predicted VO_2 max and reaction time

Reaction Time	Predicted VO_2 max	
	Correlation Coefficient (r)	*P*
Visual	-0.340	0.048*
Auditory	-0.245	0.169

Note: Pearson test; *significant if *P* <0.05

DISCUSSION

The study involved 33 participants with a mean age of 41 years (range: 22–51). This aligns with Jovanović et al, who reported a mean age of 45.6 years among Serbian security officers, and Malavia et al who reported a younger average of 31 years.[17,18] VO_2 max typically declines with age due to reductions in maximal heart rate and cardiac output.[19]

In terms of smoking status, 90.9% were active smokers, mostly with light to moderate Brinkman Index scores. This contrasts with Godinho et al, where 89.5% were non-smokers.[20] Smoking has been associated with reduced VO_2 max, even at light to moderate levels.[21,22]

Only 9.1% had a history of hypertension, with no other comorbidities reported (e.g., chronic obstructive pulmonary disease [COPD], asthma, diabetes). Prior studies have noted higher cardiovascular risks among security officers, attributed to stress, smoking, irregular shifts, and low physical activity.[17] Lower VO_2 max is inversely related to higher blood pressure.[22]

The mean BMI was 27.5±3.7 kg/m², with 60.6% overweight and 15.2% obese. Obesity is linked to cardiopulmonary diseases and higher mortality. Similar findings were reported by Pongen et al in Indian security officers, despite adequate physical fitness by step test measures.[23]

Using the GPAQ, 63.6% had moderate physical activity, defined as achieving 600–1499 MET-min/week. This matches Malavia and Shah, who found 44% of security officers had moderate activity.[18] GPAQ classifies physical activity across work, transportation, and recreation domains, with MET scores calculated per domain.

From the 6MWD calculation obtained the mean is 515.3±38.7 m, so the predicted VO_2 max based on Nury's formula is 17.9 (10.3–24.6) mL/kg/min. According to cardiorespiratory fitness classifications, this value falls within the poor category for both men and women aged 40–49 years.[24] The Nury formula is preferred over the simpler Cahalin formula for Indonesian populations, due to its incorporation of sex, age, height, and weight, which account for ethnic physiological differences.[16]

Comparable results were observed in Santausa's study, with a result of 19.8±3.8 ml/kg/min. It's likely influenced by a predominantly female sample likely influenced.[25] Different from Malavia and Shah, who used the Chester step test, reported a much higher VO_2 max (60.6±11.8 ml/kg/min), and Buttar et al who used direct measurement among healthy adults.[18,26]

Meanwhile, COPD patients showed a much lower range of 14.14 ml/kg/min.[27] The corresponding MET value from predicted VO_2 max was 5.2±0.8, lower than general fitness standards.[25] However, MET demands for security tasks vary (e.g., standing, walking, responding to emergencies), generally ranging from 2.5 to 3.5 METs, making the observed levels functionally adequate and not impede task performance.[28]

The result of bivariate analysis identified BMI and physical activity as significant predictors of VO_2 max. After multivariate analysis using linear regression and including age, only BMI (*P*=0.005) remained significant. These findings are consistent with Buttar et al's study which reported significant differences in VO_2 max by sex and BMI.[26] BMI negatively influences VO_2 max. Higher adiposity is associated with lower cardiorespiratory fitness, likely due to reduced lean muscle mass and increased fat percentage.[29–31]

In reaction time measurement, the means for visual and auditory were within the normal range

(150–240 ms), with the auditory reaction time significantly faster. These findings are supported by Jain et al who observed shorter auditory than visual reaction times in medical students.[32] A study reported that auditory reaction times to sport-specific stimuli were 20–40 ms faster than visual ones, despite the longer physical transmission of sound. This advantage reflects the brain's faster auditory processing and more direct motor pathway activation compared to the broader cortical engagement required for visual input.[33]

Based on the correlation test of VO_2 max with visual reaction time, there was a negative correlation and a statistically significant (r = -0.340; *P*=0.048), but not with auditory reaction time (r = -0.245; *P*=0.169). These results align with studies showing that higher aerobic capacity improves cognitive speed and reaction time via enhanced cerebral oxygenation.[34]

Jain et al also reported that significantly faster reaction times were observed in physically active individuals than in sedentary individuals. While Shivalingaiah et al observed that VO_2 max negatively correlated with auditory and visual reaction times among runners.[8,32] Moreover, a recent meta-analysis found that acute aerobic exercise produces broad improvements in cognitive functions, including enhancements in reaction time and task accuracy.[35]

Similarly, Liu et al suggested that an increase in cerebral blood flow may mediate the exercise-induced improvements in executive function observed in young people.[36] In contrast, Dewi et al reported delayed reaction times and cognitive decline in taxi drivers with COPD.[37]

The weaker and nonsignificant results of auditory correlation in this study can be due to stimulus variability or the small sample size, which reduces statistical power. Differences in sensory processing between visual and auditory stimuli may also contribute to inconsistent correlation patterns.

LIMITATION

This study has several limitations. First, the cross-sectional design only allows for the identification of associations between variables, without establishing causal relationships. Second, BMI was not complemented with body composition analysis, preventing assessment of muscle mass and fat percentage. Lastly, auditory reaction time measurements did not include screening for hearing impairments, which may have affected the accuracy of the results.

CONCLUSION

In this study, predicted VO_2 max was not strongly but significantly associated with faster visual reaction time among security guards. Meanwhile, no significant correlation was found with auditory reaction time. Task performance was not impaired in the participants, as their MET capacity was appropriate for the physical demands of their duties (mean MET participants 5.2±0.8; MET requirements 2.5–3.5). Interventions targeting smoking cessation and weight management are recommended, not only to improve VO_2 max, but also to reduce the risk of smoking- and obesity-related diseases and to enhance overall quality of life. Future studies should investigate this relationship across diverse occupational groups, incorporate fatigue-related variables such as pre- and post-shift assessments, and explore alternative VO_2 max measurement methods (e.g., the Rockport test).

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CONFLICT OF INTEREST

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