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Original paper

Blood Pressure Response to Isometric Contractions in Healthy Young Males

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Abstract

To obtain basic data for risk management, this study examined the changes in blood pressure during isometric contractions, and the influence of the location and strength of the contractions. Nine healthy male subjects, 20-23 years of age, performed consecutive shoulder, elbow and fingers flexion isometric contractions, at maximal voluntary contraction (MVC) and 50% MVC. As the contractions were performed, systolic (SBP) and diastolic blood pressure (DBP) were measured continuously at the right radial artery with a non-invasive blood pressure measuring apparatus. All maximal SBP and DBP values increased significantly compared with those at rest except for fingers flexion at 50% MVC. All minimal SBP and DBP values decreased significantly compared with those at rest except for fingers flexion at 50% MVC. Maximal and minimal SBP and DBP values at 100% MVC were greater than those at 50% MVC. Fluctuations in the SBP and DBP values seemed to become progressively greater from the fingers flexion to the elbow flexion to the shoulder flexion. These results indicate that occupational and physical therapists should manage blood pressure change risk more carefully when they have their patients do exercises.

Introduction

In clinical practice, occupational and physical therapists frequently direct their patients to contract muscles isometrically for several seconds with maximal effort, because it is part of muscle strengthening exercises and training for the activities of daily life. For risk management, it is very important to check blood pressure during the exercise, because some patients have unstable blood pressures. However, since it is very difficult to measure blood pressure during exercise without special apparatus or direct recording by artery catheterization, occupational and physical therapists commonly measure blood pressure before and after exercise. Many investigators [1-7] have reported that isometric contractions elicited an increase in systolic and diastolic blood pressure, and the magnitude of this increase depended on the strength of the contraction.

The purpose of this study was to examine changes in blood pressure during isometric contractions, and the influence of the location and the strength of the contractions. This information is important for the management of risk.

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Subjects and Methods

Nine healthy male volunteers, 20-23 years of age (20.9 ± 1.1), participated in this study. They were provided informed consent forms and trained before testing.

The subjects were seated in chairs with backrests and the trunk and thighs were secured to the chair with belts. A continuous, non-invasive blood pressure measuring apparatus (JENTOW-7700, Nippon Colin), connected with a sensor at the right radial artery, was utilized to measure and analyze systolic (SBP) and diastolic blood pressure (DBP) during each heart beat. After calibration, this apparatus measures SBP and DBP of the brachial artery by monitoring blood pressure at the radial artery with the pressure sensor. On arriving for the experiment, the subject's resting blood pressure was measured.

Maximal voluntary contractions (MVC) were measured in three different types of isometric contractions. Left shoulder flexion was performed against a padded iron bar on which a strain gauge had been mounted. The flexion angle of the shoulder joint was 80° and the angle of the elbow joint was 0° . Left elbow flexion was performed in a similar position. The flexion angle of the elbow joint was 45° and the flexion angle of the shoulder joint was 45° . Shoulder flexion and elbow flexion were performed using a strain gauge (GT-30, OG-Giken) which displayed the tension exerted during contraction. Left fingers flexion was performed using a Smedley's hand dynamometer that showed the tension exerted during contraction. The hand dynamometer was individually adjusted according to the size of the subject's hand. Flexion was performed with the left forearm on the subject's left thigh.

These three types of isometric contractions were performed at 100% and 50% of MVC for 5 seconds. The tension was held at a constant level through visual feedback. The order of performance was shoulder flexion at 100% MVC, shoulder flexion at 50% MVC, elbow flexion at 100% MVC, elbow flexion at 50% MVC, fingers flexion at 100% MVC, and fingers flexion at 50% MVC. Subjects were given sufficient rest between each contraction. Blood pressures were recorded continuously, and the succeeding contraction was begun after the subject's blood pressure had returned to the resting level.

The maximal and minimal values of SBP and DBP were compared under the different conditions. Data was analyzed using the analysis of Wilcoxon with the level of significance at $p<0.05$.

Results

Some examples of recorded blood pressure measurements while subjects performed isometric contractions are shown in Figure 1. In many subjects, both SBP and DBP increased immediately at the start of contraction and reached the maximum within 1 to 3 seconds. This was followed by a gradual decrease during the remainder of the contraction. After the contraction was stopped, both SBP and DBP decreased rapidly, and reached a minimum after the first 2 to 4 seconds. These SBP and DBP values were lower than those at rest. After 8 to 16 seconds, the SBP and DBP values recovered to resting levels (Fig.1-A, B). However, there were a few cases in which SBP and DBP values became minimal during the contraction (Fig.1-C).

The maximal and minimal SBP and DBP values during contractions and the resting periods are shown in Table 1. In comparing contractions with resting periods, all maximal SBP and DBP values for each of the contractions increased significantly except for fingers flexion at 50% MVC. All minimal SBP and DBP values decreased significantly except for fingers flexion at 50% MVC. In comparing contraction strength, the maximal SBP and DBP values at 100% MVC were significantly higher than 50% MVC for elbow flexion and fingers flexion. The minimal SBP and DBP values at 100% MVC were significantly lower than 50% MVC for all three types of contractions. In comparing contraction types at 100% MVC, the maximal DBP

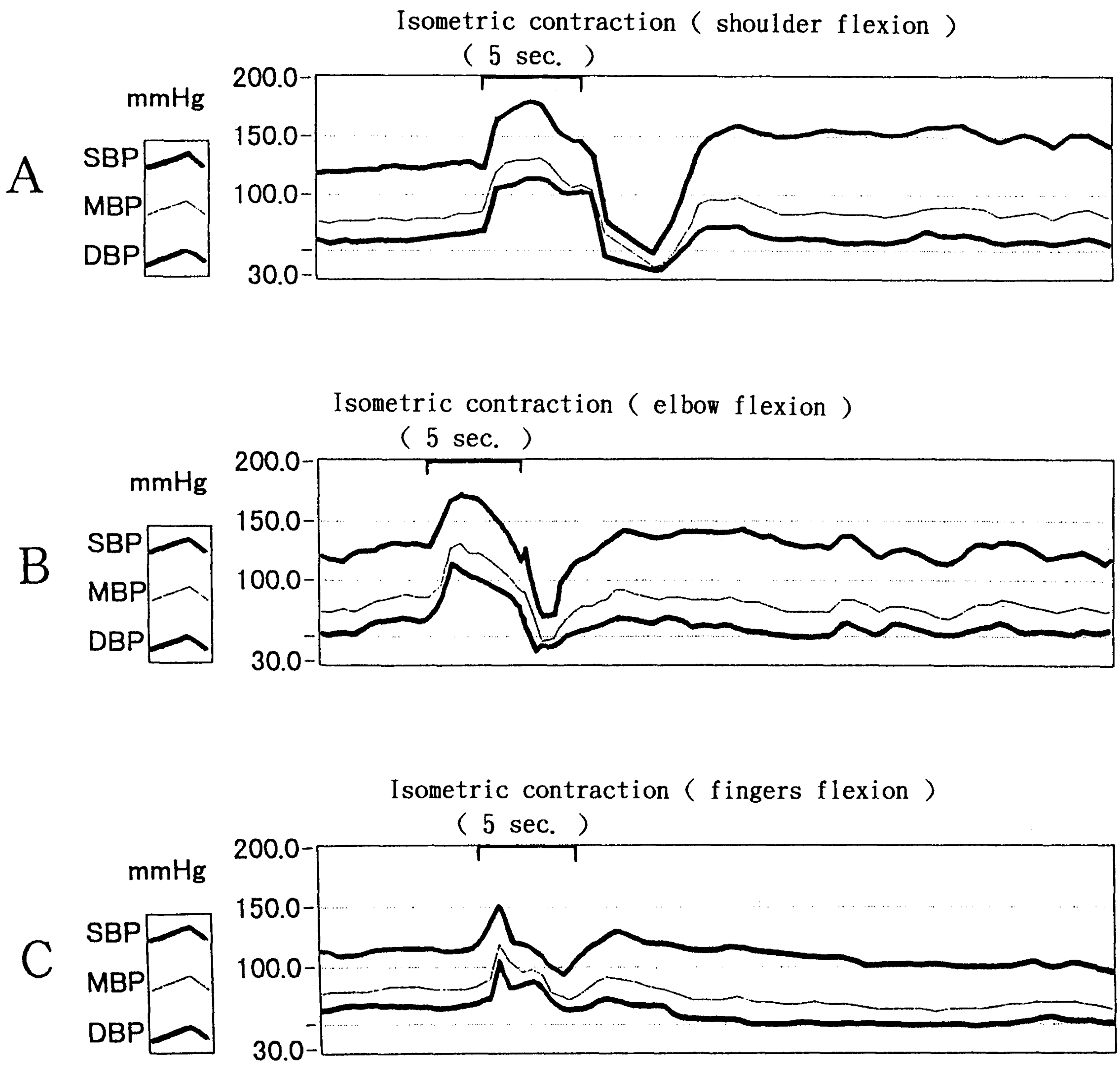

Fig. 1 Some examples of blood pressure recordings while subjects performed isometric contractions.
A:Shoulder flexion at maximal voluntary contraction
B:Elbow flexion at maximal voluntary contraction
C:Fingers flexion at maximal voluntary contraction

values for shoulder flexion and elbow flexion were significantly higher than those for fingers flexion. Also minimal SBP values for shoulder flexion were significantly lower than those for elbow and fingers flexion.

Discussion

The main purpose of this study was to examine the changes in blood pressure during isometric contraction. A non-invasive method of tonometry was utilized. Blood pressure was measured at each heart beat with a pressure sensor at the radial artery. This pressure was then related to pressure at the brachial artery by calibration. Thus, the authors believe that detailed changes in blood pressure during isometric contractions were measured. When the contraction was started, both SBP and DBP increased immedi-

Table 1 The maximal and minimal SBP and DBP values during the three types of isometric contractions.

	SBP		DBP	
	Maximum	Minimum	Maximum	Minimum
Rest	134±14	120±12	73±12	65±10
Shoulder flexion				
100% MVC	156±23	85±24	111±22	51±12
50% MVC	147±23	113±13	88±13	60±11
Elbow flexion				
100% MVC	151±28	97±19	106±19	55±12
50% MVC	143±24	113± 9	84±16	59± 9
Fingers flexion				
100% MVC	155±28	102±32	96±17	58±19
50% MVC	137±22	121±16	76±15	62±14

mean ± SD (mmHg) * : p< 0.05

ately, and when the contraction was stopped, both SBP and DBP decreased rapidly. These SBP and DBP values were lower than those at rest. After 8 to 16 seconds, the SBP and DBP values recovered to resting levels. Many investigators have reported that isometric contractions elicited an increase in SBP and DBP [1-7]. But there have been few reports of the decrease in SBP and DBP during isometric contractions. The authors believe that the increase in SBP and DBP was due to muscle's activity and the Valsalva maneuver, and the decrease in SBP and DBP was due to the Valsalva maneuver. Furthermore, a rise of activity in the sympathetic nervous system seems to increase SBP and DBP, whereas a decrease in activity may decrease SBP and DBP. An increase in blood pressure is known to be the result of an increase in heart rate and cardiac output, and vasoconstriction in all peripheral vessels. The Valsalva maneuver is known to both increase and decrease blood pressure. McArdle et al [8] reported that with the onset of the Valsalva maneuver at the start of the lift, blood pressure rose abruptly as the elevated intrathoracic pressure forces blood from the heart into the arterial system. Stroke volume and blood pressure then fall sharply due to the reduced venous return from the thoracic veins. MacDougall et al [5] reported that a brief Valsalva maneuver, which exaggerates the increase in blood pressure, was unavoidable when desired force production exceeds 80% MVC. They showed that the Valsalva maneuver initially increased blood pressure. However, if the Valsalva maneuver was maintained for 3 seconds, blood pressure began to decline rapidly. A previous study by the authors [7] also showed that the Valsalva maneuver appeared when isometric contractions exceeded 75% MVC, and the Valsalva maneuver maintained for 5 seconds elicited a decrease in blood pressure equal to the decrease in blood pressure caused by a maximal isometric contraction of the unilateral quadriceps femoris muscle for 5 seconds.

The second purpose of this study was to examine the influence of the location and the strength of the contraction on blood pressure. The results when comparing contraction strength in three locations showed that maximal and minimal SBP and DBP values at 100% MVC were greater than those at 50% MVC.

Therefore, fluctuations in SBP and DBP at 100% MVC were greater than those at 50% MVC. These results support previous reports. Many investigators [1-7] have reported that isometric contractions elicited an increase in SBP and DBP, and the magnitude of the increase depended on the strength of the contraction. MacDougall et al [5] reported that the magnitude of the blood pressure response was related to intensity of effort.

The results in comparing contraction location seemed to show that SBP and DBP changes became progressively greater from fingers flexion to elbow flexion to shoulder flexion. These results would support the conclusions of Seals et al [6] who reported a direct relationship between the size of the active muscle mass and the magnitude of the increases in blood pressure.

The fluctuations of 70mmHg in SBP and 60mmHg in DBP during the maximal shoulder flexion isometric contraction for 5 seconds should be given careful consideration, especially in patients with unstable blood pressures. Further studies should be carried out under more clinical conditions, because the patients who undergo occupational and physical therapy are usually older and may have unstable blood pressures.

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