

COMPARATIVE ANALYSIS OF THE 1-MILE RUN TEST EVALUATION FORMULAE: ASSESSMENT OF AEROBIC CAPACITY IN MALE LAW ENFORCEMENT OFFICERS AGED 20–23 YEARS

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Abstract

Objectives: The purpose of this study was to compare values of aerobic performance in the 1-mile run test (1-MRT) using different formulae. **Material and Methods:** Aerobic capacities of 351 male volunteers working for the Turkish National Police within the age range of 20–23 years were evaluated by the 1-MRT and the 20-metre shuttle run (20-MST). VO_{2max} values were estimated by the prediction equations developed by George et al. (1993), Cureton et al. (1995) and Kline et al. (1987) for the 1-MRT and by Leger and Lambert (1982) for the 20-MST. **Results:** The difference between the results of the different formulae was significant ($p = 0.000$). The correlation coefficient between the estimated VO_{2max} using Cureton's equation, George's equation, Kline's equation and the 20-MST were 0.691 ($p < 0.001$), 0.486 ($p < 0.001$) and 0.608 ($p < 0.001$), respectively. The highest correlation coefficient was between the VO_{2max} estimated by the 20-MST and Cureton's equation. Similarly, the highest correlation coefficient ($r = -0.779$) was between the 1-mile run time and the VO_{2max} estimated by Cureton's equation. **Conclusions:** When analysing more vigorous exercise than sub-maximal exercise, we suggest that Cureton's equation be used to predict the VO_{2max} from 1-mile run/walk performance in large numbers of healthy individuals with high VO_{2max} . This research compares the use of 3 different formulae to estimate VO_{2max} from 1-mile run/walk performance in male law enforcement officers aged 20–23 years for the first time and reports the most accurate formula to use when evaluating aerobic capacities of large numbers of healthy individuals.

Key words:

Maximal oxygen uptake, Field aerobic tests, Police officers, One mile run test, Physical fitness, Young adults

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INTRODUCTION

Since the duty of law enforcement is a high-risk profession, personnel have to endure adverse conditions that might arise from this risk, and have to expend very high physical effort when encountering crime [1–3]. Police officers have physically strenuous jobs and it is crucial for them to be in top physical health in order to perform their job to the best of their abilities. Therefore, policemen should be healthy with a high level of physical fitness [4,5].

Aerobic fitness (cardiorespiratory endurance) is one of the most important components of health-related physical fitness relating to the ability of the circulatory and respiratory systems to supply fuel during sustained physical activity and to eliminate fatigue products after supplying fuel. Aerobic capacity, measured by maximal oxygen uptake (VO_{2max}), is the “ability to perform large muscle, dynamic, moderate-to-high intensity exercise for a prolonged period” [6–9].

Law enforcement agencies should implement programs that prepare officers to perform their jobs within their own genetic potential and in good health for the length of their careers [10]. Physical fitness has a direct impact on job performance. Based on job descriptions, a core list of physical tasks required to perform the duties of a law enforcement officer has been identified. These tasks are: running, climbing, jumping, lifting/carrying, dragging, pushing, and the use of force [11]. The majority of police departments test police candidates’ physical fitness. Test batteries consist of the events that require from the candidates to perform simulations of important tasks that are part of a police officer’s job. Body composition, strength, aerobic fitness (endurance) and coordination are required in these events. In addition, a physical agility test must be passed by all candidates [12,13]. A specific aerobic capacity is necessary for a police officer to perform these physical requirements adequately. Therefore, aerobic capacity of police officers is also tested. Studies have shown that there is a statistically high correlation between high aerobic capacity and arrests [14]. Fitness programming for

the law enforcement officers should focus on improving aerobic fitness [15]. The aerobic capacity standard is job related and consistent with business necessity, and there is an “obvious relationship between aerobic capacity and the critical and important duties of a police officer” [14,16]. Law enforcement officers who remain physically fit prove more readily able to cope with the day-to-day stress of the job and are better prepared to handle critical incidents [17]. Cardiovascular endurance is necessary in approximately 11% of foot pursuits and over 50% of the use of force encounters [18].

The importance of testing VO_{2max} is becoming increasingly recognized in the assessment of fitness levels. Maximum oxygen intake (VO_{2max}) is considered one of the most valid parameters to evaluate cardio-respiratory capacity [8,19–21]. However, despite a high level of accuracy, direct measurement VO_{2max} tests are primarily reserved for the laboratory settings because of costly equipment, the need for trained technicians and the inability to test large numbers of people at one time [22]. It is also time consuming – the test requires about 30 minutes and only one person can be measured at a time. Therefore, the direct measurement of aerobic capacity is not possible or practical for most field settings, such as schools, police departments or armies where large numbers of people must be subjected to the test. The ability to track cardiovascular fitness (VO_{2max} , $ml \times kg^{-1} \times min^{-1}$), and therefore, cardiovascular health status of large populations of school age youth and young adults using standard laboratory protocols is not feasible. To deal with these problems, a number of field tests have been developed to estimate cardiorespiratory fitness [19,23,24]. Running/walking based field tests are by far the most popular types of tests used to estimate cardiorespiratory fitness in both young people and in adults [25,26]. Such tests require the subject either to cover as much distance as possible in a set time [27] or to cover a set distance in the fastest time possible [28,29]. The 1-mile run [23,30–33]; 1.5-mile run/walk (MRW) and the Progressive Aerobic Cardiovascular Endurance Run [34–37]

have been established as the most valid and reliable field tests when assessing cardiovascular fitness of school age youth and young adults. The 1-MRT and 20-MST estimate aerobic capacity from running performance as well as participant's characteristics such as age, gender, body weight, heart rate (HR) and the ratio of weight to height. Several equations have been developed to estimate the highest rate of oxygen uptake (VO_{2max}) and aerobic capacity from 1-mile run/walk time (1-MRWT) [21,22,30].

The Cooper Institute has worked with fitness programs in law enforcement, public and military safety since 1976 and it recommends the 1.5-MRT for police officers [38]. This fitness test has the validity to predict an officer's ability to perform essential and critical physically demanding tasks regardless of age, gender or handicap condition. The 1.5-MRT has also been found to be scientifically valid and defensible in court, as it is job related [38]. The 20-MST has been reported by the laboratory to provide estimates of VO_{2max} for the members of an active adult population. However, the objective of the present study was to assess the criterion related validity of the 1-MRT for estimating VO_{2max} in untrained healthy people. Although most of the police officers' and police candidates' aerobic capacities were tested by the 1-MRT, the extent to which these equations have criterion related validity in endurance-trained youth police with high aerobic capacity is unclear. No study has investigated the validity of the 1-MRT for male law enforcement officers aged between 20 and 23 years. Therefore, the purpose of this study was to compare the values of aerobic performance using 3 different formulae for the 1-MRT and the 20-MST for youth police.

MATERIAL AND METHODS

Subjects

In this study, 351 male volunteers working for the Turkish National Police within the age range of 20–23 years were investigated. The volunteers were endurance-trained

youth police officers with high aerobic capacity. Before the volunteers were accepted to participate in this study, they were required to attend basic military training 5 times per week for 12 weeks. Major characteristics of the organized training consisted of 35% aerobic endurance, 25% strength, 15% speed, 15% agility, 10% coordination and flexibility.

Anthropometric measurements

Height (to the nearest 0.01 mm) and weight (to the nearest 0.1 kg), without shoes, were measured in the case of each participant using a portable stadiometer (Holtain, UK) and physician's scale (Tanita TBF 401 A, Japan). Body mass index (BMI) was calculated using the formula: weight (kg) divided by height (m) squared [39].

Aerobic Capacity Assessment

The aerobic capacities of the policemen were evaluated by the 1-MRT and the 20-MST within a 2-week period. Aerobic capacities obtained from the 1-MRT were compared with aerobic capacities obtained from the 20-MST.

The participants were instructed and encouraged to complete the distance of one mile as quickly as possible. Because the rate of oxygen uptake is related in part to the pace sustained, it is possible to estimate the highest rate of oxygen uptake possible from the average pace sustained. Walking was permitted if the participant could not keep running. The tests were performed on a 400 m track laid out on the running field. Time needed to complete the test and the post-exercise HR was recorded immediately following the test. One week before the test, all the participants received comprehensive instructions about the test, after which they practised it once. All tests were conducted by the same investigators and at the same time of the day in the case of each participant [33]. Age, gender and body fatness also affect prediction of aerobic capacity. Therefore, aerobic capacity is predicted from 1-mile run time, age, gender and BMI using different equations.

The equations of Cureton (equation 1) [30], Kline (equation 2) [21] and George (equation 3) [22] were used to predict VO_{2max} ($ml \times kg^{-1} \times min^{-1}$) for the 1-MRT.

$$VO_{2max} = 0.21 (\text{age} \times \text{gender}) - 0.84 (\text{BMI}) - 8.41 (\text{time}) + 0.34 (\text{time}^2) + 108.94 \quad (1)$$

$$VO_{2max} = -0.3877 (\text{age}) + 6.315 (\text{gender}) - 0.0769 (\text{weight}) - 3.2649 (\text{time}) - 0.1565 (\text{bpm}) + 132.853 \quad (2)$$

$$VO_{2max} = 100.5 + 8.344 (\text{gender}) - 0.1636 (\text{body mass}) - 1.438 (\text{jog time}) - 0.1928 (\text{bpm}) \quad (3)$$

The 20-MST is a multi-stage test published by Léger and Lambert [40] and revised in 1988 [34]. It involves running back and forth across a 20-metre course in time to music played from a tape or CD. Beeps on the sound track indicate when a person should reach the ends of the course. The test begins at a slow pace, and each minute the pace increases. The running speed increases by $0.14 \text{ m} \times \text{s}^{-1}$ each minute; this change in running speed is described as a change in the level. A participant continues running until the pace can no longer be maintained. If the line is not reached in time for each beep, the subject has to run to the line, turn and try to catch up with the pace within two more 'beeps'. In addition, if the line is reached before the beep sounds, the subject has to wait until the beep sounds. The test is stopped if the subject fails to reach the line (within 2 m) for 2 consecutive ends.

The equation of Léger & Lambert (equation 4) [40] was used for prediction of aerobic capacity from the 20-MST.

$$VO_{2max} = 5.857 \times \text{The Maximal Speed} (\text{km} \times \text{h}^{-1}) - 19.458 \quad (4)$$

ETHICS

This study was approved by The Research Ethics Committee of the Ankara University Medical Faculty and the Health Department of Turkish National Police. The authors confirm this study meet the guidelines of the Helsinki Declaration.

STATISTICS

Means and standard deviations are given as descriptive statistics. Differences between the groups were analysed using the student t-test for independent samples. The correlations between the results were made using Pearson's Correlation Analysis. For all statistics the significance level was set at $p < 0.05$. Data were analysed using the Statistical Package for Social Sciences (SPSS) MS Windows Release 13.0.

RESULTS

Three hundred fifty one male volunteers working for the Turkish National Police within the age range of 20–23 years were investigated. Their mean age, height, body weight and BMI were 21.50 ± 1.061 years, 177.18 ± 5.20 cm, 69.51 ± 7.08 kg and 22.11 ± 1.95 kg/m^2 respectively. The mean estimated VO_{2max} ($ml \times kg^{-1} \times min^{-1}$) and 1-MRWT (min) are presented in Table 1.

The correlation coefficient between the estimated VO_{2max} by the 20-MST ($ml \times kg^{-1} \times min^{-1}$) and the estimated VO_{2max} using Cureton's equation ($r = -0.691$, $p < 0.001$), Kline's equation ($r = -0.608$, $p < 0.001$) and George's equation ($r = -0.486$, $p < 0.001$) were significant (scattergrams shown in Figure 1, Figure 2 and Figure 3 respectively). The correlation coefficient between the 1-MRWT and the estimated VO_{2max} using Cureton's equation ($r = -0.779$, $p < 0.001$), Kline's equation ($r = -0.617$, $p < 0.001$) and George's equation ($r = -0.332$, $p < 0.001$) were significant (scattergrams shown in Figure 4, Figure 5 and Figure 6 respectively). The correlation coefficient between the HR at the end of the 1-MRT (bpm) and the VO_{2max} estimated by Kline's equation ($r = -0.502$, $p < 0.001$) and George's equation ($r = -0.734$, $p < 0.001$) were significant. There was no significant correlation between the HR at the end of the 1-MRT (bpm) and Cureton's equation ($r = -0.002$, $p > 0.001$). All correlation data are shown in Table 2.

Table 1. The mean estimated VO_{2max} and 1-MRWT

Variables	Male (N = 351) M±SD
1-MRWT (min)	5.44±0.39
Estimated VO_{2max} by 1-MRT (Cureton equation) ($ml \times kg^{-1} \times min^{-1}$)	59.23±2.55
Estimated VO_{2max} by 1-MRT (Kline equation) ($ml \times kg^{-1} \times min^{-1}$)	70.99±2.22
Estimated VO_{2max} by 1-MRT (George equation) ($ml \times kg^{-1} \times min^{-1}$)	52.32±1.98
Estimated VO_{2max} by the 20-MST (Leger equation) ($ml \times kg^{-1} \times min^{-1}$)	62.05±4.26

VO_{2max} – maximal oxygen uptake.
1-MRWT – 1-mile run walk time.
M – mean; SD – standard deviation.

Table 2. Correlation between 1-MRWT, estimated VO_{2max} by the 20-MST, HR at the end of the 1-MRT and estimated VO_{2max} using different equations

Variables	Estimated VO_{2max} by the 1-MRT ($ml \times kg^{-1} \times min^{-1}$)		
	Cureton's equation	Kline's equation	George's equation
1-MRWT (min)	-0.779**	-0.617**	-0.332**
Estimated VO_{2max} by the 20-MST ($ml \times kg^{-1} \times min^{-1}$)	0.691**	0.608**	0.486**
HR at the end of the 1-MRT (bpm)	-0.002	0.502**	-0.734**

HR – heart rate. Other abbreviations as in Table 1.
** Correlation is significant at the 0.01 level (2-tailed).

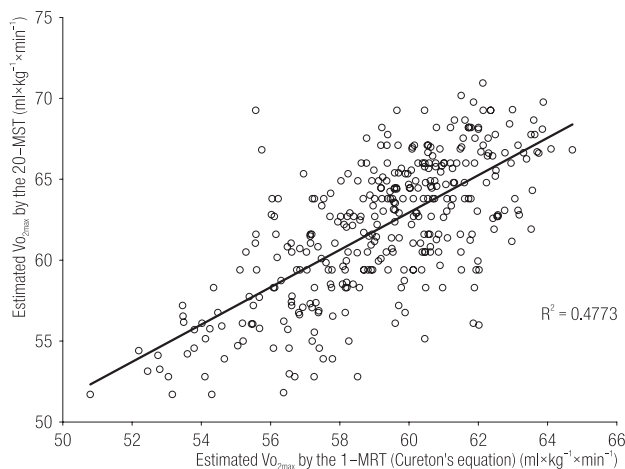


Fig. 1. Scattergrams of the estimated VO_{2max} using the 1-MRT equation from Cureton et al. [30] vs. the estimated VO_{2max} using the 20-MST equation from Leger and Lambert [40]

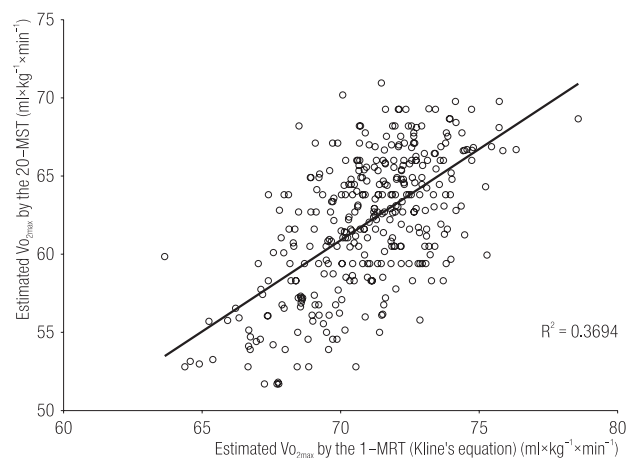


Fig. 2. Scattergrams of the estimated VO_{2max} by the 1-MRT equation from Kline et al. [21] vs. the estimated VO_{2max} by the 20-MST equation from Leger and Lambert [40]

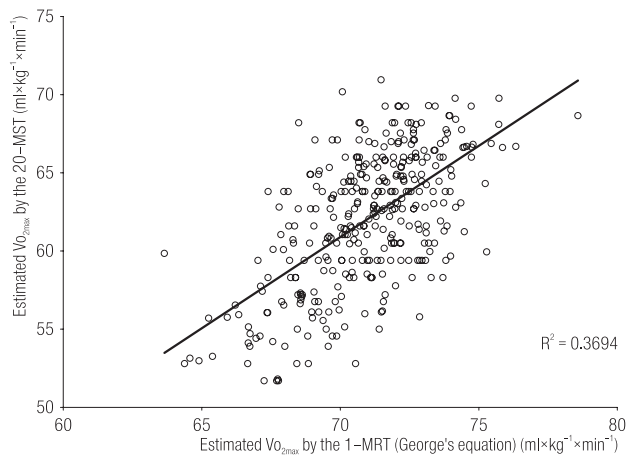


Fig. 3. Scattergrams of the estimated $\text{VO}_{2\text{max}}$ by the 1-MRT equation from George et al. [22] vs. the estimated $\text{VO}_{2\text{max}}$ by the 20-MST equation from Leger and Lambert [40]

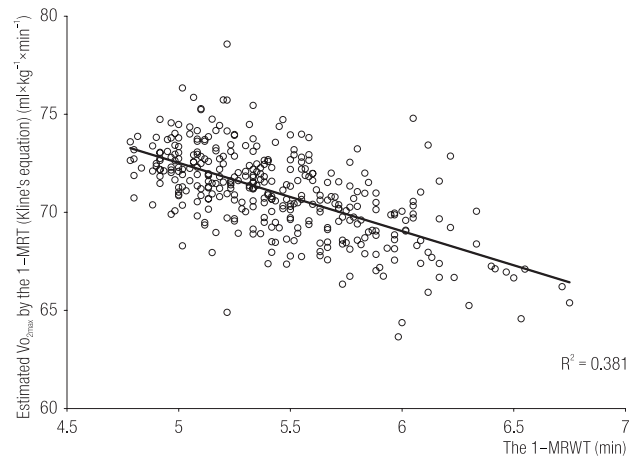


Fig. 4. Scattergram showing the relationship between the 1-mile run/walk time (1-MRWT) and the estimated $\text{VO}_{2\text{max}}$ by 1-MRT (Kline's equation) in male law enforcement officers aged 20–23 years

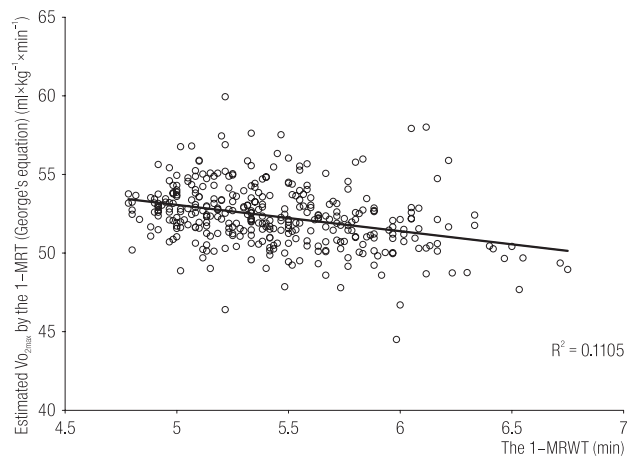


Fig. 5. Scattergram showing the relationship between the 1-mile run/walk time (1-MRWT) and the estimated $\text{VO}_{2\text{max}}$ by 1-MRT (George's equation) in male law enforcement officers aged 20–23 years

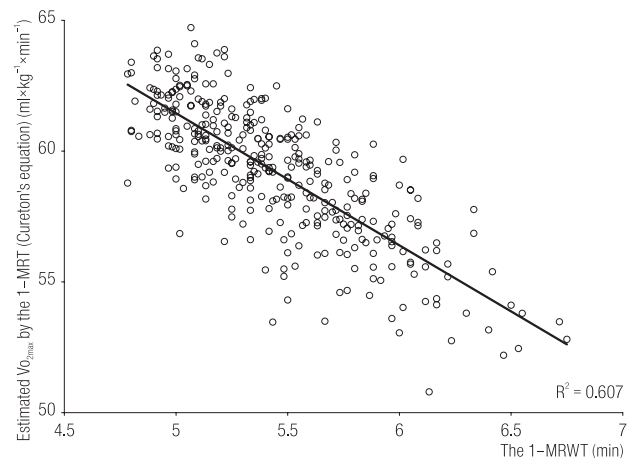


Fig. 6. Scattergram showing the relationship between 1-mile run/walk time (1-MRWT) and the estimated $\text{VO}_{2\text{max}}$ by 1-MRT (Cureton equation) in male law enforcement officers aged 20–23 years

DISCUSSION

The 1-MRT and the 20-MST are reliable and valid methods of testing aerobic performance. They have been used for assessment of aerobic capacity in different disciplines and for all ages and genders. In the studies concerning the 20-MST, the tests were mostly performed indoors, on a 20 m track [35]. However, weather and surface conditions must be considered. The 20-MST and the Timed

Distance Runs are assumed to be relatively easy to administer, with no special qualifications required. One aspect that needs extra experience is the measurement of anthropometric data, which is performed in most studies [23,30,35–37,41–44]. The 20-MST is recommended officially in Japan by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to assess cardiovascular fitness in middle-aged adults [45]. George's,

Cureton's and Kline's equations for the 1-MRT require a little more expertise due to the recording of anthropometric data as well as HR measurements, either manually or by using different measuring devices [22].

George's [22], Kline's [21] and Cureton's [30] equations were used to estimate the same parameter of VO_{2max} using the results of the 1-MRT. However, the difference between the results of the 3 formulae was significant ($p = 0.000$) and the correlation coefficients obtained using the 3 formulae differ in our present study. In the view of our results, we suggest that the subjects should be evaluated using more than one equation to predict aerobic capacity. Prior to the 1-MRT or 1.5-MRT, subjects are instructed to "run as fast as possible" or "give maximum effort" and as a result untrained individuals may have difficulty running at a proper pace. Also, high intensity exercise has been associated with greater cardiovascular risk and orthopaedic injury to the foot, ankle and knee.

Kline et al. [21] and George et al. [22] developed a 1-MRT using the multiple linear regression analysis and employed elapsed walk time, exercise HR, age, gender and body mass as independent variables to predict VO_{2max} for sedentary or untrained individuals. Based on their results, the 1-MRT appears relatively accurate, safe and convenient. The elapsed run time criterion (≥ 8 min for males) and exercise HR limit (≤ 180 bpm) utilized for the 1-mile run were based on typical energy costs and age specific HR data involving running activity [22]. In previous studies, the mean values for run time 9.4 ± 1.3 min [22]; 13.30 ± 1.35 min [21] and HR at the end of the test 169.00 ± 5.9 bpm [22]; 175.4 ± 6.7 bpm [21] in the subjects were determined. In our present study, the mean values for run time of our subjects (5.44 ± 0.39 min) was determined to be shorter and the HR at the end of the test (193.58 ± 7.97 bpm) was higher than in the case of Kline et al. [21] and George et al. [22]. Although Weiglein et al (2011) [46] demonstrated that the 1-MRT using the equation of Kline et al. [21] to predict VO_{2max} is a valid predictor of aerobic capacity and also can be suggested

as an alternative to the 1.5-MRT in assessing cardiovascular fitness of U.S Air Force males in active duty, our study has shown that the 1-MRT using Kline's equation may overestimate VO_{2max} by 14% according to our 20-MST results (Table 1).

Similarly, Dolgener et al (1994) and George et al (1998) have shown that the equation of Kline et al. may overestimate the VO_{2max} in civilians under the age of 40 years by as much as 23 % [47,48]. The over-prediction of VO_{2max} using Kline's equation in the aforementioned studies was likely due to the shorter run time. Our subjects' run time (5.44 ± 0.39 min) is by nearly 8 minutes shorter than Kline's subjects (13.30 ± 1.35 min). On the other hand, George's equation underestimates VO_{2max} by approximately 16% according to the 20-MST results. This can be explained by the higher HR. In George's equation, HR has a negative effect on the estimated VO_{2max} . In George's study, the subjects finish the 1-MRT in 9.4 ± 1.3 minutes with a HR of 169.00 ± 5.9 bpm. Our subjects' run time is nearly 2 times shorter than George's subjects' time. As a result of fast running, our subjects' exertion (193.58 ± 7.97 bpm) was higher than George's subjects' (169.00 ± 5.9 bpm). Due to the impact of HR in the equation, the lowest correlation coefficient ($r = -0.332$) was found between the 1-mile run time and the VO_{2max} evaluated by George's 1-MRT equation (Table 2).

Inclusion of the HR measurement may jeopardize validity of the test. Therefore, the tests where no pulse is recorded are preferred over the tests where HR is required for the estimation of VO_{2max} . Day to day variances in heartbeat due to, among other reasons, stress, tiredness, or illness make the reliability of these measurements questionable. In the study of Boreham et al. [36] the linear relationship that existed between heartbeat and oxygen consumption might have been influenced by emotional factors giving a less reliable result. To illustrate this effect, Cureton's equation was used to predict VO_{2max} ($ml \times kg^{-1} \times min^{-1}$) for the 1-MRT in our study. After eliminating the HR effect,

the highest correlation coefficient ($r = 0.691$) was found between the estimated VO_{2max} evaluated by the 20-MST and the estimated VO_{2max} evaluated by Cureton's 1-MRT equation. In contrast, the lowest correlation coefficient ($r = 0.486$) was found between the estimated VO_{2max} evaluated by the 20-MST and the estimated VO_{2max} evaluated by George's 1-MRT equation due the influence of HR in the equation.

In summary, when analysing more vigorous exercise than sub-maximal exercise over a short duration, we conclude that Cureton's equation provides valid estimates of VO_{2max} from 1-mile run/walk performance in young police officers. Furthermore, we suggest that George's equation cannot be used instead of Cureton's and Kline's equations in males aged between 20 and 23 years whose HR at the end of the test is high (≥ 180 bpm). The main finding of this study is that George's equation underestimates aerobic capacity in endurance-trained youth police officers with high VO_{2max} . The police volunteers in this study can also be thought of as healthy young adults with high aerobic capacity, therefore, this conclusion can be extended to cover physically fit young individuals.

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