Prediction of Aerobic Capacity in Firefighters Using Submaximal Treadmill and Stairmill Protocols

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Abstract

Tierney, MT, Lenar, D, Stanforth, PR, Craig, JN, and Farrar, RP. Prediction of aerobic capacity in firefighters using submaximal treadmill and stairmill protocols. *J Strength Cond Res* 24(3): 757–764, 2010—Accurate assessments of aerobic capacity are essential to ensuring the health and well-being of firefighters, given their arduous and stressful working conditions. The use of a submaximal protocol, if proven accurate, addresses concerns such as administrative cost, time, and ease of test performance. The purposes of this study were to develop and validate graded submaximal and maximal stairmill protocols and to develop accurate maximal and submaximal equations to predict peak $\dot{V}O_2$ using both the stairmill and Gerkin treadmill protocols. Fifty-four subjects, men (36.3 ± 5.6 years) and women (36.4 ± 6.3 years), performed maximal graded exercise tests using both the stairmill and Gerkin treadmill protocols. Significant predictors of peak $\dot{V}O_2$ included body mass index, time to completion for maximal protocols, and time to 85% of predicted maximal heart rate for submaximal protocols. Maximal prediction equations were more accurate on both the treadmill ($R^2 = 0.654$, standard error of the estimate [*SEE*] = 3.73 $ml\cdot kg^{-1}\cdot min^{-1}$) and stairmill ($R^2 = 0.816$, *SEE* = 2.89 $ml\cdot kg^{-1}\cdot min^{-1}$) than developed submaximal prediction equations for both the treadmill ($R^2 = 0.325$, *SEE* = 5.20 $ml\cdot kg^{-1}\cdot min^{-1}$) and stairmill ($R^2 = 0.480$, *SEE* = 4.85 $ml\cdot kg^{-1}\cdot min^{-1}$). Both of the newly developed submaximal prediction equations more accurately predict peak $\dot{V}O_2$ than the current Gerkin equation. In summary, we support the use of both the stairmill and treadmill as a means for aerobic assessment in this population. The use of the developed submaximal prediction equations should lead to a reduced cost and time of assessment; however, direct measurement of maximal oxygen consumption remains the better alternative.

Key Words Gerkin, peak $\dot{V}O_2$, heart rate (HR), body mass index (BMI)

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Introduction

The high physical demands placed on firefighters are numerous and well documented. They are often required to work at or near maximal capacity under extreme external temperatures with protective garments weighing as much as 35 kg. Exposure to chemical and physical hazards increases the likelihood of trauma to the musculoskeletal system, and imposes high metabolic demands and high levels of sympathetic drive. These conditions can place a great deal of stress on the body.

One of the keys to mitigating this stress is improvement in all the relevant aspects of physical fitness. Although addressing muscular strength is vital to any firefighter's health and performance (14), aerobic fitness is also of much concern. Coronary heart disease has historically been the leading cause of fatal injuries, accounting for 39% of all on-duty career firefighter fatalities and 50% of all on-duty volunteer firefighter fatalities (13). Poorly conditioned firefighters have a 90% greater risk of myocardial infarction than those who are aerobically fit (12). Although it is not wholly descriptive of the physical conditioning of a firefighter, improving aerobic capacity can help to ensure successful job performance and provide resistance to cardiovascular diseases in this population.

Developed in 1997, the *Fire Service Joint Labor Management Wellness/Fitness Initiative* addresses the health and safety issues of the profession. The initiative recommends a maximal oxygen uptake (peak $\dot{V}O_2$) of no less than 42 $ml\cdot kg^{-1}\cdot min^{-1}$ to adequately meet the aerobic demands of the job. Firefighters with a peak $\dot{V}O_2$ less than 33.5 $ml\cdot kg^{-1}\cdot min^{-1}$ have been found to be unlikely to safely perform required job tasks for longer than a few minutes (6,11). Given this potential for injury and cardiac compromise because of inadequate aerobic fitness, an accurate assessment of aerobic capacity is crucial to firefighters' well-being.

Direct measurement of peak $\dot{V}O_2$ is the most accurate and reliable method of determining aerobic fitness, but can prove difficult to deliver for 2 reasons: First, expensive and sophisticated equipment is required for the assessment, and second, many subjects are unwilling or unable to exercise to a level required to achieve peak oxygen consumption. In large group settings, submaximal exercise protocols using other variables such as heart rate (HR) or time to completion are often substituted (8). In the first 2 editions, the *Fire Service Joint Labor Management Wellness/Fitness Initiative* endorsed a standardized submaximal test then known as the Gerkin treadmill protocol (4,11). Its simplicity and ease of use have made it a popular mode of assessing aerobic capacity in firefighters. Unfortunately, the current prediction equation for estimating peak $\dot{V}O_2$ based on this protocol greatly overestimates aerobic capacity. It relies on the American College of Sports Medicine (ACSM) metabolic equation for running predicted peak $\dot{V}O_2$, which is based on steady-state values for each level of intensity (10). However, a steady state cannot be achieved during the Gerkin treadmill protocol because intensity increases each minute, thereby overestimating peak $\dot{V}O_2$ at any exercise stage.

The New York City fire department (FDNY) developed a 3-minute submaximal test performed on a stairmill to enhance applicability by using an activity that is considered job relevant (9). It, however, is a constant workload protocol that is not comparable with the Gerkin treadmill protocol.

Accordingly, the primary purposes of this study were to (a) develop and validate graded submaximal and maximal stairmill protocols to mirror the Gerkin treadmill protocol and (b) to develop accurate submaximal prediction equations from the Gerkin treadmill and newly developed stairmill protocols to predict peak $\dot{V}O_2$. Secondary purposes of this study were to (a) develop maximal prediction equations from the Gerkin treadmill and stairmill protocols to predict peak $\dot{V}O_2$ and (b) to compare results from the Gerkin and stairmill protocols.

Methods

Experimental Approach to the Problem

Each subject performed maximal graded exercise tests using the stairmill and treadmill to directly measure aerobic capacity from recorded gas exchange measurements. These data and simultaneously recorded HR data were inserted into a stepwise multiple regression analysis to develop maximal and submaximal prediction equations that use only recorded HR data, age, and standard body composition measurements. In developing submaximal prediction equations, time to 85% of maximal HR was determined using 2 equations that predict maximal HR: (a) $220 - \text{age}$ and (b) $208 - 0.7 \times \text{age}$ (2,16). Accuracy of each predictive equation obtained was evaluated and compared with others developed using submaximal or maximal predictive variables obtained from the stairmill or Gerkin treadmill protocol.

Subjects

A total of 76 firefighters (59 men under the age of 45, 17 women under the age of 55) volunteered to participate in this study. Twenty-two of the 76 participants did not complete all of the tests for personal reasons. Therefore, data from 54 subjects (40 men, 14 women) are presented. Subjects were recruited primarily from the Austin Fire Department. Each subject completed a health and fitness screening questionnaire before participation and a daily questionnaire before each session. Two subjects were smokers, and all subjects were free of any cardiovascular or other chronic diseases. None of the subjects reported taking medications that might interfere with the physiological responses to exercise, and none reported having a physical limitation that might preclude him or her from maximal exercise. Subjects were asked to abstain from food, caffeine, nicotine, and decongestants $\leq$3 hours and alcohol $\leq$12 hours before testing. Before each session, height, weight, resting HR, and resting blood pressure were measured and recorded. Subjects rested at least 48 hours between testing sessions. All testing was performed under normal laboratory conditions. All procedures involved in the study were explained, and written informed consents were obtained from the subjects before participation. All procedures were approved by the Institutional Review Board at the University of Texas at Austin.

Procedures

Each subject performed a minimum of 3 maximal graded exercise tests (2 stairmill and 1 treadmill). A stairmill test was performed during the first session, and the order of the remaining tests (1 stairmill and 1 treadmill) was randomly determined. The stairmill test resulting in the highest recorded peak $\dot{V}O_2$ was used. If maximal effort was not attained during the treadmill test, a second treadmill test was performed on another day. Gas exchange measurements and HR were measured continuously by a telemetric portable metabolic system (k4b^2, Cosmed, Rome, Italy) and a Polar–HR monitoring system (Polar Electro Oy, Kempele, Finland) and recorded in 15-second intervals. Peak $\dot{V}O_2$ was recorded as the highest average of 4 consecutive 15-second intervals. At the beginning of each testing period, the time necessary for the gas expired by the subject to pass within the sampling line before being analyzed was updated using a delay calibration, and the bidirectional digital turbine (28-mm diameter) was calibrated with a 3-L syringe (SensorMedics, Anaheim, CA, USA). Immediately before each test, gas analyzers were calibrated with ambient air (O_2: 20.93% and CO_2: 0.03%) and a gas mixture of known composition (O_2: 15% and CO_2: 5%). To validate the efficacy of the k4b^2, a simultaneous comparison of gas exchange measurements between the k4b^2 and a Physiodyne Max-1 metabolic cart (Fitness Instrument Technologies, Quogue, NY, USA) was performed on a treadmill at

5.5 and 7.0 mph before, midway, and after completion of the study. No differences were found.

Gerkin Treadmill Protocol. Using a Stairmaster Clubtrack 612 Plus (Nautilus, Vancouver, WA, USA), the test began with a warm-up period of 3 minutes at a speed of 3.5 mph. After the warm-up, the treadmill speed was increased to 4.5 mph. The speed (0.5 mph) and grade (2%) were then alternately increased every 60 seconds until the subject reached exhaustion. Time to 85% of predicted maximal HR was recorded as the 15-second interval before achieving actual 85% of predicted maximal HR. For example, someone achieving 85% of maximal HR at 10:20 was recorded as 10.25 minutes, and someone achieving 85% of maximal HR at 10:30 was recorded as 10.5 minutes.

Stairmill Protocol. Using a Stairmaster Stepmill 7000PT (Nautilus), the test began with a warm-up period of 2 minutes at level 4 (46 steps·min^{-1}) and 1 minute at level 5 (53 steps·min^{-1}). After the warm-up, the stairmill speed was increased to level 7 (65 steps·min^{-1}) and continued to increase 1 level every 60 seconds (~7.2 steps·min^{-1}) until the subject reached exhaustion. Time to 85% of predicted maximal HR was recorded as the 15-second interval before achieving actual 85% of predicted maximal HR as outlined above.

Statistical Analyses

All analyses were performed using Statistical Package for the Social Sciences, Version 14.0 (SPSS Inc., Chicago, IL, USA). A significant level of $p \leq 0.05$ was used to determine statistical significance. A paired *t*-test was used to determine any significant difference between the peak $\dot{V}O_2$ measured on the treadmill and stairmill, the maximal HR measured on the treadmill and stairmill, and the measured and predicted maximal HRs. A stepwise multiple regression technique was used to develop prediction equations from all protocols, both maximally and submaximally. Crossvalidation was used to test the accuracy of each regression equation. Data were partitioned into 3 subsamples with each subsample used once as the training set. Equations developed from each training set were applied to the remaining validation subsets and tested for statistical significance.

Results

Physical characteristics of both male and female subjects used in the development of the regression equations are presented in Table 1. Results from the maximal treadmill and stairmill tests are presented in Table 2. Paired *t*-tests determined that the measured peak $\dot{V}O_2$ and maximal HR were not significantly different between the treadmill and stairmill tests ($p > 0.05$). No significant differences existed between the peak $\dot{V}O_2$ values recorded from the first and second stairmill tests ($p > 0.05$), ensuring that the stairmill protocol reliably elicited peak $\dot{V}O_2$ during each testing session. Paired *t*-tests also determined that there were no significant differences between measured maximal HR and maximal HR predicted by the equation 220 − (age) or the equation 208 − 0.7 × (age) ($p > 0.05$). Time to completion was significantly longer with the treadmill protocol (13.02 ± 1.69 minutes) than the stairmill protocol (11.35 ± 2.15 minutes) ($p < 0.05$).

Table 1. Physical characteristics of the subjects.*

	Men (n = 40)	Women (n = 14)	All (n = 54)
Age (y)	36.3 ± 5.6	36.4 ± 6.3	36.3 ± 5.7
Body mass (kg)	84.0 ± 11.7	65.9 ± 5.4	79.3 ± 12.9
Height (cm)	179.8 ± 6.2	165.9 ± 3.1	176.2 ± 8.2
BMI (kg/m^2)	26.0 ± 3.3	23.9 ± 1.3	25.5 ± 3.0
Resting HR (bpm)	63.7 ± 9.4	66.5 ± 11.9	63.9 ± 9.3
Resting SBP (mmHg)	122.4 ± 10.3	125.4 ± 8.8	122.0 ± 9.8
Resting DBP (mmHg)	78.9 ± 9.4	81.0 ± 7.7	77.7 ± 9.0

*Data are depicted as mean ± *SD*. SBP = systolic blood pressure; DBP = diastolic blood pressure.

Table 2. Peak $\dot{V}O_2$ values after completion of the Gerkin treadmill and stairmill protocols.*

	Gerkin treadmill	Stairmill
Peak $\dot{V}O_2$(ml·kg^{-1}·min^{-1})	46.1 ± 6.3	45.3 ± 6.7
Maximal heart rate (bpm)	183.8 ± 10.7	184.5 ± 10.5
Maximal ventilation (L·min^{-1})	132.1 ± 26.3	138.5 ± 29.8
Maximal RER	1.30 ± 0.20	1.26 ± 0.11
Time of completion (min)	13.02 ± 1.69†	11.35 ± 2.15†

*Data are depicted as mean ± *SD* (n = 54). Peak $\dot{V}O_2$ = maximal oxygen consumption; RER = respiratory exchange ratio.
†Significant difference between Gerkin treadmill and stairmill protocols ($p < 0.05$).

Table 3. Submaximal equations to predict peak $\dot{V}O_2$ in firefighters.*

	Treadmill			Stairmill		
	β Coef.	R^2	*SEE*	β Coef.	R^2	*SEE*
BMI/220 − (age)						
Intercept	56.853	0.300	5.20	57.700	0.500	4.85
Time to 85% Max HR	1.235			1.700		
BMI	−0.803			−0.900		
BMI/208 − 0.7 × (age)						
Intercept	56.981	0.328	5.20	57.774	0.479	4.86
Time to 85% Max HR	1.242			1.757		
BMI	−0.805			−0.904		
BW/220 − (age)						
Intercept	43.619	0.221	5.59	45.283	0.395	5.24
Time to 85% Max HR	1.390			1.944		
BW	−0.107			−0.149		

*Data are depicted as mean ± *SD* ($n = 54$). Peak $\dot{V}O_2$ = maximal oxygen consumption; *SEE* = standard error of estimate; BMI = body mass index; Max HR = maximal heart rate; and BW = body weight.

Predicting Peak $\dot{V}O_2$ from Submaximal Protocols

Stepwise regression equations to estimate peak $\dot{V}O_2$ were developed for the Gerkin submaximal treadmill and the newly developed submaximal stairmill protocols. Time to 85% of maximal HR and body mass index (BMI) were significant and entered into the equations for both the treadmill and stairmill tests. Time to 85% of maximal HR using either 220−(age) or 208−0.7 × (age) yielded similar results. Note that these times include the warm-up period. Gender and weight were not significant and did not enter into the equations. The equations are given in Table 3. For the treadmill, R^2 was 0.325 and standard error of the estimate (*SEE*) was 5.20 $ml\cdot kg^{-1}\cdot min^{-1}$ or 11.3% of the mean peak $\dot{V}O_2$. For the stairmill, R^2 was 0.480, and *SEE* was 4.85 $ml\cdot kg^{-1}\cdot min^{-1}$ or 10.7% of the mean peak $\dot{V}O_2$.

Predicting Peak $\dot{V}O_2$ from Maximal Protocols

Stepwise regression equations to estimate peak $\dot{V}O_2$ were developed for the Gerkin maximal treadmill and the newly developed maximal stairmill protocols. Time to completion and BMI were significant and entered into the equations for both the treadmill and stairmill. Time to completion using either 220 − (age) or 208 − 0.7 × (age) yielded similar results. Again, note that these times include the warm-up period. Gender and weight were not significant and did not enter into the equations. The equations are given in Table 4.

Table 4. Maximal equations to predict peak $\dot{V}O_2$ in firefighters.*

	Treadmill			Stairmill		
	β Coef.	R^2	*SEE*	β Coef.	R^2	*SEE*
BMI/220 − (age)						
Intercept	14.821	0.700	3.70	15.100	0.800	2.89
Time to completion	2.874			2.800		
BMI	−0.242			−0.100		
BW/220 − (age)						
Intercept	10.535	0.652	3.74	14.699	0.816	2.89
Time to completion	3.017			2.821		
BMI	0.047			−0.018		

*Data are depicted as mean ± *SD* ($n = 54$). Peak $\dot{V}O_2$ = maximal oxygen consumption; *SEE* = standard error of estimate; BMI = body mass index; and BW = body weight.

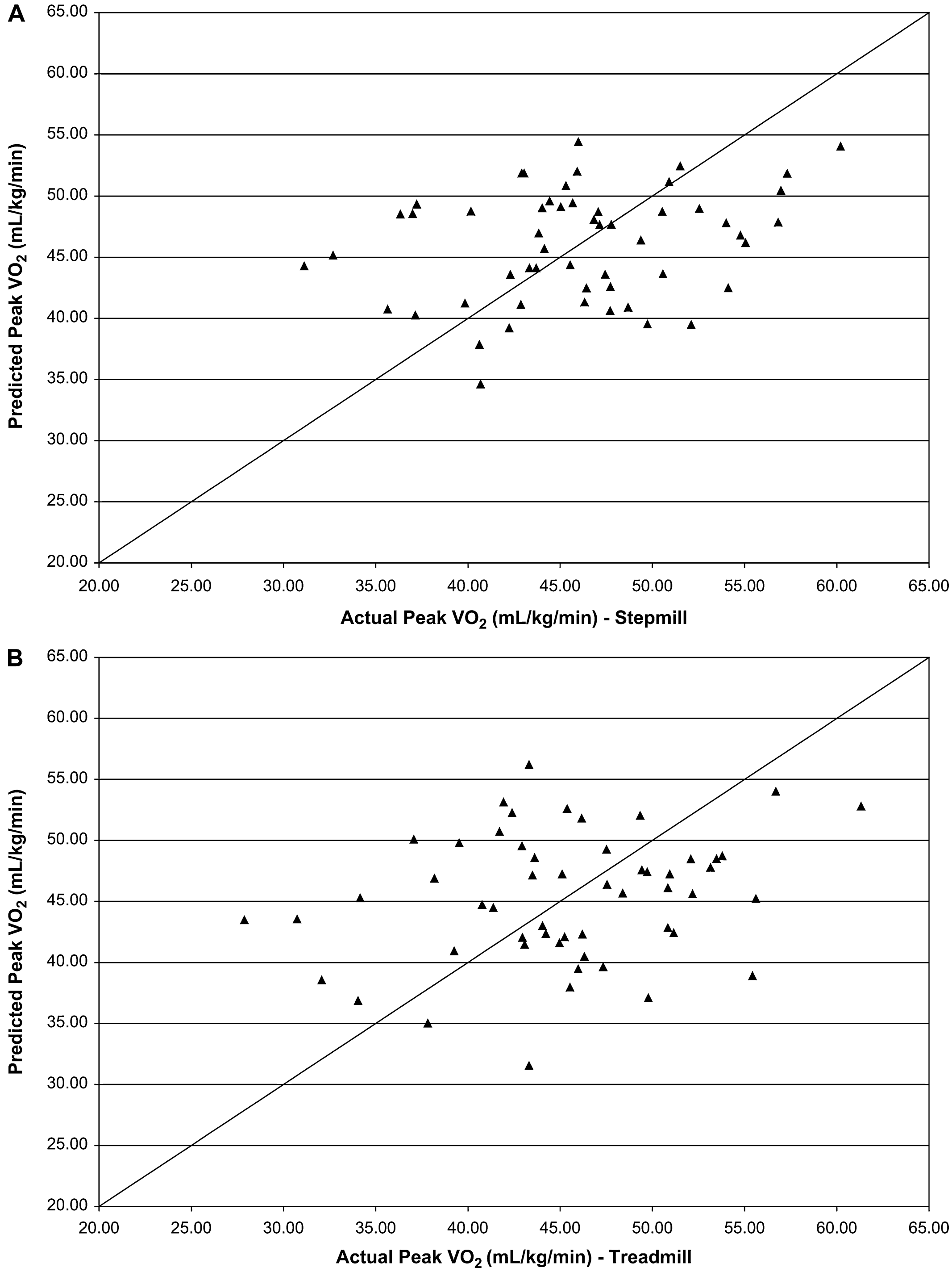

Figure 1. Scatter plot comparing measured and predicted peak $\dot{V}O_2$ values. Submaximal predictive variables obtained from the (A) stairmill and (B) Gerkin treadmill protocols ($n = 54$).

For the treadmill, R^2 was 0.654, and *SEE* was 3.73 ml·kg^{-1}·min^{-1} or 8.1% of the mean peak $\dot{V}O_2$. For the stairmill, R^2 was 0.816, and *SEE* was 2.89 ml·kg^{-1}·min^{-1} or 6.4% of the mean peak $\dot{V}O_2$.

Crossvalidation

All data were checked and revealed no problems with outliers or influential data points. Collinearity diagnostics suggested minimal correlations among independent variables.

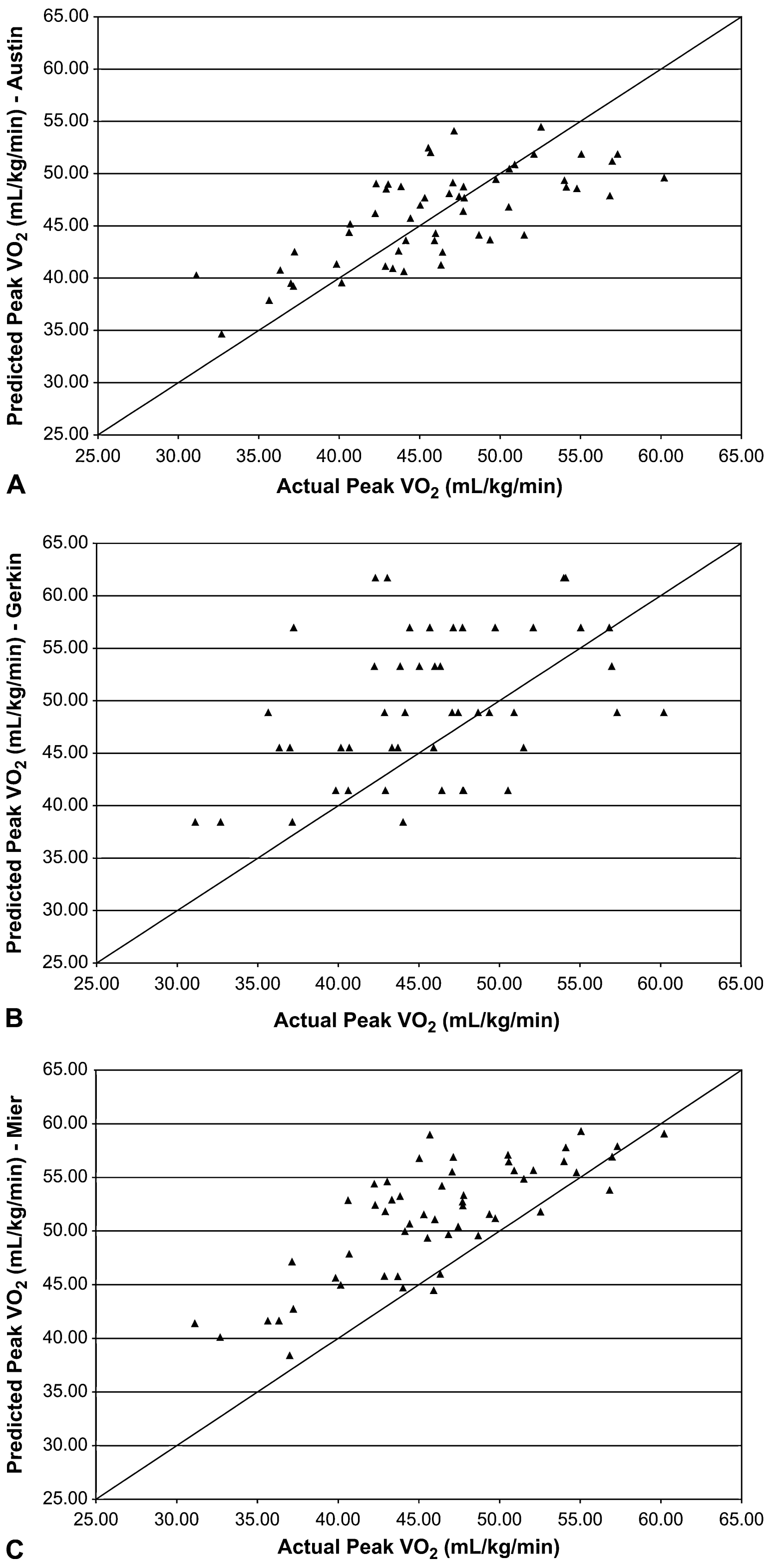

Figure 2. Scatter plot comparing predicted and actual peak $\dot{V}O_2$ using (A) Austin, (B) Gerkin, and (C) Mier equations ($n = 54$).

Crossvalidation was used to test the accuracy of each regression equation. There were no significant differences between the training set and remaining validation set ($n = 27$), supporting the ability of the equations developed to perform within the population.

Discussion

One purpose of the current study was to develop accurate prediction equations for the Gerkin submaximal treadmill protocol to predict peak $\dot{V}O_2$. This was done using a stepwise multiple regression equation technique as described in previous studies (5,9,10,15). Potential prediction variables included time to 85% of predicted maximal HR, age, gender, body mass, and BMI. As expected, time to 85% predicted maximal HR made the largest contribution to the equation, whereas BMI also improved its predictive capability. No other variables were significant.

Our equation produced lower R^2 and higher *SEE* values than other submaximal protocols (7). We do not have an explanation for this; however, our equations more accurately predict peak $\dot{V}O_2$ than the current Gerkin equation and the Mier and Gibson equation. As seen in Figure 2B, when comparing the measured peak $\dot{V}O_2$ values from our study with those estimated by the current Gerkin equation, the Gerkin equation significantly overestimated peak $\dot{V}O_2$ by 8.2 $ml \cdot kg^{-1} \cdot min^{-1}$ ($t = -7.268$, $p < 0.05$). These findings are similar to those of Mier and Gibson (10) who found the mean difference between the peak $\dot{V}O_2$ estimated from the Gerkin equation and measured peak $\dot{V}O_2$ to be 8.0 $ml \cdot kg^{-1} \cdot min^{-1}$. Mier and Gibson discuss this overestimation and cite its reliance on the ACSM metabolic equation, which is based on steady state values and will overestimate peak $\dot{V}O_2$ when it is applied to a maximal exercise stage where steady state has not yet been reached (10). However, as seen in Figure 2C, when applied to our population, the Meir and Gibson equation also significantly overestimated peak $\dot{V}O_2$ by 5.1 ml·kg^{-1}·min^{-1} ($t = -9.455$, $p < 0.05$).

To determine how these submaximal equations would perform in practice, we considered the *Fire Service Joint Labor Management Wellness/Fitness Initiative*, which recommends a peak $\dot{V}O_2$ of no less than 42 ml·kg^{-1}·min^{-1} (6,11). Of the 54 subjects in this study, 12 did not achieve this goal during a maximal treadmill test. When using our submaximal equation (Table 3), 3 of the 12 subjects who did not achieve 42 ml·kg^{-1}·min^{-1} were said to have a sufficient peak $\dot{V}O_2$ when this was not the case (false positive). In comparison, 8 false positives occurred with the Gerkin equation, and 6 occurred with the Mier and Gibson equation. Of the 42 subjects that did meet the requirements of the initiative, 4 were wrongly identified as having an insufficient peak $\dot{V}O_2$ using our prediction (false negative). Two false negatives occurred with the Gerkin equation, and none occurred with the Mier and Gibson equation. This analysis provides further evidence of the tendency of both the Gerkin and the Meir and Gibson equations to overestimate peak $\dot{V}O_2$. Furthermore, should the *SEE* be considered, no false positives or false negatives would occur with our submaximal equation because no subject was predicted to be further than 3.28 ml·kg^{-1}·min^{-1} above or below the required peak $\dot{V}O_2$ (Table 3).

This same analysis was performed for the submaximal stairmill test with similar results to our submaximal treadmill equation; however, we were not able to form comparisons because this is the first prediction equation developed for a graded stairmill protocol. Of the 13 subjects who did not achieve this standard during a maximal stairmill test, 5 subjects had false positive tests when using our equation (Table 3). Of the 41 subjects that did meet the requirements of the initiative, 4 had false negative tests. Again, when considering the *SEE*, no false positives or false negatives would occur because no subject was further than 3.15 ml·kg^{-1}·min^{-1} from the required peak $\dot{V}O_2$ (Table 3).

Although our equations were best able to accurately segregate individuals based on the requirements of the initiative, incorrect evaluations are still present. These can endanger the health of firefighters inaccurately identified as capable (in the case of a false positive) and remove capable firefighters from duty (in the case of a false negative). We recommend further application of each predictive equation to this population to reveal the true predictive capabilities of each equation.

Body mass index is often seen as an unattractive measure of body composition, certainly in this population because the physical demands of firefighters often favor mesomorphic body types. The Center for Disease Control states that "BMI is not a direct measure of body fatness and is calculated from an individual's weight which includes both muscle and fat. As a result, some individuals may have a high BMI but not a high percentage of body fat (3)." Our study did not use BMI as a measure of body composition but as a predictive variable. Still, in response to this concern, regression equations were also developed with body weight. As shown in Tables 3 and 4, submaximal predictive equations using body weight were inferior to those using BMI. Because BMI provides information about the subject's height and weight, it is a more informative variable than simply body weight and should not be viewed as an illusive or inaccurate variable.

Intraindividual variability in maximal recorded HR is a large contributor of the observed variability in these prediction equations. Mier and Gibson (10) question $220 -$ (age) as an accurate predictor of maximal HR, but we have found this equation to be effective in this population. Still, the more recently developed $208 - 0.7 \times$ (age) was found to be nearly as effective when predicting maximal HR. When predicting a higher maximal HR in older populations, this equation adjusts for the age-related reduction in maximal HR and consequently better predicts maximal HR in older adults (16). Medical liability prevented the testing of men $>$45 years and women $>$55 years, and their inclusion may make $208 - 0.7 \times$ (age) the more appropriate alternative in practice. We recommend it receive considerable attention and have developed regression equations presented in Table 3.

Finally, it should be noted that the stairmill was able to generate slightly more accurate equations, both maximally and submaximally, in predicting peak $\dot{V}O_2$ than the treadmill in this population. Comparisons between measured and predicted peak $\dot{V}O_2$ values using both the stairmill and Gerkin treadmill protocols can be seen in Figure 1. Because the treadmill is a generally more accepted method of testing, we had not anticipated this and have no opinions on why this occurred. However, until the present study, there was no previous graded stairmill test available for predicting peak $\dot{V}O_2$. It was hypothesized by the FDNY that a stairmill protocol would enhance applicability by using an activity that is considered job relevant (9). Stair climbing in this sample of firefighters (Austin Fire Department) would seem to be less relevant than in a more densely populated city such as New York, but is still pertinent to the daily activities of any firefighter. Peak $\dot{V}O_2$ is a physical characteristic that is independent of the type of aerobic activity being performed to determine it. We do not see an advantage to using any particular test if it has been proven to accurately elicit peak $\dot{V}O_2$ and therefore recommend either method of testing for the aerobic testing of firefighters.

In summary, we support the use of both the stairmill and the treadmill as a means for aerobic assessment in this population. Equations for submaximal testing using both the stairmill and Gerkin treadmill protocols have been developed and have several advantages; however, the better alternative is still a maximal test. Maximal tests offer prediction variables that can only be attained when the subject is taken to maximal intensity, and result in a higher predictive accuracy. Further testing is needed to improve upon the accuracy of submaximal equations so that peak $\dot{V}O_2$ can be more accurately predicted within this population.

Practical Applications

The equations developed can be used to predict maximal aerobic capacity in firefighters without an apparatus capable of directly measuring aerobic capacity. After validation of this equation within the population, these equations should lead to a reduced cost and time needed to assess aerobic fitness. Maximal predictive variables should be obtained if possible because they best predict peak $\dot{V}O_2$, but if not available aerobic capacity can still be estimated using submaximal predictive variables. Finally, we failed to observe a significant difference in recorded maximal oxygen consumption between the stairmill and treadmill. Therefore, we support the use of a previously untested graded stairmill exercise protocol as an accurate means of measuring aerobic capacity in firefighters.

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