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The Relationship Among Maximal Aerobic Capacity, Pulmonary Function Tests, and Cognitive Functions in Healthy Middle-Aged Adults

Sağlıklı Orta Yaşlı Yetişkinlerde Maksimal Aerobik Kapasite ve Solunum Fonksiyon Testleri ile Bilişsel Fonksiyonlar Arasındaki İlişki

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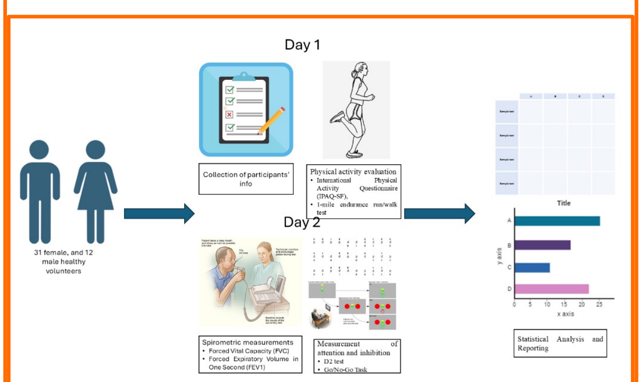
GRAPHICAL ABSTRACT

There is a moderate positive correlation observed between Forced Expiratory Volume in 1-Second (FEV1) and psychomotor speed.

Recent research found a beneficial relationship between cardiorespiratory endurance and cognitive performance, including executive function, psychomotor speed, verbal memory, selective attention, inhibitory response.

This study aimed to investigate if maximal aerobic capacity and pulmonary function tests can be a predictor of cognitive function including selective attention and inhibitory response in healthy middle-aged adults.



A moderate positive correlation was observed between psychomotor speed and FEV1 (r=0.35) and was statistically significant as a predictor in regression analysis (p=0.02).

No significant correlation was observed between other aerobic capacity and pulmonary function test results and values related to attention and inhibition

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ABSTRACT

Aim: This study aimed to investigate if maximal aerobic capacity and pulmonary function tests can be a predictor of cognitive function including selective attention and inhibitory response in healthy middle-aged adults.

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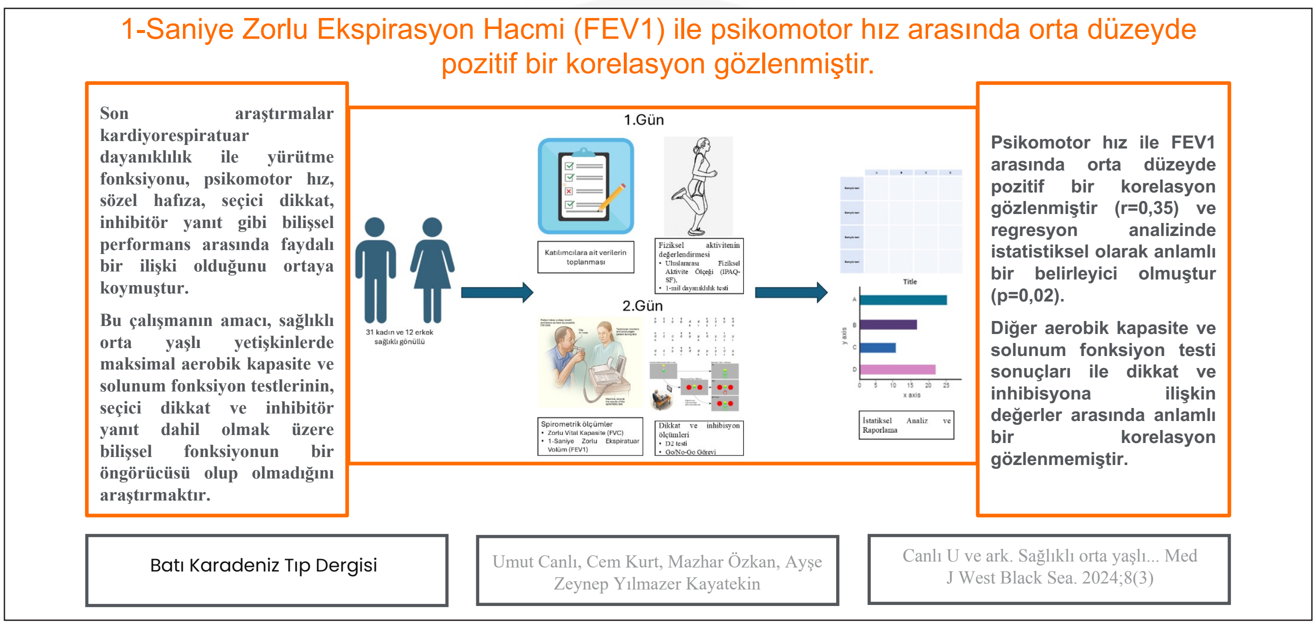
Material and Methods: The study involved 43 people, comprising 31 females and 12 males. The research included evaluations of maximal aerobic capacity (VO2max), pulmonary function tests, and cognitive assessments. VO2max was assessed by the 1-mile Endurance Run/Walk Test, and pulmonary function evaluations were conducted via a spirometer. Selective attention was measured via the d2 test, whilst inhibitory response was evaluated using a computer-based Go/No-Go test.

Results: The TM parameter was not significantly predicted by TM Model 1 ($F(4, 38) = 1.324$, $p = 0.279$) or TM Model 2 ($F(8, 34) = 1.752$, $p = 0.122$). Similarly, E1 Model 1 did not show statistical significance in predicting the E1 parameter. Analysis of the inhibitory parameters GCR and NGRC also revealed no significant associations, as indicated by GCR Model 1 ($F(4, 38) = 0.389$, $p = 0.815$), GCR Model 2 ($F(8, 34) = 0.333$, $p = 0.947$), NGRC Model 1 ($F(4, 38) = 1.917$, $p = 0.128$), and NGRC Model 2 ($F(8, 34) = 2.042$, $p = 0.071$). However, a moderate positive correlation was observed between TM and FEV1 ($r = 0.35$, $p < 0.05$).

Conclusion: It can be concluded from these results that the VO2max test and the outcomes of the pulmonary function tests are not reliable indicators of cognitive abilities in middle-aged, healthy persons. Nonetheless, FEV1 may function as a marker of selective attention. Additional research involving a larger sample size is needed to better understand the relationship between maximal aerobic capacity, pulmonary function tests, and cognitive performance.

Keywords: VO2max, attention, inhibition, FEV1

GRAFİKSEL ÖZET



ÖZ

Amaç: Bu çalışmanın amacı, sağlıklı orta yaşlı yetişkinlerde maksimal aerobik kapasite ve solunum fonksiyon testlerinin seçici dikkat ve inhibitör yanıtı içeren bilişsel fonksiyonun bir belirleyicisi olup olmadığını araştırmaktır.

Gereç ve Yöntemler: Otuz bir kadın ve 12 erkek olmak üzere toplam 43 katılımcı çalışmaya alındı. Katılımcılara ayrı günlerde maksimal aerobik kapasite (VO2max), bazı solunum fonksiyon testleri ve kognisyon testleri uygulanmıştır. Maksimal aerobik kapasite 1 Mil Dayanıklılık Koşu/Yürüyüş Testi ile belirlenmiş ve solunum fonksiyon testleri taşınabilir spirometre ile yapılmıştır. Deneklerin seçici dikkati d2 testi ile, inhibitör yanıtı ise bilgisayar tabanlı Go/No-Go testi ile ölçülmüştür.

Bulgular: TM parametresinin TM Model 1: ($F(4\text{-}38) = 1.324$, $p=0.279$); TM Model 2: ($F(8\text{-}34) = 1.752$, $p=0.122$) ile tahmininde veya E1 parametresinin E1 Model 1: ($F(4\text{-}38) = 1.433$, $p=0.242$); E1 Model 2: ($F(8\text{-}34) = 0.824$, $p=0.588$) ile tahmininde anlamlı bir ilişki bulunmamıştır. Benzer şekilde, GCR ve NGRC inhibisyon parametrelerinin tahmininde sırasıyla GCR Model 1: ($F(4\text{-}38) = 0.389$, $p=0.815$); GCR Model 2: ($F(8\text{-}34) = 0.333$, $p=0.947$) ve NGRC Model 1: ($F(4\text{-}38) = 1.917$, $p=0.128$); NGRC Model 2: ($F(8\text{-}34) = 2.042$, $p=0.071$) ile anlamlı bir ilişki bulunmamıştır. TM ile FEV1 arasında orta düzeyde pozitif korelasyon bulunmuştur ($r=0.35$; $p<0.05$).

Sonuç: Bu sonuçlara dayanarak, ne VO2max testinin ne de solunum fonksiyonları testinin sonuçlarının sağlıklı orta yaşlı yetişkinlerin bilişsel fonksiyonlarının bir belirleyicisi olamayacağı sonucuna varılabilir. Bununla birlikte, FEV1 seçici dikkatin bir göstergesi olabilir. Maksimal aerobik kapasite ve solunum fonksiyon testleri ile bilişsel fonksiyonlar arasındaki ilişkiyi açıklayabilmek için daha geniş örneklemli ileri araştırmalara ihtiyaç vardır.

Anahtar Sözcükler: VO2max, dikkat, inhibisyon, FEV1

INTRODUCTION

Cardiorespiratory endurance is a health-related fitness component and is generally expressed as maximal aerobic capacity (VO2max) (1-2). Enhanced cardiorespiratory endurance correlates with several cardiovascular and non-cardiovascular advantages, including decreased incidence of coronary artery disease, diabetes, high blood pressure, ischaemic stroke, and malignancy (3). Recent research found a beneficial relationship between cardiorespiratory endurance and cognitive performance, including executive function, psychomotor speed, verbal memory, selective attention, inhibitory response, and others (4–7).

Cognitive functioning is typically used when discussing various mental processes, including cognition, education, linguistics, logic, focus, and visuospatial abilities (8). Studies investigating the association between physical activity and cognitive function across various populations have yielded inconsistent findings, with some research highlighting a positive correlation between physical activity and cognitive performance (4,5,7,9,10) and others indicating a lack of such a relationship (11–13). Cognitive functions, influenced by factors such as information processing speed, attention span, language proficiency, and visual-spatial orientation, are critical determinants of cognitive ability (14). One of the often employed tests for the evaluation of certain cognitive processes related to learning and performance is the reaction time (RT) test (14). According to Hillman et al. (7), RT has been utilized as the main indicator of psychomotor performance and is often shorter in physically active older adults compared to sedentary older adults. This highlights the significance of RT in terms of cognitive function.

The influence of physical exercise on cognitive abilities is believed to be facilitated by the secretion of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), insulin-like growth factor 1 (IGF-1), and vascular endothelial growth factor (VEGF) (10). These factors are linked to enhanced plasticity, increased volume, and improved connectivity in the temporal and prefrontal lobes (10,15). Also, it has been believed that aerobic exercise increases the vascularisation of the brain and cerebral blood (7).

In the presence of equivocal results obtained from literature, this study aimed to if maximal aerobic capacity and pulmonary function tests can serve as indicators of cognitive function, encompassing selective attention and inhibiting response, in healthy middle-aged individuals. In our hypothesis, it was anticipated that maximal aerobic capacity would serve as a reliable predictor of cognitive function, encompassing selective attention and inhibitory response, whereas the outcomes of pulmonary function tests were not expected to exhibit such predictability.

MATERIALS and METHODS

This study was conducted at the Sports Sciences Application and Research Centre and the sports complex of Tekirdağ Namık Kemal University.

Participants

The participants included in our study were selected from among the volunteers who applied through the internal e-mail announcement system of the University and the posters hung among those who met the inclusion criteria. For the study, 43 healthy middle-aged adults (12 men and 31 women) were included. Table 1 lists these traits in compre-

Table 1. Descriptive statistics of study variables.

Variables	Findings (n=43)	Range
Demographics		
Age (years± SD)	42.3±9.8	24-66
Gender n(%)		-
Female	31 (72.1)	
Male	12 (27.9)	
Height (cm± SD)	162.3±8.0	147-180
Body mass (kg± SD)	71.4±14.9	50.2-110.1
BMI (kg/m^2± SD)	27.1±5.1	20.2-41.29
PAL± SD	740.6±700.7	0-3186
Respiratory parameters and VO_2max		
FVC (L± SD)	4.2±1.3	1.1-8.5
FEV1 (L/s± SD)	2.8±1.0	0.7-5.0
VO_2max(ml/kg/min)	42.2±5.2	31,3-54,7
Inhibition parameters		
GCR± SD	94.5±5.1	79-100
GWR± SD	5.5±5.1	0-21
GCRL± SD	240.4±77.9	0-404.5
NGRC± SD	98.2±2.6	90-100
NGWR± SD	1.8±2.6	0-10
NGWRL± SD	323.5±71.5	221.2-651.3
Attention parameters		
TN± SD	514.3±89.9	338-646
E1± SD	123.2±50.3	15-299

FVC refers to Forced Vital Capacity, while FEV1 represents Forced Expiratory Volume in the First Second. GCR denotes the number of correct responses in the Go task, and GWR represents the number of incorrect responses in the same task. GCRL indicates the latency of correct responses in the Go task. Similarly, NGCR refers to the number of correct responses in the No-Go task, NGWR represents the number of incorrect responses, and NGWRL denotes the latency of incorrect responses in the No-Go task. TN reflects the total number of items processed, representing participants' psychomotor speed, whereas E1 corresponds to unmarked letters, reflecting selective attention. PAL stands for Physical Activity Level, M denotes the mean, and SD represents the standard deviation.

hensive detail. The study's methodology was fully disclosed to the subjects. Each participant signed a consent form after receiving full information. Tekirdağ Namık Kemal University Non-Interventional Clinical Research Ethics Committee (Decision No: 2021.275.11.19, Date: 30.11.2021) gave its approval to the study protocol. The experiment was carried out in conformity with the Declaration of Helsinki's ethical principles from 1964. Age of 18 years or older and the absence of any musculoskeletal injuries, cardiovascular conditions, or neurological abnormalities were the inclusion criteria. Anyone who was taking medication for cognitive impairment was not allowed to participate in the study.

Procedures

The data collection process was completed over two days. On the first day, demographic information such as age, gender, medical history (including the presence of chronic health conditions), smoking status, and other relevant details were gathered (16). Physical activity levels were assessed using the short form of the International Physical Activity Questionnaire (IPAQ-SF), a 10- to 15-minute interview-based survey. Additionally, participants' height and weight were measured to calculate their body mass index (BMI) using the formula BMI = kg/m². Following these measurements on the first day, participants undertook a 1-mile endurance run/walk test. Before commencing this test, standardized instructions were provided, allowing participants to pause if necessary but encouraging them to resume as soon as possible. Throughout the 1-mile endurance run/walk test, participants received regular verbal encouragement, including phrases like "You're doing well" and "Keep up the excellent job." Using a Polar brand pulse rate monitor, participants' heart rates were recorded both before and after the one-mile run or walk. Completion time for the 1-mile test was determined using a smartphone GPS device.

On the second day of the study, participants received comprehensive instructions and demonstrations for performing spirometric measurements before cognitive testing commenced. Cognitive testing involved the administration of the Go/No-Go and d2 attention tests, each conducted individually with only the participant and the test administrator present. The testing environment was deliberately selected to be quiet and free from potential distractions. To maintain consistency, the same researchers administered the tests and measurements in the same sequence to all participants.

Prior to the aerobic endurance test, participants were allowed to complete a standard warm-up routine, including a 10-minute jog and 5 minutes of dynamic stretching. To minimize the influence of circadian rhythms on the study's results, all tests were conducted during the same time window (from 5:30 p.m.to 7:30 p.m.). Participants were given an appropriate period for cool-down activities following the conclusion of the tests.

Measurements

Anthropometric Evaluation

Participants' height and body weight were measured while they were barefoot and dressed in shorts and T-shirts. Height was measured using a portable stadiometer (Mesilife 13539) with a precision of 0.1 cm, and body weight was recorded using an Omron scale accurate to 0.01 kg. Body mass index (BMI) was determined by applying the formula: BMI = weight in kilograms divided by the square of height in meters (kg/m²).

Physical Activity Assessment

The height and body weight of participants were recorded with them barefoot and wearing shorts and T-shirts. The questionnaire was given to participants between the ages of 15 and 65 to determine their levels of physical activity (17). Saglam et al. (18) verified the reliability and validity of the IPAQ in its Turkish adaptation. The IPAQ assessment recommends engaging in physical activities lasting at least 10 minutes per session. Participants were asked to report the amount of time spent on vigorous exercise, moderate exercise, walking, and sitting during a typical day.

The formula below was used to convert walking and intense, moderate physical activity durations to the corresponding basal metabolism in MET units (1 MET = 3.5 ml/kg/min). The overall physical activity score (MET - min/week) was then computed.

1-Mile Endurance Run/Walk Test

A one-mile run/walk test, a well-established assessment of aerobic endurance (19), was conducted. Participants were instructed on the test protocols before the pre-test, which included a health risk assessment and informed consent. The test involved running or walking a mile as quickly as possible, with the course delineated using cones. Participants were encouraged to complete the distance in the shortest time possible. The test's duration in minutes and seconds was recorded and compared to age-group standards (20). VO2max was calculated using the following equations:

"For males: VO2max=108.844-0.1636W-1.438T-0.1928H"

"For females: VO2max=100.5-0.1636W-1.438T-0.1928H"

In this context, W denotes weight in kilograms, T represents the time taken to complete the one-mile run, and H is the heart rate recorded at the end of the run (21). Heart rate variability during the run/walk test was monitored using the Polar Verity Sense optical heart rate monitor, which transmitted data to an app via Bluetooth®, ANT+, and internal memory for storage.

Measurement of Attention

Participants' attention span was assessed using the d2 attention test, a method for measuring focus and selective attention. The test consists of 14 rows, each with 47 letters, some marked with one, two, three, or four tiny markings. Participants had 20 seconds to identify "d" letters while ignoring extraneous ones (22,23). Performance was quantitatively evaluated through the Total Matter Score Processed (TM) and the Error Percentage (E%). Concentration performance (CP) was determined by subtracting E2 from the total number of accurate strikes. The frequency rate (FR) was calculated as the difference between the highest and lowest counts of processed items. The TM-E score, representing overall performance, integrates accuracy with processing speed. Percentile intervals for TM-E scores were defined as follows: 50-60% is poor, 60-70% is mediocre, 70-85% is typical, and over 85% is excellent.

Measurement of Inhibition

Response inhibition was assessed using the Go/No-Go Task, which restricts a well-established response using X and O images as stimuli (24). The task consisted of 200 stimuli, with 100 as non-target (No-Go) and 100 as target stimuli (Go). Stimuli were displayed for 50 milliseconds, with 1,450 milliseconds of inter-stimulus intervals (ISI). The correct reaction score counted the number of accurate responses to a target stimulus, while the incorrect reaction score recorded the times a response was not given to a non-target stimulus. The incorrect reaction latency represented the average reaction time for correct responses to a target stimulus.

Spirometric Measurements

All spirometric measurements were performed according to Mottram (25). The measurements were taken from the participants while standing in an upright position with the help of a spirometer device (Firstmed SP-10-brand). Initially, the participants' date of birth, sex, height, and body weight were entered into the spirometer. They were asked to hold the mouthpiece between their lips and close their mouth tightly against air leakage. Participants were instructed to breathe normally twice, followed by a maximal exhalation of fully inhaled air through the mouthpiece. Each test was performed twice, with the highest values recorded. The device was calibrated, and the mouthpiece was replaced after each measurement. During this procedure, Forced Vital Capacity (FVC) and Forced Expiratory Volume in One Second (FEV1) were measured.

Statistical Analysis

Statistical analyses were conducted using SPSS software (version 18; IBM Corporation, New York, United States), with the level of statistical significance set a priori at $p < 0.05$. Descriptive statistics were utilized to outline participant characteristics, while the normality of the outcome variables was determined through the Kolmogorov-Smirnov test and visual assessments, including histograms and Q-Q plots. Gender differences in reaction latency values were analyzed using the independent samples t-test. Partial correlation analysis was performed to examine relationships between cognitive functions, respiratory parameters, and VO2max. The strength of partial correlation coefficients was classified as small (0–0.30), moderate (0.31–0.49), large (0.50–0.69), very large (0.70–0.89), and nearly perfect (0.90–1.00) (26).

Furthermore, multiple linear regression models (hierarchical regression) based on ordinary least squares (OLS) were used to assess the contributions of respiratory parameters and VO2max in predicting attention and inhibition. The analysis also evaluated the specific roles of individual components of respiratory parameters and VO2max with the components of attention and inhibition (27), while controlling for age, sex, BMI, and PAL.

To ensure the appropriateness of hierarchical regression analysis, multicollinearity among predictor variables was assessed. This was done by calculating Variance Inflation Factors (VIF) and Tolerance Values (Tolerance = 1/VIF), which measure the proportion of variance not explained by other independent variables. Multicollinearity was considered absent if the highest VIF value was below 10 and the Tolerance value exceeded 0.2 (28). The analysis verified that these conditions were met.

An additional condition for multiple linear regression to produce reliable results is that the residuals (the differences between observed and predicted values) must follow a normal distribution. This was assessed by generating a scatter plot of standardized predicted values (Z-Predicted) against standardized residuals (Z-Residuals). A random dispersion of points around zero in the plot indicates that the residuals follow a normal distribution and display constant variance (28). The analysis confirmed that this condition was met in the research data.

Results

Table 1 provides a detailed overview of the variables, including their means, standard deviations, and percentages. According to the 2003 guidelines of the International Physical Activity Questionnaire Committee (29), participants were categorized as minimally active. Hierarchical regression analysis was conducted to investigate how attention parameters are influenced by age, gender, BMI, and physical activity level, as well as FVC, FEV1, PEF, and VO2max. The results revealed no significant associations between the TM and E1 parameters and attention metrics. Specifically, neither TM Model 1 ($F(4, 38) = 1.324$, $p = 0.279$) nor TM Model 2 ($F(8, 34) = 1.752$, $p = 0.122$) showed significant relationships with the TM parameter. Similarly, no significant relationship was found for the E1 parameter with E1

Model 1 (F(4, 38) = 1.433, p = 0.242) or E1 Model 2 (F(8, 34) = 0.824, p = 0.588) (Table 2).

Likewise, the inhibitory parameters GCR and NGRC showed no significant associations. For GCR, both Model 1 (F(4, 38) = 0.389, p = 0.815) and Model 2 (F(8, 34) = 0.333, p = 0.947) were non-significant. Similarly, NGRC predictions were not significant in either Model 1 (F(4, 38) = 1.917, p = 0.128) or Model 2 (F(8, 34) = 2.042, p = 0.071) (Table 3). It was found a moderate positive correlation between TM and FEV1 (r=0.35; p<0.05). No correlation was found between other parameters representing attention and inhibition characteristics of the participants and FVC, FEV1, and VO2maxvalues (p>0.05) (Table 4).

Both correct response latencies and incorrect response latencies of the males are lower than that of the females. However, However, a statistically significant difference was observed between genders only in wrong answer latency (p=0.02; Figure 1).

DISCUSSION

This study aimed to investigate if maximal aerobic capacity and pulmonary function tests can be a predictor of cognitive function including selective attention and inhibitory response in healthy middle-aged adults. It has also been hypothesized that maximal aerobic capacity would be a good predictor of cognitive function including selective attention and inhibitory response, but the results of pulmonary function tests would not be.

The main findings of the study were a) maximal aerobic capacity, which is expressed as VO2max, is not an indicator of cognitive functions (selective attention and inhibitory response) of healthy middle-aged adults, b) Since founded moderately positive relationship between participants' psychomotor speed (TN: Total number of matters processed) and Forced expiratory volume (FEV1) (r=0.35;p<0.05), FEV1 can be considered as an indicator of participants' psychomotor speed based on d2 attention test, c) Both correct

Table 2. The multiple linear regression analysis outcomes of respiratory parameters and VO_2max predicting performance on Attention.

TM	Predictors	B	SE	β	t	p	R^2	Adj.R^2
Model 1	Age	-1.911	1.430	-0.207	-1.336	0.190	0.122	0.030
	Sex[a]	32.680	31.685	0.165	1.031	0.309		
	BMI	-2.029	2.848	-0.116	-0.712	0.481		
	PAL	-0.026	0.021	-0.205	-1.273	0.211		
Model 2	Age	0.495	1.801	0.054	0.275	0.785	0.292	0.125
	Sex[a]	43.151	51.138	0.218	0.844	0.405		
	BMI	-2.620	3.591	-0.150	-0.729	0.471		
	PAL	-0.039	0.021	-0.303	-1.840	0.075		
	FVC	-2.260	16.605	-0.034	-0.136	0.893		
	FEV	62.424	24.559	0.662	2.542	0.016		
	VO_2max	-2.318	3.618	-0.134	-0.641	0.526		
E1								
Model 1	Age	1.564	0.796	0.304	1.966	0.057	0.131	0.040
	Sex[a]	16.192	17.628	0.146	0.919	0.364		
	BMI	-0.419	1.585	-0.043	-0.265	0.793		
	PAL	0.003	0.011	0.036	0.227	0.821		
Model 2	Age	2.221	1.096	0.431	2.027	0.051	0.162	-0.035
	Sex[a]	14.683	31.099	0.133	0.472	0.640		
	BMI	-0.442	2.184	-0.045	-0.202	0.841		
	PAL	0.001	0.013	0.019	0.107	0.915		
	FVC	1.030	10.098	0.028	0.102	0.919		
	FEV	11.779	14.935	0.223	0.789	0.436		
	VO_2max	-0.418	2.200	-0.043	-0.190	0.851		

[a]0 = men; 1 = women, SE = Std. Error; TM Model 1: ($F_{(4\text{-}38)}$=1.324, p=0.279); TM Model 2: ($F_{(8\text{-}34)}$=1.752, p=0.122); E1 Model 1: ($F_{(4\text{-}38)}$=1.433, p=0.242); E1 Model 2: ($F_{(8\text{-}34)}$=0.824, p=0.588).

Table 3. The multiple linear regression analysis outcomes of respiratory parameters and VO2max predicting performance on Inhibition.

GCR	Predictors	B	SE	β	t	p	R^2	Adj.R^2
Model 1	Age	0.043	0.085	0.083	0.510	0.613	0.039	-0.062
	Sex[a]	-0.644	1.878	-0.057	-0.343	0.733		
	BMI	0.149	0.169	0.150	0.880	0.384		
	PAL	-6.884	0.001	-0.009	-0.056	0.955		
Model 2	Age	0.039	0.117	0.075	0.335	0.739	0.073	-0.146
	Sex[a]	-0.774	3.315	-0.069	-0.234	0.817		
	BMI	0.128	0.233	0.129	0.548	0.587		
	PAL	3.254	0.001	0.004	0.024	0.981		
	FVC	0.626	1.076	0.165	0.581	0.565		
	FEV	-1.300	1.592	-0.243	-0.817	0.420		
	VO_2max	-0.027	0.235	-0.027	-0.114	0.910		
NGRC								
Model 1	Age	-0.08	0.04	-0.31	-2.07	0.04	0.168	0.080
	Sex[a]	-1.41	0.89	-0.24	-1.57	0.12		
	BMI	0.02	0.08	0.05	0.33	0.73		
	PAL	0.00	0.00	0.05	0.37	0.70		
Model 2	Age	-0.07	0.05	-0.26	-1.39	0.17	0.325	0.166
	Sex[a]	-0.04	1.44	-0.00	-0.02	0.97		
	BMI	-0.04	0.10	-0.08	-0.43	0.66		
	PAL	0.00	0.00	-0.07	-0.47	0.63		
	FVC	0.95	0.47	0.49	2.02	0.05		
	FEV	-0.89	0.69	-0.32	-1.28	0.20		
	VO_2max	-0.11	0.10	-0.22	-1.07	0.29		

[a]0 = men; 1 = women, SE = Std. Error; GCR Model 1: (F(4-38)=0.389, p=0.815); GCR Model 2: ($F_{(8-34)}$=0.333, p=0.947); NGRC Model 1: ($F_{(4-38)}$=1.917, p=0.128); NGRC Model 2: ($F_{(8-34)}$=2.042, p=0.071)

Table 4. Partial correlation outcomes of measured variables.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1.GCR	-	-1.00*	0.01	0.61*	-0.61*	0.34*	0.28	0.13	0.07	-0.15	-0.11	-0.01
2.GWR	-1.00*	-	-0.01	-0.61*	0.61*	-0.34*	-0.28	-0.13	-0.07	0.15	0.11	0.01
3.GCRL	0.01	-0.01	-	-0.04	0.04	0.01	0.17	0.14	-0.26	0.14	0.25	-0.18
4.NGRC	0.61*	-0.61*	-0.04	-	-1.00*	-0.18	0.28	0.04	0.21	0.10	0.23	-0.18
5.NGWR	-0.61*	0.61*	0.04	-1.00*	-	0.18	-0.28	-0.04	-0.21	-0.10	-0.23	0.18
6.NGWRL	0.34*	-0.34*	0.01	-0.18	0.18	-	0.09	0.17	-0.07	-0.22	**-0.33***	0.00
7.TN	0.28	-0.28	0.17	0.28	-0.28	0.09	-	0.22	0.14	**0.35***	0.05	-0.12
8.E1	0.13	-0.13	0.14	0.04	-0.04	0.17	0.22	-	0.09	0.04	-0.10	-0.03
9.FVC	0.07	-0.07	-0.26	0.21	-0.21	-0.07	0.14	0.09	-	0.15	-0.20	-0.05
10.FEV1	-0.15	0.15	0.14	0.10	-0.10	-0.22	0.35*	0.04	0.15	-	0.67*	-0.06
11.VO_2max	-0.01	0.01	-0.18	-0.18	0.18	0.00	-0.12	-0.03	-0.05	-0.06	-0.02	-

Partial correlation was conducted by adjusting for age, sex, BMI, and PAL. *p<0.05.

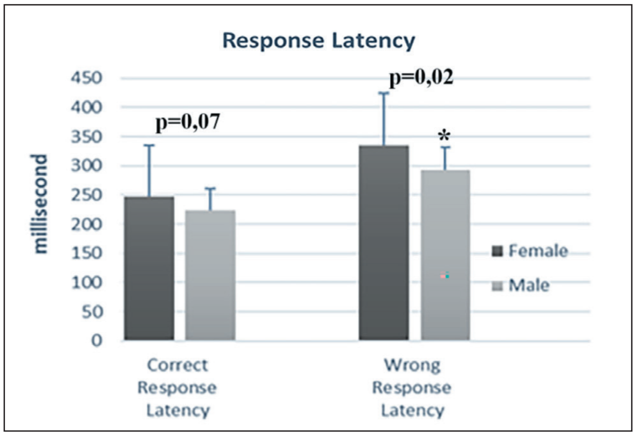


Figure 1: Comparison of response latency values in terms of gender.

response latencies and incorrect response latencies of the males are lower than females. However, there were no statistically meaningful differences between groups (p>0.05) (Figure 1). Based on these results, the study hypothesis cannot be confirmed.

The present study found that VO2max level is not an indicator of cognitive functions in healthy middle-aged adults. However, the study by Esmailzadeh et al. (30) and by Reigal et al. (31), argued that cardiorespiratory fitness level is a good indicator of cognitive functions including inhibitory response, attention, processing speed, and cognitive flexibility in young subjects between 15 – 24 years old subjects. These equivocal results might be caused by the age of the subjects. As differ from the study by Esmailzadeh et al., (30) and Reigal et al., (31) our subjects are middle-aged instead of young. Many studies have reported that improved physical fitness including grip strength and VO2max significantly associated with better cognitive functions (32-40). However, a few studies as in our study, have reported no relationship between improved physical fitness and cognitive functions (41-43).

Another aim of this study was to determine if pulmonary function tests can be an indicator of cognitive functions. The results of the study showed that FEV1 can be considered an indicator of participants' psychomotor speed based on the d2 attention test. Most studies have reported that strong association between pulmonary function tests and cognitive functions (44-47). Kara et al. reported that the Stroop test score which was used for evaluating selective attention was negatively correlated with FVC and FEV 1. These results are interpreted as decreasing oxygenation affecting memory negatively by Kara et al. (46). Additionally, Carroll et al. (45) observed that decreased cognitive capacity in adolescence was related to diminished lung function, as shown by lower FEV1, in adolescence. Lung function could be viewed as a significant predictor of the growth of cognition, according to a study by Qiao et al. (44). Memory, temporal orientation, and executive function decrease rates in middle-aged and older persons are accelerated by poor lung function.

One of the study's findings was that males have lower correct response and incorrect response latencies than females. There were no statistically significant variations between the groups, though. The amount of time between the onset of a stimulus and the corresponding response is known as response latency (48). Emmerson-Hanover et al. (49) showed that while there were few gender differences in latencies during development, males tended to have longer latencies than females into adulthood, which is different from the current study. Across the lifespan, females had higher amplitudes. Men displayed longer latencies than women, according to Dehan and Jerger (50) as well. The genesis of gender differences has been determined to be a mix of hormonal and head-size differences (50).

As noted, equivocal results from the literature and the current study concern whether maximal aerobic capacity and pulmonary function tests can be predictors of cognitive function, including selective attention and inhibitory response in healthy middle-aged adults. These equivocal results might be caused by several factors; a) the background of the subjects; sedentary or active, healthy or sick, age, gender, etc., b) Different types of Cognitive tests; computer-based or Paper-and-pencil assessment, the Stroop test, d2 test, Go/No-Go test, etc., c) Test procedure which used for evaluating cardiorespiratory fitness; 1-Mile Endurance Run/Walk Test, Rockport 1-mile fitness walking test, a 6-minute walking test, graded exercise testing (Balke protocol), etc.

The most important limitation of the study is recruiting only 43 middle-aged adults. Small sample sizes make it hard to generalize the results of the study.

Maximal aerobic capacity (VO2max) cannot be used for predicting selective attention and inhibitory response in healthy middle-aged adults. However, FEV1 can be an indicator of selective attention. Further studies are needed with larger sample sizes to be able to determine the relationship between VO2max and cognitive functions in healthy middle-aged adults.

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Conceptualization: **Umut Canlı,** Methodology: **Umut Canlı, Mazhar Özkan, Ayşe Zeynep Yılmazer Kayatekin,** Resources: **Umut Canlı, Mazhar Özkan, Ayşe Zeynep Yılmazer Kayatekin,** Data curation: **Umut Canlı, Mazhar Özkan, Ayşe Zeynep Yılmazer Kayatekin,** Writing—original draft preparation: **Umut Canlı, Mazhar Özkan, Ayşe Zeynep Yılmazer Kayatekin, Cem Kurt,** Writing—review and editing: **Umut Canlı, Cem Kurt, Mazhar**

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Conflicts of Interest

The authors declare no conflict of interest.

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Ethical Approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved Tekirdağ Namık Kemal University Scientific Research and Publication Ethics Committee (Protocol No: 2021.275.11.19; Date: 30.11.2021).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Review Process

Externally peer-reviewed.

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