A COMPARISON OF TWO PROTOCOLS FOR TREADMILL EXERCISE TOLERANCE TESTING IN SEDENTARY COLLEGE MALES

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ABSTRACT

Fifteen sedentary male students have perfomed the standard Bruce and USAFSAM (US Air Force School of Aerospace Medicine) treadmill exercise tolerance tests. Treadmill speed and grade were designed to be increased every 3 minutes for the Bruce protocol while only grade was increased every 3 minutes for the USAFSAM protocol. Each subject performed two maximum tests from each protocol, one test a week for four weeks.

No significant differences were found between the protocols at maximum for oxygen uptake and heart rate, while slightly higher values were observed in theBruce protocol for pulmonary ventilation. In addition, the maximum treadmill exercise time for the Bruce protocol was shorter by 25% than that for the USAFSAM protocol.

Based on the finding described above, it may be concluded that the USAFSAM protocol at which constant walking speed is utilized has more advantages and practicality for routine maximum testing for sedentary people as compared to theBruce protocol which requires multiple work loads.

It is noteworthy to see that maximum oxygen uptake obtained from the young in this study is significantly lower than that of middle-age exercisers which was previously tested with the same test protocol. This fact clearly suggests the lowered cardiorespiratory fitness of young men due to the lack of physical activity, especially, endurance activity. [Chukyo University Bull., The faculty of the Liberal Arts, 19(1): 173-185, 1978.]

非運動鍛練者の最大有酸素作業能力測定のためのトレッドミル・テスト方法の検討

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(要　　約)

最大作業（運動）能力は主として肺から作業筋に運ばれることのできる最大量の酸素に支配される。最大作業時に人体が摂り込む酸素の量，すなわち最大酸素摂取量（$\dot{V}o_2$ max）は人間の呼吸循環器系の体力（全身持久力）の最もすぐれた示標として広く用いられている。一般に，この $\dot{V}o_2$ max の測定にはトレッドミル走行テストが広く用いられているが，中高年者や臨床的にはトレッドミル歩行テストが持久的体力の評価に用いられる。今日まで，種々のテスト・プロトコールが発表されているが，その中から，積極的に運動に参加しない学生を対象とする時に適応されるトレッドミル・テストを選らぶ目的で，2～3の検討が行なわれた。そのために，15名の男子学生が次の2つのトレッドミル作業テストに参加した。Bruce プロトコールでは，トレッドミルの傾斜とスピードが3分毎に，45.3m／分，10%；66.7m／分，12%；90.7m／分，14%；112m／分，16%；133.3m／分，18%；というように増加され，一方のUSAFSAM（米空軍航空医学校）プロトコールでは，スピードは90m／分に固定され，傾斜だけが3分毎に5%づつ増加された。

テストの結果，換気量を除いて，酸素摂取量と心拍数の最大値では両テスト間に有意差を認めなかった。最大トレッドミル作業時間においては，Bruce プロトコールがUSAFSAMよりも約25%短かかった。しかし，両テストとも，最大酸素摂取量とトレッドミル運動時間の間には高い相関（r＝0.82）が得られ，その関係直線は Bruce で，$\dot{V}o_2$ max（mℓ／分／kg

体重) =12.4+2.42 (トレッドミル時間);USAFSAMでは13.8 + 1.76 (時間) であった。

このように，測定の主パラメターが両テストにおいて類似したために，歩行スピードが一定であるUSAFSAM*M*プロトコールの方が，被検者の歩行スピードに対する調整の必要性はテスト開始当初だけでよく，また Bruce の multi-stage にくらべて操作上の誤差もより小さくなるために，体力の評価テストとしてより高い実用性を有すると云えよう。

本研究で得られた若年者の最大酸素摂取量 (42.6ml／分／kg体重) は同じテスト方法で得られた中年齢の運動鍛練者 (40.6才) の値 (46.3) より低いものであった。この結果は身体活動，とくに持久的運動，の習慣化の意義を示唆するものといえる。

INTRODUCTION

The purpose of exercise tolerance test is to observe an individual's cardiovascular responses during exercise in order to determine his capacity to adapt to physical stress. Rapid technological developments have decreased the amount of physical activity which was formerly an integral part of every day life. The lack of physical activity has caused a rise in chronic, degenerative diseases. Even in young college students, when they are sedentary, their cardiorespiratory fitness, i.e., total body endurance, is considerably lower than that of the corresponding men a few decades ago. It is, therefore, required to establish standard exercise test which is suitable for the routine evaluation of the cardiovascular fitness in sedentary men and women.

Maximal oxygen uptake is dependent upon many factors, which is considered the best index of work capacity and maximal cardiovascular function (6, 10). Maximal oxygen uptake was initially measured using treadmill protocols with interrupted, progressive work loads. The work load stages were separated by either days or 10 min (7, 9). However, the very strenuous nature of this test makes it poorly suited for sedentary people. Subsequently, other investigators designed more convenient treadmill protocols which are more applicable for sedentary men and women. Balke and Ware designed a continuous protocol (3), in which the constant speed of 90 meters per minute with a 1% increase in grade each minute was utilized. Later Bruce et al. (4) have used a continuous protocol increasing the speed and grade every three minutes. In recent years, Wolthuis et al. (11) of US Air Force School of Aerospace Medicine have presented results using a modification of the Balke ahd Ware protocol with an increment of 5% every 3 minutes in stead of 1% per minute in order to avoid the excessive average time to maximum effort in the Balke and Ware protocol, and the multi-speed of the Bruce protocol. Wolthuis et al. (11). demonstrated reproducibility of maximal oxygen uptake and maximal heart rate measurements comparable to the original Balke and Ware protocol.

Besides these tests described, there are some more protocols for the maximum exercise tolerance tests (1, 2). As a result, the need for comparing the various tests exists to determine the most suitable treadmill exercise tolerance test for sedentary men. The purpose of this study was to determine and compare the two treadmill test protocols with the same subject population.

METHODS AND PROCEDURE

Subjects for the present study were 15 healthy male students all of whom were sedentary. Their mean age, height, weight, are 20 years (±1), 168.3 cm (±4.1), and 57.8 kg (±2.9), respectively. The subjects were instructed to eat a light meal three hours before the test and they performed treadmill exercise tolerance tests on the same day each week and at the same time for each individual. Each subject was encouraged to perform a maximum test effort; end point of the maximum exercise test was defined as that point at which the individual felt that he could not walk or run another full minute.

The two maximal treadmill tests studied in the present study were the standard Bruce and USAFSAM. The description of each test protocol is shown in Fig 1. The Bruce protocol increased both treadmill speed and grade every 3 minutes in the manner of 45.3 m/min, 10%; 66.7, 12%; 90.7, 14%; 112, 16%; 133.3, 18%; 146.7, 20% and so forth, respectively. The USAFSAM, on the other hand, used a constant walking speed of 90 m/min, but increased treadmill grade 5% every 3 minutes. Each subject performed 2 maximal treamill exercise tests at a week interval for 4 weeks. Subjects were subgrouped so that a portion of the subjects performed a sequence of the Bruce treadmill tests followed by USAFSAM treadmill test, while the remainder of the subjects performed the tests in reverse sequence. This sequence was designed to nagate performance bias

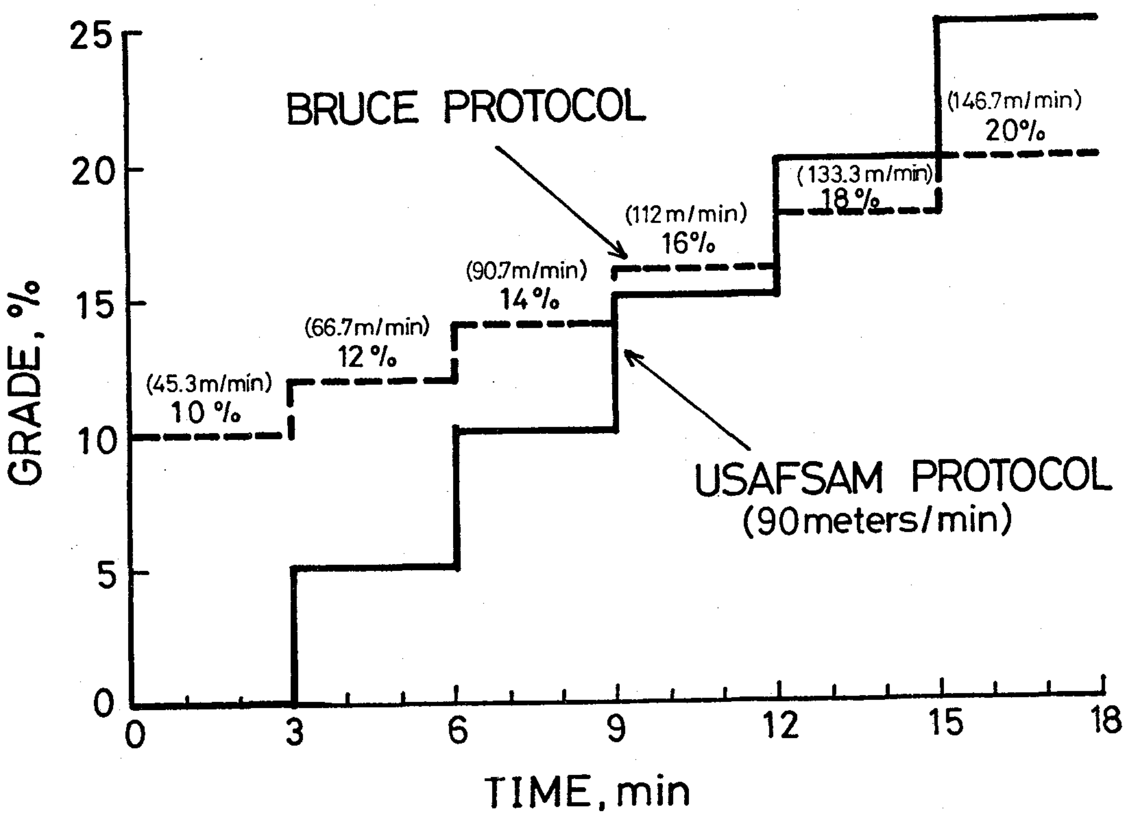

Fig. 1. Format of treadmill protocols

for one protocol due to possible learning effects from the other protocol.

Subjects arrived in the laboratory dressed for the experiment. After resting on a laboratory cot for approximately 20 min, the subjects were seated on a chair and ECG electrodes and a gas mask were fixed in position. The V5 lead was monitored every minute during exercise by means of radio telemetry system. Minute heart rate (HR) was counted through measuring 10 consecutive QRS waves. Expired air was measured at the stage of 14% grade for the Bruce protocol and 15% for the USAFSAM protocol; and at maximum effort. Samples of expired gas were collected using the Douglas bag technique. Oxygen consumption ($\dot{V}o_2$) and CO_2 production were calculated from the composition of the expired gas collected and the ventilation measured during the sampling time period.

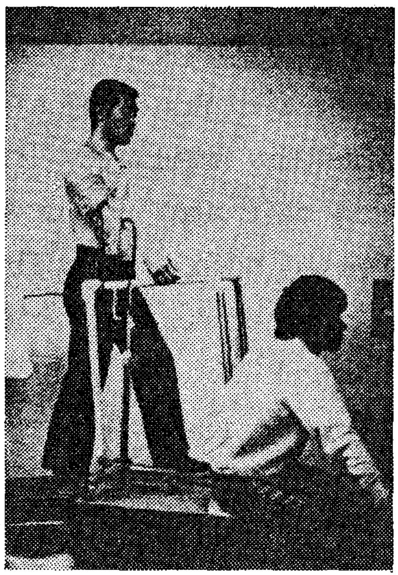

Fig. 2. Treamill exercising testing

RESULTS

Table 1 shows the maximal data of $\dot{V}o_2$ and HR with maximum treadmill time. Overall mean values of the maximum data for each protocol including pulmonary ventilation ($\dot{V}_E$) and respiratory exchange ratio (RER) are summarized in Table 2. The response to the two maximum treadmill tests was considered similar for the maximal $\dot{V}o_2$ and HR. The results may suggest that the measurement of maximal $\dot{V}o_2$ is equally reproducible by both Bruce and USAFSAM protocols. The mean maximum exercise time for the Bruce protocol was 12.3 minutes while 16.4 minutes for the USAFSAM protocol; this difference in the exercise time was significant ($p<0.01$). Maximal pulmonary ventilation was significantly lower in the USAFSAM test ($p<0.05$).

The relationship of maximal oxygen uptake and maximum

Table 1. Maximal data of HR, $\dot{V}o_2$ max, and treadmill exercise time for 15 subjects

	Vo_2 max				HR		MAXtread-mill time	
	$l \cdot min^{-1}$		$ml/kg \cdot min^{-1}$		$beats \cdot min^{-1}$		minute	
Subj.	BRUCE	USAF SAM	BRUCE	USAF SAM	BRUCE	USAF SAM	BRUCE	USAF SAM
1	2.28	2.24	40.0	39.0	198	192	12	16
2	2.17	2.32	37.4	39.7	191	190	11	14
3	2.47	2.30	44.9	41.4	172	168	13	17
4	3.13	3.06	50.5	49.4	184	181	15	19
5	2.00	2.24	37.8	41.8	159	162	12	16
6	2.45	2.39	43.0	41.9	192	190	12	16
7	2.90	3.08	48.3	51.7	186	184	15	18
8	2.05	2.11	34.8	36.0	183	192	11	15
9	3.18	2.99	50.4	47.4	198	200	14	18
10	2.21	2.45	39.4	43.7	180	173	12	18
11	2.20	2.28	40.9	42.3	192	197	11	17
12	2.73	2.49	45.5	41.5	200	199	12	16
13	2.45	2.27	43.0	39.9	200	196	13	14
14	2.28	2.27	40.8	40.5	186	196	10	13
15	2.39	2.54	39.8	42.4	192	187	12	16

Table 2. Means and standard deviations ofmaximal treadmill parameters

	BRUCE		USAFSAM		P
	MEAN	SD	MEAN	SD	
$\dot{V}o_2$ max, $l \cdot min^{-1}$	2.28	0.37	2.47	0.32	NS
$\dot{V}o_2$ max, $ml/kg \cdot min^{-1}$	42.4	4.7	42.6	4.0	NS
MAX HR, bpm	188	11	187	12	NS
MAX Treadmill time, min	12.3	1.4	16.4	1.7	$P<0.01$
$\dot{V}_E$ max, $l \cdot min^{-1}$ BTPS	124	16	110	14	$P<0.05$
RER	1.22	0.06	1.17	0.04	NS

NS represents no significant difference.

treadmill time for each subject in each protocol is illustrated graphically in Fig 3. The regression equations with standard error of estimate and correlation coefficient for each protocol are shown in Table 3.

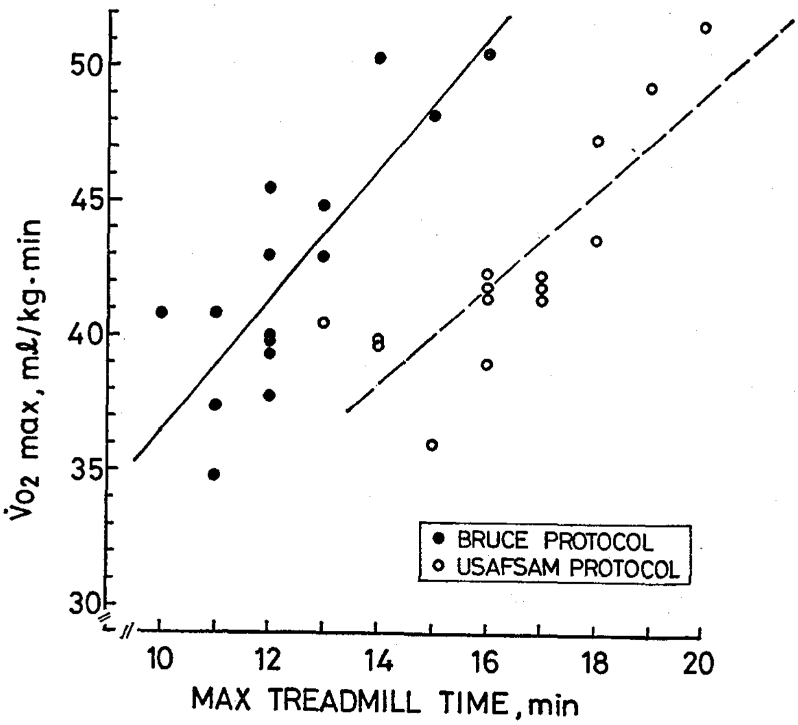

Fig. 3. Data plot of maximal olxygen uptake against maximal treadmill time

Table 3. Comparable stages between Bruce and USAFSAM protocols

	BRUCE (9th min 90. 7m·min^{-1}, 14%)		USAFSAM (12t hmin 90m·min^{-1}, 15%)		
	MEAN	SD	MEAN	SD	DIFF
$\dot{V}o_2$, l·min^{-1}	2.09	0.25	2.10	0.28	NS
$\dot{V}o_2$, ml/kg·min^{-1}	36.0	4.2	36.8	7.3	NS
HR, beats min^{-1}	169	14	170	17	NS

Figure 4 shows the rate of increase in mean HR with standard deviation for the two protocols. The slope for the Bruce protocol was steeper than that for the USAFSAM protocol. Both protocols have the stages which can be comparable in terms of

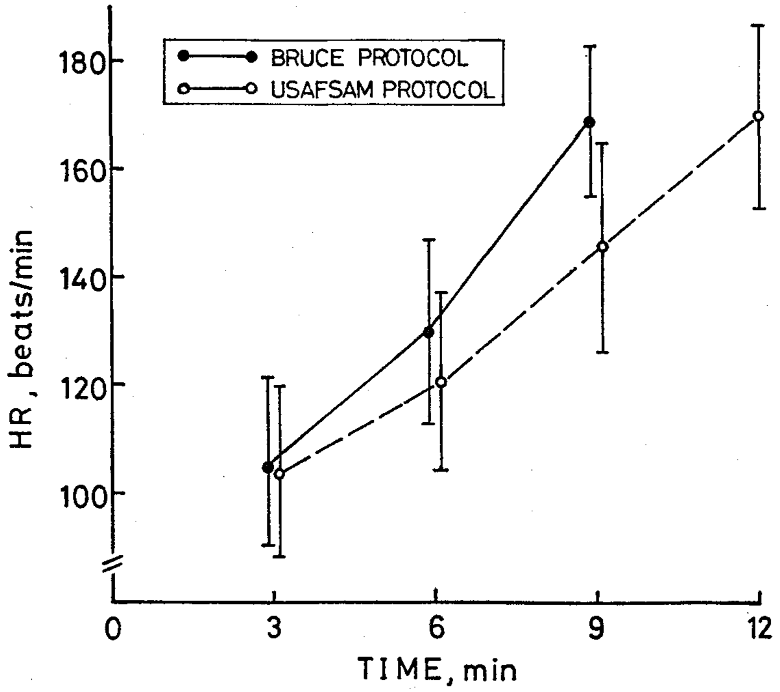

Fig. 4. Heart rate changes during exercise

the work loads. Physiological measurements taken from these stages in the two protocols are summarized in Table 4. No differences were found between the stages in $\dot{V}O_2$ and HR.

Table 4. Prediction equations, standard errors of estimate, and correlation coefficients of the two protocols

BRUCE protocol		
$\dot{V}O_2$ max	=	2.42 (Treadmill time) + 12.4
r	=	0.82
SEE	=	3.25
USAFSAM protocol		
$\dot{V}O_2$ max	=	1.76 (Treadmill time) + 13.8
r	=	0.82
SEE	=	2.99

SEE represents standard error of estimate.

DISCUSSION

This study allows comparison of data obtained using the Bruce protocol which has been used extensively for the assessments of maximal oxygen uptake for sedentaries as well as for cardiac patients, with data obtained using the USAFSAM protocol which has been newly invented as a modified Balke exercise protocol with regard to physiologic parameters of physical performance.

Statistical analyses showed no significant difference in the measurements of oxygen consumption and heart rate between the Bruce and USAFSAM for maximal and submaximal treadmill efforts. These similarities between the two protocols suggest that a selection out of the treadmill tests as the routine cardiovascular testing is dependent on user's own convenience.

The leveling-off pattern, as a criterion for determining maximal oxygen consumption (9) was rarely seen in the 30 maximal tests. The results from this investigation demonstarated the plateauing of oxygen uptake only 13 and 7 percent for the Bruce and USAFSAM protocols, respectively. As far as the Bruce and USAFSAM protocols, the value obtained from this study is in good agreement with the results of the previous study (5), but appeared to be far below than the finding by pollock et al. (8), in which a 69% was reported.

High correlation between maximal $\dot{V}o_2$ and treadmill time was obtained from both Bruce and USAFSAM protocols (see Table 3 and Fig 3). This finding suggests that estimation of maximal $\dot{V}o_2$ from treadmill exercise appeared to be valid in both protocols. Concerning the estimation of maximal $\dot{V}o_2$ from treadmill time, Froelicher et al (5) reported a lower value for prediction using Balke and Bruce protocols. As an explanation for the result, they pointed out the lack of familialization to the testing prior to the assessments of maximal $\dot{V}o_2$. The high correlation between maximal $\dot{V}o_2$ and treadmill time in the present study might be due to subjects' familialization to the testing because each subject was requested to perform the testing at least twice for each protocol prior to the assessments of $\dot{V}o_2$ max.

The shorter treadmill time required to reach maximum level is in favour of the Bruce protocol. Due to its constant treadmill speed, however, USAFSAM protocol, in comparison to Bruce protocol, seems more favorable not only for laboratory technicians because it reduces their adjustments, but also for subjects, especially inactive subjects, because the constant walking speed would minimize anxiety derived from their adjusting to speed changes as required for the Bruce protocol. Furthermore, the regular equal increments in treadmill grade are easy to implement for an evaluation of physical fitness.

Figure 5 shows a comparison of maximal $\dot{V}o_2$ obtained from the present study with those from other studies using Bruce

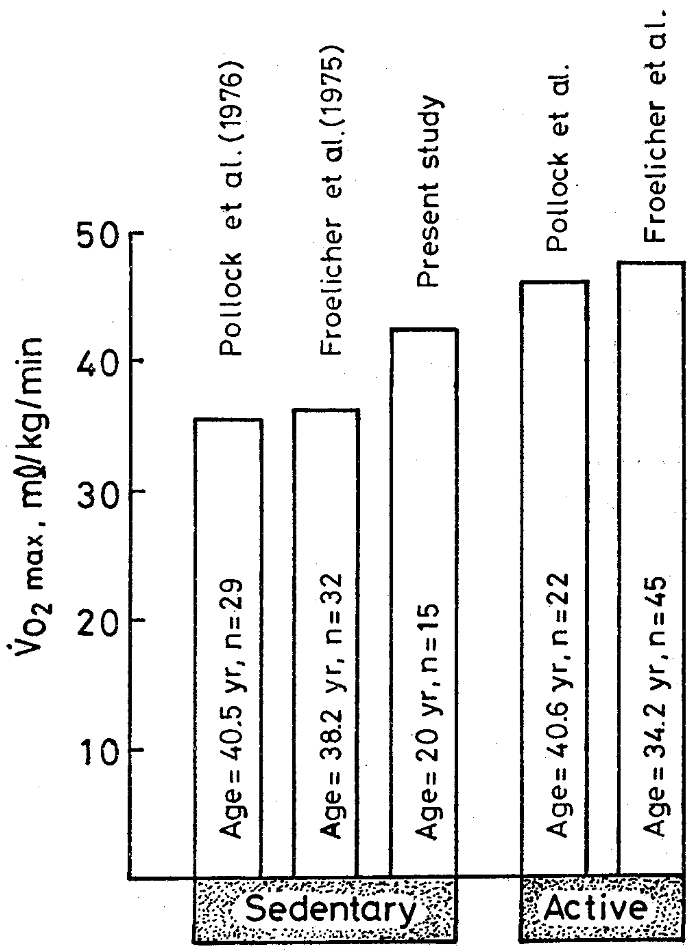

Fig. 5. Comparison of maximal oxygen uptakes

protocol. It should be noted that mean value of maximal $\dot{V}o_2$ of our subjects is greater than that of middle-aged men, but is less than that of exercisers of middle-aged men. This clearly suggests us that young men are, if they are inactive or sedentary, unfitted to cardiovascular fitness as compared to that of middle-aged men if they are physically active. For this reason, aerobic endurance exercises are required for even young men in order to maintain or increase their cardiovascular fitness which is the most important factor of physical fitness.

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