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A comparison of the cardiovascular responses to treadmill and bicycles ergometer exercise in healthy male Nigerians

M.O. Balogun, B.O. Sulyman and P.O. Akinwusi

Department of Medicine and Department of Medical Rehabilitation, College of Health Sciences, Obafemi Awolowo University, Ile-Ife

Summary

Cardiovascular responses to maximal exercise testing with treadmill (TD) and bicycle ergometers (BE) were compared in 60 healthy male Nigerians aged 20-45 years. The duration of exercise (DOE), maximal heart rate (MHR), peak systolic blood pressure (PSBP), and peak rate pressure product (PRPP) values were higher with TD than BE ($P < 0.0001$). The MHR correlated significantly with the DOE in both exercise modes ($r = 0.5$) but only with age in the TD mode ($r = -0.4$; $P < 0.05$). Twenty of these subjects (aged 20-26 years) were further randomized to commence with either TD or BE and afterwards to proceed with the second exercise. Haemodynamic responses were significantly higher at submaximal exercise on BE than TD, while during maximal exercise these responses were significantly higher on TD than BE. The rate of perceived exertion was different for two exercise modes. Seventeen subjects (85%) preferred the TD while 3 (15%) preferred the BE for their personal physical exercise programme. Factors such as varying exercise test responses, exercise mode preference, and rate of perceived exertion should be taken into consideration whenever exercise testing or training is required in various individuals with or without heart disease.

Résumé

Les response cardiovasculqires aux exercise maximaux testé avec le treadmill (TD) et la biyclette ergométrique (B. E) ont été comparé chez 60 males Nigerians en parfaite Santé âgés de 25 à 45 ans. La durée de l'exercise (DOE), la vitesse maximale du coeur (NHR), le peak de la pression du prodnit ont été plus fortes avec le TD qu'avec la BE ($P < 0.0001$). Le MHR a eut une correlation significative avec la DOE dans les deux modes d'exercices ($r = 0.4$; P 0.05). Vingt de ces sujects (âges de 20 à 26 ans) ont été plutard choisis au hasard afin de commencer solt avec le TD ou le BE, et par aprés demandé de procédér avec le second mode d'exercise. Les responses haemodynamique ont été de maniere significative plus élevé en TD qu en BE. Le taux de perception de l'exercise a été different pour les 2 modes d'exercise. Dix-sept sujects (85%) ont préférré la BE pour leur programme personnel d'exercise physique. Les facteurs telsque: les responses aux teste d'exercise, et taux de percetion des exercices devraient être tenu en considération à chaque fois que les testes à certains exercices ou les formations à certains exercices sont necessaire chez les divers individus, avec ou sans maladies cardique.

Introduction

Exercise testing is an established non-invasive diagnostic and prognostic technique in cardiology. Many exercise protocols are in use but no single test is universally applicable to a wide range of patients and subjects. A further problem is, that various exercise laboratories use different modes of dynamic exercise testing including simple walking tests, step tests, field testing, bicycle ergometer, and treadmills [1,2].

Various factors determine the choice of exercise mode and these include the type of individuals to be studied, the familiarity of the subjects with the various exercise devices, the intensity of cardiovascular stress intended, and the type of data to be collected [3].

The bicycle ergometer and treadmill are now the most commonly used dynamic exercise testing devices [2,4]. While bicycle ergometers predominate in mainland Europe, treadmills are favoured in United States and United Kingdom [5,6]. There are essential differences between these two modes of exercise testing. Different exercise modes have been employed in the exercise testing of Nigerian patients with or without cardiovascular disease and also in normal subjects [7-14]. There is little data, if any, on the comparative circulatory responses to both bicycle ergometer and treadmill exercise and the preferred mode of exercise testing in our population.

The purpose of this study was, therefore, to compare the cardiovascular responses of normal subjects to multistage maximal exercise testing using the bicycle ergometer and treadmill and to evaluate the rate of perceived exertion as well as the exercise mode preference in the population studied.

Materials and methods

Cardiovascular responses to maximal multistage exercise testing with the treadmill and bicycle ergometer were compared in 60 healthy male volunteers aged 20-45 years at the Electro-Diagnostic Unit of Obafemi Awolowo University Teaching Hospital. Subjects were recruited after a thorough clinical examination and laboratory investigations in order to exclude individual, with contraindications to exercise testing [4]. Informed consent was obtained from all subjects and ethical clearance was given by the Hospital Ethical Committee.

Thirty subjects each were assigned randomly to exercise on the treadmill ($n = 30$) and bicycle ergometer ($n = 30$) (Table 1). Twenty of the 60 subjects (aged 20-26 years, mean age = 23.7 ± 1.6 years) who responded to request for further exercise testing* were randomized on a separate day to commence with either the treadmill or bicycle ergometer and afterwards were allowed to proceed with the second mode of exercise.

All the subjects had a demonstration on both the treadmill and bicycle ergometer, received general instructions with respect to exercise testing, and were requested to avoid non-essential physical work and strenuous exercise on the day before the test. They were also requested not to smoke, or drink alcohol or coffee on the day of the exercise test [15]. All tests were performed in the morning and in air-conditioned exercise laboratory with the room temperature kept between 20°C and 25°C. A standard multi-stage maximal exercise test was conducted on a motorized treadmill (Model 3060 Cambridge Medical Instruments Division, New York, USA) according to the Bruce protocol [16] and as described in detail elsewhere [7]. The electrocardiogram (EGG) was monitored on the CM 3400 non-fade 4-channel electrocardiographic

Correspondence: Dr. M. O. Balogun, Department of Medicine, College of Health Sciences, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

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monitor. The bicycle ergometer test was performed on a calibrated, electrical ergonometer according to standard protocol and with an ECG oscilloscopic monitor [1-4]. Each subject randomized to the bicycle ergometer commenced exercise at 50 watts workload after the bicycle ergometer height had been adjusted and the work load was increased by 25 watts every 3 minutes until the exercise was terminated. The pedal speed was constant throughout the exercise for each subject at 50 revolutions per minute.

The electrocardiogram, heart rate, and blood pressure were monitored and recorded pre-exercise, during the last minute of each stage of exercise and in the post exercise period till the variables returned to baseline. After the subjects exercised on the two exercise modes. they were required to fill out a questionnaire on how the exercise was perceived and their exercise mode preference.

A defibrillator, Cardio/Pak 936/s (Mennen Medical Inc, New York, USA) equipped with a portable ECG monitor was available.

Statistical analyses

Data are presented as mean ± standard deviation or as ranges. Statistical analysis was by the two sample *t* test and, where appropriate, by the Mann-Whitney U test and the chi-square. A P value of < 0.05 was considered significant. Linear regression was used to determine relationships between variables. All analyses were performed using a MINITAB software package on an IBM computer.

Results

Table 1 shows the characteristics of the subjects studied. There was no statistically significant difference in the variables of the subjects who had treadmill exercise compared with those who had bicycle exercise. They were also comparable in their history of alcohol intake, smoking habits and history of parental hypertension.

Table 1: Characteristics of subjects (n = 60)

Variable	Treadmill n = 30	Bicycle n = 30
Age range (years)	20-45	20-45
Age (years)	27.7 ± 6.8	27.8 ± 6.8
Activity		
Sedentary	27	30
Active	3	0

Exercise test responses: treadmill vs bicycle ergometer

Heart Rate:

During treadmill exercise, maximal heart rate and the rest-maximal heart rate difference (HR) values were significantly higher than during bicycle ergometry ($P < 0.0001$) in spite of comparable resting heart rate values (Table 2).

These findings were confirmed in the subgroup aged 20-26 years (Table 3). However, at a comparable workload of 5 metabolic equivalents (MET) (1 MET = 3.5 ml 02/kg/min), which is at 1.7 mph, grade for the treadmill and 75 watts for the bicycle ergometer, the submaximal heart rate value was significantly higher during bicycle than the treadmill exercise ($P < 0.02$, Table 3).

Blood pressure:

The maximal systolic blood pressure and rest-maximal SBP difference (SBP) were significantly higher with the treadmill than with the bicycle ergometer exercise ($P < 0.005$, Table 2), but were not found to be significantly higher when these variables were compared in the subgroup (Table 3).

Table 2: Exercise test responses

Variable	Treadmill n = 30	Bicycle ergometer n = 30
Heart rate (beats/min)		
resting	71.2 ± 12.6	75.5 ± 8.6
maximal	192.4 ± 12.1	153.7 ± 21.2*
rest-maximal change (ÙHR)	121.2 ± 17.4	78.2 ± 23.7*
Systolic Blood Pressure (mmHg)		
resting	119.3 ± 15.7	109.7 ± 9.8
maximal	189.3 ± 21.6	160.6 ± 22.7*
rest-maximal change (ÙSBP)	70.0 ± 21.7	50.9 ± 21.4**
Peak rate pressure product (PRPP) (mmHg x beats/min x 10^{-2})	363.8 ± 42.6	248.1 ± 53.1*
Duration of exercise (DOE) (seconds)	697.8 ± 84.3	451.0 ± 237.0*
DOE	0.53 ± 0.09	0.66 ± 0.28***

* $P < 0.0001$ ** $P < 0.005$ *** $P < 0.02$

Table 3: Exercise test responses of subgroup (Aged 20-26) years

Variable	Treadmill n = 20	Bicycle ergometer n = 20
Heart Rate (beats/min)		
resting	69.1 ± 10.6	70.1 ± 10.5
submaximal	118.8 ± 19.9	133.4 ± 15.7***
maximal	178.6 ± 23.3	152.5 ± 19.7*
Blood pressure (BP) mmHg		
resting systolic BP	108.7 ± 10.7	108.2 ± 10.9
resting diastolic BP	65.7 ± 9.4	66.2 ± 6.9
submaximal systolic BP	135.5 ± 12.8	148.2 ± 28.9
maximal systolic BP	168.5 ± 16.9	158.7 ± 26.3
Duration of exercise (Secs)	742.5 ± 165.8	358.4 ± 179.7***
Rate-pressure product (RPP) (mmHg x beats/min x 10-2)		
Submaximal RPP	162.3 ± 38.4	198.6 ± 50.0***
Maximal RPP	306.6 ± 53.8	243.3 ± 54.2

* $P < 0.001$ ** $P < 0.005$ *** $P < 0.02$

Submaximal workload at 5 metabolic equivalents (METS) for treadmill = 1.7 mph,
10% grade and for bicycle ergometer = 75 watts or 450 kg/min (1).
1 MET = 3.5 ml O_2/kg/min.

Duration of exercise and pressure rate product:

During the treadmill exercise, the peak rate-pressure product and the duration of exercise were significantly greater than during bicycle ergometry ($P < 0.0001$). However, at submaximal exercise, the rate-pressure product was significantly higher with the bicycle ergometer than with the treadmill exercise ($P < 0.02$, Table 3). The maximal rate-pressure product normalized for the duration of the exercise was significantly lower with the treadmill than with the bicycle ergometer exercise ($P < 0.02$, Table 2).

Relationship among variables:

The mean maximal heart rate values decreased with increasing age in both exrcise modes. There was a significant correlation of maximal heart rate with age during treadmill exercise, thus: maximal heart rate (beats/min) =212-0.723 (age in years) ($r = -0.41$; $r^2 = 16.7\%$ $P = 0.025$)

There was no correlation of age with exercise blood pressure variables. Similarly there was no significant correlation of resting heart rate and blood pressure variables with maximal heart rate and blood pressure parameters, respectively.

During the bicycle ergometer exercise, there was a significant correlation of maximal heart rate ($r = 0.6$, $P = 0.005$); and a slight but non-statistically significant correlation of age ($r = 0.33$; $P = 0.07$) with the duration of the exercise in seconds. With the treadmill exercise, there was a significant correlation of maximal heart rate ($r = 0.5$; $P = 0.003$) and a significant negative correlation of age ($r = -0.8$; $P < 0.0001$) with duration of exercise in seconds such that duration of exercise = 962 - 9.54 (age in years). In the subgroup, exercise variables on one mode of exercise were not predictive of exercise variables on other mode of exercise.

Perceived exertion, mode preference, and main limiting symptoms:

Amongst the subgroup of twenty young male subjects the rate of perceived exertion, exercise mode preference, and main limiting symptom during maximal exercise were significantly different by Chi-square analysis when the treadmill was compared with the bicycle ergometer exercise (Table 4).

Table 4: Perceived exertion, exercise mode preference and main limiting symptoms in twenty male subjects (n, %)

Variable	Treadmill n = 20	Bicycle ergometer n = 20
Perceived exertion		
not quite hard	14 (70.0)	3 (15.0)*
just hard	6 (30.0)	12 (60.0)*
very hard	0 (0.0)	5 (25.0)*
Exercise mode preference		
yes	17 (85.0)	3 (15.0)*
no	3 (15.0)	17 (85.0)*
Main limiting symptom		
exhaustion	10 (50.0)	2 (10.0)*
muscle fatigue	10 (50.0)	18 (90.0)*

* $P < 0.01$

None of the subjects considered the treadmill as a "very hard" mode of exercise while 5 (25%) considered the bicycle ergometer as "very hard". Muscle fatigue as the reason for terminating exercise was observed in 18 subjects (90%) compared with 10 subjects (50%) during the treadmill exercise. Seventeen subjects (85%) preferred the treadmill while 3 subjects (15%) preferred the bicycle for their future exercise testing and for their personal physical exercise programme.

There were no untoward events or morbidity post-exercise with the two methods of exercise testing. No subject had evidence of myocardial ischaemia or arrhythmias during exercise testing.

Discussion

Previous studies comparing the treadmill and bicycle ergometer modes of exercise have been carried out in Western countries in normal patients as well as in patients with coronary artery disease [5,17]. We have, therefore, investigated for the first time in Nigerians the comparative cardiovascular responses to treadmill and bicycle ergometer exercises.

We observed a significantly higher maximal heart rate, rate-pressure product, and systolic blood pressure during the treadmill exercise compared with cycle ergometry. This is in agreement with previous studies comparing treadmill with bicycle ergometer exercises [5,17-21]. Highest values of maximal oxygen uptake, heart rate, and lactate were achieved with a treadmill rather than with a bicycle ergometer or a step test in direct comparison in 24 normal men aged 20-40 years [22]. The treadmill exercise, therefore, imposes a greater heamodynamic burden on the myocardium than the bicycle exercise as indicated by the rate-pressure product, which is a reliable non-invasive index of myocardial oxygen consumption [23,24].

In a recent study, stress-induced reversible myocardial ischaemia during a treadmill exercise was approximately 45% higher than it was during a bicycle ergometer exercise [17] indicating that the treadmill might have a higher sensitivity for the detection of coronary artery disease in contrast to the study of Wicks *et al* [18] in which no significant difference was found.

Maximal heart rate decreased linearly with increasing age in both exercise modes. As we have previously observed, [7] there was a significant negative correlation of maximal heart rate with age during the treadmill exercise. We found no significant correlation of age with exercise blood pressure variables. In contrast to maximal exercise, the bicycle ergometer exercise imposes a greater haemodynamic stress as reflected in significantly greater heart rate and rate-pressure product values than the treadmill exercise at comparable submaximal work loads. In studies in which oxygen uptake and cardiac output were directly measured, this observation suggests a lower stroke volume during bicycle exercise at submaximal levels [20,25].

In agreement with other studies, the duration of exercise on the treadmill was significantly greater than on the bicycle ergometer [17]. There was a significant correlation of maximal heart rate with duration of exercise on both modes of exercise. Peak rate-pressure product significantly correlated with duration of exercise during the bicycle ergometer exercise but not with the treadmill exercise. There was a highly statistically significant negative correlation of age with duration of exercise on the treadmill ($r = -0.8$; $P < 0.0001$) such that the duration of exercise could be reliably predicted from age using this regression equation: duration of exercise (seconds) = 962 - 9.54 (age in years). However, from our study, performance on one mode of exercise was not predictive of performance on the other mode of exercise.

Possible reasons for a difference in exercise duration include an early end to exercise because of localized muscle fatigue and pain in the quadriceps experienced in 18 subjects with the bicycle compared with 10 subjects during the treadmill exercise. It is also probable that this might have influenced the rate of perceived exertion and exercise mode preference in our subjects. This is not surprising since our subjects were derived from the southwestern part of Nigeria, a population more familiar with walking than cycling.

Cardiovascular responses to the treadmill exercise differ from those in the bicycle ergometer exercise in healthy Nigerian men. Factors such as varying haemodynamic responses, exercise mode preference, rate of perceived exertion, and the type of subjects or patients studied should be taken into consideration whenever exercise testing or training is required in various individuals.

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