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Original Article

Acute changes in arterial stiffness following exercise in people with metabolic syndrome

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ABSTRACT

Background: This study aims to examine the changes in arterial stiffness immediately following sub-maximal exercise in people with metabolic syndrome.
Methods: Ninety-four adult participants (19–80 years) with metabolic syndrome gave written consent and were measured for arterial stiffness using a SphygmoCor (SCOR-PVx, Version 8.0, Atcor Medical Private Ltd, USA) immediately before and within 5–10 min after an incremental shuttle walk test. The arterial stiffness measures used were pulse wave velocity (PWV), aortic pulse pressure (PP), augmentation pressure, augmentation index (AI), subendocardial viability ratio (SEVR) and ejection duration (ED).
Results: There was a significant increase ($p < 0.05$) in most of the arterial stiffness variables following exercise. Exercise capacity had a strong inverse correlation with arterial stiffness and age ($p < 0.01$).
Conclusion: Age influences arterial stiffness. Exercise capacity is inversely related to arterial stiffness and age in people with metabolic syndrome. Exercise induced changes in arterial stiffness measured using pulse wave analysis is an important tool that provides further evidence in studying cardiovascular risk in metabolic syndrome.

1. Introduction

Metabolic syndrome (MS) is a cluster of cardiovascular risk factors. It includes a combination of increased blood glucose, alterations in the lipid levels, increased abdominal obesity and increased blood pressure. The prevalence of metabolic syndrome is increasing all over the world. Different countries show different clusters of epidemic risk factors. There is an increased risk of coronary artery disease as well as cerebrovascular disease in Asians with MS [1]. There is evidence for a large prevalence of MS and diabetes in South Asians and it is continuously escalating [2]. Poor exercise capacity is one of the clinical characteristics of cardiovascular disease with low cardio respiratory fitness commonly observed in metabolic syndrome [3].

Arterial stiffness is also identified as a marker of cardiovascular diseases. Generally, an increase of arterial stiffness occurs with age. The increase in arterial stiffness is exacerbated by common cardiac risk factors (Mitchell 2006). Metabolic syndrome is independently associated with arterial stiffness, with the presence of carotid artery plaque and increased arterial wall thickness [4]. Components of metabolic syndrome alter the structure and function of the large arteries. There is an increase in circumferential wall stress and flow mediated shear stress of the arterial wall. Further, metabolic syndrome can accelerate vascular aging [5].

Exercise capacity is related to arterial stiffness as cardiac output is determined by aortic compliance. The reason is that proximal aortic compliance is the primary factor that determines pulse pressure and thus myocardial consumption [6]. Acute exercise results in immediate changes in arterial compliance. Generally, there is an increase in vasodilatation of the vasovasorum of the aortic wall (independent of the increase in mean arterial pressure) due to various factors such as increase of temperature and nitric oxide in exercising muscles. The possible mechanism is the decrease in smooth muscle tone which transfers the stress forces from the stiff collagen fibres to the extensible elastin fibres [7].

Pulse wave analysis is one of the recently developed methods to measure arterial stiffness non-invasively. Alterations in both structure and function of the microcirculation occur during aging and this may play an important role in the pathophysiology of

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cardiovascular and metabolic diseases associated with aging [8]. To the investigators' knowledge, the immediate changes in arterial stiffness following acute sub-maximal intensity exercise have not been studied in people with metabolic syndrome in India.

This study was carried out to establish the immediate changes in arterial stiffness using pulse wave analysis following acute sub-maximal exercise in people with metabolic syndrome.

2. Methods

2.1. Subjects

After achieving institutional ethical approval, a free health screening for metabolic syndrome was carried out at Father Muller Medical College & Hospitals, Mangalore, India. The International Diabetic Federation's (IDF) definition was used to diagnose metabolic syndrome. The people diagnosed with metabolic syndrome were invited to participate in the study. The participants were excluded if they had a resting heart rate > 120 beats/min after a 15 min rest, a systolic blood pressure > 200 mm Hg and/or a diastolic blood pressure > 100 mmHg, a history of any cardiovascular disorders such as unstable angina and myocardial infarction and a physical disability that prevented the safe performance of the test. In total, 94 eligible people with metabolic syndrome volunteered to participate in the study and signed a written consent.

2.2. Sub-maximal exercise and exercise testing

The incremental shuttle walk test (ISWT) was the sub-maximal intensity exercise used to determine the participants' sub-maximal exercise capacity [9].

A medical history was obtained before the test to establish any contraindications to exercise testing. Participants rested for 15 min before starting the shuttle test. All the participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and an International Physical Activity Questionnaire (IPAQ) to establish minimum of safety before the test.

Two cones were placed nine metres apart and the distance to walk around the cones was 10 m. The participant was required to walk between two cones in time to a set of auditory beeps played from a CD. Initially the walking speed was very slow and increased progressively to running. The ISWT had 12 levels and 1020 m of maximum distance to be covered. The participants walked as long as they could until either they were too breathless to continue or not able to pace themselves with the speed of the audio beeps. The completed number of shuttles were counted and recorded in metres.

The ISWT was measured twice with 30 min rest between the tests. This is to avoid the learning effects, as many individuals tend to perform better in repeated administration of the test [10]. The best result of the two tests was recorded. Only the standardized instructions from the developers' guidelines were used. The walking track was the same for all the participants. Exercise termination criteria was used as per the American Thoracic Society guidelines [11], however none of the participants had to terminate the test due to any abnormal signs or symptoms. Rate of perceived exertion was measured using BORG's scale (6–20 scale) before, during (every minute) and at the end of the test. The exercise was also terminated when the participants reached 17 (very hard) on BORG's scale.

2.3. Measurement of arterial stiffness

Participants were asked not to smoke for three hours before the study. Arterial stiffness was assessed with a SphygmoCor system (SCOR-PVx, Version 8.0, Atcor Medical Private Ltd, USA). It uses an arterial applanation tonometer for recording pressure waveforms that includes pulse wave velocity (PWV), pulse pressure (PP), augmentation pressure (Aug. P), augmentation index (AIx), augmentation index corrected for heart rate at 75 bpm (AIx@HR75), subendocardial viability ratio (SEVR) and ejection duration. An electrocardiogram (ECG) recording during measurements is used for synchronization of carotid and radial pulse wave times and heart rate. The measurements were repeated within 5–10 min after the completion of an incremental shuttle walk test.

2.4. Statistical analysis

Data analysis was carried out using statistical software SPSS for windows (18.0). A paired *t*-test was used to compare the changes in arterial stiffness variables following exercise. Pearson's correlation test was used to find the relationship between the variables used. A Levene's test was used to confirm the homogeneity of the variances. The baseline differences among age groups were analysed using ANOVA and Tukey's test. ANCOVA was used to test the influence of age and sex in the arterial stiffness changes after exercise.

3. Results

3.1. Physical characteristics and exercise capacity

In total, 57 females and 37 males participated in the study aged from 19 to 80 (49.5 ± 13.8). According to age they were divided into three groups, young (19–40 years, n = 24, 31.1 ± 7.1), middle (41–60 years, n = 45, 50.5 ± 5.9) and old (61–80 years, n = 25, 65.4 ± 4.9). Their physical characteristic details are given in Table 1. There was no significant difference on all anthropometric variables among the age groups (p = 0.103). The exercise capacity, measured by the distance achieved in the ISWT is listed in Table 1 with age and gender differences. Young age groups and males had higher exercise capacity.

3.2. Total group changes

The changes in arterial stiffness variables following exercise for the total group are illustrated in Table 2. There was a significant

Table 1
Physical characteristics and exercise capacity of the participants.

	Height (Mean ± SD) cm	Weight (Mean ± SD) kg	Body Mass Index (Mean ± SD)	ISWT distance (m)	
Total	161.5 ± 9.6	72 ± 17.5	26.8 ± 4.0	Male	Female
Age 19–40 years (n = 24)	165.5 ± 9.2	77.1 ± 13.5	28.1 ± 3.9	950.0 ± 111.8	786.4 ± 129.6
Age 41–60 years (n = 45)	160.9 ± 9.2	72.2 ± 19.0	26.6 ± 4.5	722.9 ± 221.4	557.9 ± 171.6
Age 61–80 years (n = 24)	158.8 ± 9.9	68.6 ± 17.7	25.7 ± 2.7	497.1 ± 239.0	427.7 ± 183.6

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