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Cardiovascular Responses to Isotonic and Isometric Exercise in Young Subjects

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ABSTRACT

Muscular exercise has long been known to play a vital role in health and maintenance of body fitness.To assess and compare cardiovascular responses to isotonic and isometric exercise in young healthy subjects.Ten apparently healthy male subjects aged16 to 26 years, who were not accustomed to physical exercise, performed different levels of isotonic and isometric exercise. Heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined before and after the exercise. Isotonic (dynamic) exercise was achieved on bicycle ergometer, based on the modified Leeds University method while the two (sub-maximal and maximal) levels of isometric exercise were achieved by lifting loads of varied weights in static position.In maximal isotonic exercise, it was observed that the HR was significantly increased by 67.3 ± 9.0% ($p < 0.001$). In sub-maximal and maximal levels of isometric exercise, the HR was elevated by 12.3 ± 2.7% ($p < 0.05$) and 24.4 ± 5.0% ($p < 0.001$), respectively. In maximal isotonic exercise, the SBP was also increased significantly by 21.8 ± 3.9% ($p < 0.01$) whereas in sub-maximal isometric exercise, it was slightly elevated by 5.0 ± 1.8% ($p > 0.5$) but significantly increased in maximal isometric exercise, by 24.4 ± 5.0% ($p < 0.001$). However, in maximal isotonic exercise, DBP was slightly elevated by 12.4 ± 5.0% ($p > 0.5$) but significantly increased in sub-maximal and maximal isometric exercise by 20.4 ± 4.0% ($p < 0.01$) and 30.9 ± 5.0% ($p <0.001$), respectively. Inisotonic exercise, changes in HR and SBP were found to be greater than that of isometric exercise but changes in DBP was observed to be higher in isometric exercise.

Key words: Cardiovascular, isotonic, isometric, exercise

INTRODUCTION

Isotonic (dynamic) or isometric exercise is performed as part of daily activities. Appropriate exercise has been shown to improve muscular strength, endurance and range of motion, or at least to minimize decrement associated with any particular physical disorder.[1]Studies in healthy young subjects have demonstrated that potent cardiovascular reflex adjustment rapidly occur during exercise.[2–5] and the magnitude of cardiovascular responses to exercise has been reported to be influenced mostly by the interaction of the contraction intensity and duration.[6]Isotonic (dynamic) exercise tests, such as treadmill and bicycle ergometertests, are usually performed with patients and healthy people to investigate the cardiovascular responses to exercise[5,7]. Similarly, static exercise tests such as hand gripping, static knee extension, weight lifting are used for different goals in athletes, coronary artery patients, hypertensives, and healthy individuals[5,8,9]. In many studies in healthy people, cardiovascular responses to static and dynamic exercise were compared using the same resistance load, and it was documented that greater increases in blood pressure occurred during isometric exercise but higher increase in heart rate was observed in isotonic exercise.,[10,11,12,13]

Despite the fact that the effect of exercise has been long and widely reported, little is still being currently employed by people on the type of exercise that is safe to perform which actually promotes cardiovascular health since it has been reported that exercise imposes sudden and significant stress on the cardiovascular system in patients with heart diseases.[14,15]In a prolonged isometric exercise where tension developed, is not accompanied with an appreciable change in muscle length, there is a progressive impediment of blood flow to active muscles because the contracting muscle fibres cause an increase in intramuscular pressure and compress arterial blood vessels within the active muscles[16,17,18]and this may consequently lead to complete vascular occlusion depending on the intensity.[19] Such partial or complete impairment of arterial inflow into statically contracting skeletal muscles results in an imbalance between oxygen supply and demand and lowers oxygen consumption[20]. At any given tension-time product, isometric (static) exercise has been since documented to result in less

oxygen consumption than isotonic

(dynamic) exercise[21]. Thus, energy requirements during static muscular contraction are met by either partial or complete conversionto anaerobic metabolism.[17]

A combination of mechanical and metabolic events has been said to cause the stimulation of afferent nerve endings in skeletal muscle,[22,23,24] leading to reflex cardiovascular responses during static contraction.[25,26,27] Systemic vascular resistance decreases during dynamic exercise largely as a result of metabolic vasodilation in the exercising skeletal muscles[28].

Although appreciable studies have been done on haemodynamic responses to exercise in developed countries, there is paucity of data in developing countries. Therefore, this study was designed to assess cardiovascular responses to isotonic and isometric exercise in healthy young Nigerian subjects.

MATERIALS AND METHODS

The study was non- interventional and was conducted among ten apparently healthy young male subjects, aged 16 to 26 years who were not trained athletes. All the subjects gave their consent to participate in the research work after they had been duly informed. Detailed history was obtained from the volunteers in order to rule out chronic diseases such as hypertension, diabetes or any other cardiovascular disease. The volunteers were excluded if there was any history of smoking, use of antihypertensive, hypoglycaemic, tricyclic antidepressant or vasoactive drugs which could adversely affect the outcome of the findings. All the information obtained from the participants was kept confidential.

The subjects' ages were taken to their nearest birthdays. Body weight (kg) was determined with the help of weighing scale and measured to the nearest 0.1kg and height was measured to the nearest 0.01m by means of the height scale. The cardiovascular parameters that were determined in the study were the heart rate, systolic blood pressure and diastolic blood pressure

Exercise Protocol

Maximal isotonic (dynamic) exercise was achieved by cycling at maximal speed of 40 – 50 Km/h on the bicycle ergometer (Welder TG – 700P) for ten minutes. If the subjects were unable to perform the exercise at this maximal speed, then, a slightly lower speed was used. All the measurements were taken when the participants were well seated. Sub-maximal and maximal levels of isometric (static) exercise were undertaken in erect posture and achieved by lifting buckets of varied weights (15kg for sub-maximal and 20kg for maximal isometric exercise) in a static position for at least, 3 minutes, depending on the volunteer's capability.

EXPERIMENTAL PROCEDURES

The subjects were allowed to rest for 10 minutes before the control readings were recorded. The participants then carried out the dynamic exercise on the bicycle ergometer provided, at a maximal speed of 40 – 50 km/h for a period of ten minutes. The heart rate, systolic and diastolic blood pressure were taken. The recovery period was set at 20 minutes. This was followed by taking baseline readings again before performing the static exercise. The sub-maximal isometric exercise was carried out and the readings taken before the subjects proceed to the maximal level of static exercise and the readings were recorded.

Measurement of Heart Rate

Heart rates (beats/minute) of the subjects were determined using an electrocardiograph machine at paper speed of 25mm/sec. The machine was standardized to show a deflection of 10mm/Mv. Subjects were allowed to rest for 10 minutes in sitting position. The placement of electrodes was done in conformity with the American Heart Association recommendations.[31] Heart rate was determined from the R-R interval in Lead II of the electrocardiogram.

Measurement of Blood Pressure

Resting blood pressure was determined by auscultatory method using Accuson mercury sphygmomanometer as per the described instructions of American Heart Association.[14,30] Subjects were allowed to rest for 10 minutes in sitting position. Appropriate cuff sizes were used. The cuff was wrapped on the right arm with the midline of bladder over the brachial arterial pulsation and inflated rapidly while palpating radial pulse. Reading at which pulse disappeared was noted and pressure was further elevated 20 – 30mmHg above this value. Then the bladder was slowly deflated while listening to the Korrotkoff's sound using a stethoscope placed on brachial arterial pulsation. Systolic Blood Pressure and diastolic blood pressure were recorded to the nearest 2mmHg as the first and fifth Korotkoffphases, respectively.

Pre-exercise cardiovascular values were used as the control data for each type of the muscular exercise.

Statistical Analysis

Data are expressed in Mean ± Standard error of the mean. The magnitudes of the cardiovascular responses in these two types of exercise were compared with the control values using Student's Paired t- test. Differences were considered significant when $p < 0.05$.

RESULTS

Table 1 shows the anthropometric data of the study subjects. The participants were quite young, having a mean age of 22.8 ± 0.95 years with the mean body mass index of 19.35 ± 0.21 kg/m².

Cardiovascular Responses to Isotonic Exercise

Their mean resting (control) cardiovascular values before and after isotonic exercise were shown in table 2. In all the subjects studied, the heart rate increased significantly ($p < 0.001$) from the mean control value of

69.9 ± 3.90 beats/minutes to 115.8 ± 7.00 beats/minute after the isotonic exercise. Similarly, there was a significant increase ($p < 0.01$)in their systolic blood pressure from mean resting value of 110.0 ± 3.00mmHg to 133.5 ± 4.20 mmHg after the dynamic exercise. However, in diastolic blood pressure, half of the subjects showed no increase while the remaining ones demonstrated an insignificant increase ($p > 0.05$) in their diastolic blood pressure, from the mean control value of 73.0 ± 3.00 mmHg to 82.0 ± 3.90 mmHg, after the exercise.

Cardiovascular Responses to Isometric Exercise

In sub-maximal level of isometric exercise, all the subjects showed a modest increase in their heart rates from the mean value of 73.2 ± 2.60 beats/minute to 82.0 ± 2.8 beats/minute. The increase was however, significant ($p < 0.05$). In systolic blood pressure, four subjects demonstrated no increase while the remaining participants showed an insignificant increase ($p > 0.05$) at this level of static exercise. Their mean systolic blood pressure rose from110.0 ± 2.10 mmHg to115.3 ± 2.30 mmHg. Nevertheless, in diastolic blood pressure, there was a significant increase ($p < 0.01$). Their mean diastolic blood pressure increased from 74.5 ± 2.60 mmHg to 89.0 ± 2.20 beats/minute (Table 3).

In maximal level of isometric exercise, all the cardiovascular parameters were appreciably elevated. The mean heart rate increased significantly ($p < 0.001$) from 73.2 ± 2.60 beats/minute to 92.9 ± 3.00 beats/minute. The mean systolic blood pressure increased significantly ($p < 0.01$) from 110.0 ± 2.10 mmHg to 119.80 ± 1.70 mmHg. The mean diastolic blood pressure also increased significantly ($p < 0.001$) from 74.5 ± 2.6 mmHg to 96.5 ± 1.70 mmHg.(Table 4)

Table 1:Anthropometric Data of the Studied Subjects

N = 10	
Age (yrs)	22.8 ± 0.95
Height (m)	1.73 ± 0.03
Weight (kg)	57.9 ± 1.93
Body Mass Index (kg/m²)	19.35 ± 0.21

Values are express in mean ± standard error of mean (SEM)
N- Number of subjects

Table 2: Cardiovascular Values before and after Isotonic Exercise

Parameters	(A) at Rest	(B) at Maximal Exercise	% Δ : (B - A)/A X	
HR (beat/min)	69.9 ± 3.90	115.8 ± 7.0067.	3 ± 9.00	< 0.001
SBP (mmHg)	110.0 ± 3.00	133.5 ± 4.20	21.8 ± 3.90	< 0.01
DBP(mmHg)	73.0 ± 3.00	82.2 ± 3.90	2.4 ± 5.00	NS

Values are expressed in mean ± standard error of mean (SEM)
KEY:
HR – Heart rate
SBP – Systolic blood pressure
DBP – Diastolic blood pressure
NS – Not significant

Table 3: Cardiovascular values before and after sub-maximal isometric exercise

Parameters	(A) At Rest	(B) Sub-maximal Exercise	% Δ: (B-A)/A X 100	p value
HR(beat/min)	73.2 ± 2.6	82.0 ± 2.8	12.4 ± 2.7	< 0.05
SBP (mmHg)	110.0 ± 2.1	115.3 ± 2.35.0 ± 1.8		>0.05 NS
DBP (mmHg)	74.5 ± 2.6	89.0 ± 2.2	20.4 ± 4.0	< 0.01

Values are expressed in mean ± standard error of mean (SEM)
KEY:
HR – Heart rate
SBP – Systolic blood pressure
DBP – Diastolic blood pressure
NS – Not significant

Table 4: Cardiovascular values before and after maximal isometric exercise

Parameters	(A) At Rest	(B) Maximal exercise	% Δ: (B – A)/A X 100	p value
HR (beats/min)	73.2 ± 2.6	92.9 ± 3.0	24.4 ± 5.0	< 0.001
SBP (mmHg)	110.0 ± 2.1	119.8 ± 1.7	9.2 ± 2.2	< 0.01
DBP (mmHg)	74.5 ± 2.6	96.5 ± 1.7	30.9 ± 5.0	< 0.001

Values are in mean ± standard error of mean (SEM)
KEY:
HR – Heart rate
SBP – Systolic blood pressure
DBP – Diastolic blood pressure

DISCUSSION

Subjects were mainly selected based on their health status. None of the subjects was hypertensive or diabetic. There was no history of any cardiovascular disease in the participants as this could adversely affect the outcome of the findings either by reduced or exaggerated cardiovascular responses to the exercise[29,30].All subjects selected in this study are males in order to eliminate varied responses which might arise from gender difference. Besides, the participants were untrained individuals who were not accustomed to physical exercise. This was done so as to prevent varied responses associated with trained and untrained men.[31]

Effect of isotonic on cardiovascular parameters

There were significant increases in heart rate ($p < 0.001$) and systolic blood pressure ($p < 0.01$) responses to maximal isotonic exercise. This observation isconstitent with peviousfindings that isotonic exercise causes significant increases in heart rate and systolic blood pressure.[32,33] The increase may be due to withdrawal of vagal inhibition on the heart and increase in cardiac output. In diastolic blood pressure, however, no significant increase ($p > 0.05$) was observed. This may be due to a net fall in total peripheral resistance, arising from the effect of the metabolites on the blood vessels in exercising muscles. It has been documented that cardiovascular responses to dynamic and static exercise are due to local, chemical, thermal, or mechanical factors or they may be neural in origin.34

Effect of isometric exercise on cardiovascular parameters Heart rates were significantly increased ($p < 0.05$) in both sub-maximal and maximal levels of isometric exercise. The heart rate response to the exercise was based on the proportion of the muscular exertion and duration, the response being significantly higher ($p < 0.0.1$) in maximal isometric exercise. However, in submaximal level of static exercise, the systolic blood pressure was not significantly elevated ($p > 0.05$). did not show a significant increase in systolic blood pressure. However, a significant increase ($p < 0.01$) was observed in maximal level of the static exercise. This increase may be due to greater increase in heart rate and contractility.[35]There were significant increases in diastolic blood pressure responses both sub-maximal ($P < 0.01$) and maximal levels of isometric exercise ($P < 0.001$). This may be largely due to increase in peripheral resistance in these active muscles.

CONCLUSION

This study has shown cardiovascular responses to isotonic and isometric exercise in healthy young subjects. Heart rate and systolic blood pressure responses were found to be greater in isotonic exercise than that of isometric exercise when compared. In isometric exercise, however, the diastolic blood pressure response was observed to be higher. Hence, work or recreaction involving frequently prolonged episodes of static exercise could be potentially harmful in hypertension and heart disease because of the stress the exercise exerts on the heart and as a result, should be avoided.

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