1. Introduction

Not only do aortas and large arteries (central arteries) connected to aortas function as conduit tubes but also provide a buffer function to level off fluctuations in blood pressure and blood flow. When upper limb arterial stiffness increases, buffer functions deteriorate, thereby increasing the blood pressure and reducing the blood flow efficiency. Intense aerobic exercise training helps to decrease stiffness in central arteries and peripheral arteries. We have demonstrated whether continuous aerobic exercise in elderly women can help to reduce stiffness in peripheral arteries, even when the exercise is relatively mild. Arterial pulse wave velocity (PMV) method was used to measure peripheral (upper arm-forearm) arterial stiffness in test subjects; eight healthy elderly women (age 62±1) who perform moderate exercises continuously and six healthy women (age 61±3) who do not exercise regularly. Findings demonstrate that stiffness in peripheral arteries is significantly lower in the elderly women who participate in continuous aerobic exercise training compared to those with no such exercise routine. These findings show that aerobic exercise on cycle ergometer that mainly uses lower limbs helps to reduce stiffness in upper limb arteries. Therefore, this study suggests that aerobic exercise training in peripheral arteries may have an effect on arteries where lower loads are to be applied.

Keywords: elderly women, exercise training, arterial stiffness, upper limb

With regard to stiffness in peripheral arteries, it has been reported that arterial stiffness is reduced in the stronger, throwing arms of hammer throwers [Giannattasio et al., (1992)]. However, Tanaka et al. (1998) concludes that stiffness in upper limb arteries, unlike in the case of aortas, is less subject to physical activity in women who continue to do aerobic exercise. In contrast, it has been reported that competitive bicyclists whose exercise is focused on the lower limbs have less arterial stiffness in both femoral arteries and upper limb arteries compared with people who have not undertaken training [Kool et al., (1992)]. That is to say that these findings suggest that exercise adaptability is created in upper limb arteries but that these arteries are not necessarily affected by peripheral exercise stress alone. However, it must be noted that many of these studies discuss the effectiveness of relatively strenuous aerobic exercise training, and therefore it remains uncertain whether relatively mild aerobic exercise training can generate adaptability in the peripheral arteries. Although medium-sized arteries in upper limbs show only a slight increase in their stiffness as people age [Nichols and O'Rourke, (1998)], if exercise training can reduce arterial stiffness, we can expect blood flow obstruction in peripheral arteries, which occurs with aging, to be compensated for to some extent, and motor function in peripheral parts to be maintained and enhanced.

The purpose of the present research is to determine whether the intensive use of lower limbs by elderly women through mild bicycle exercise, affects stiffness in peripheral arteries not used in the exercise. A comparative study was made of healthy elderly women who habitually do cycle exercise, and healthy elderly women who do not exercise, through the use of arterial pulse wave velocity (PWV : cm/sec) to evaluate stiffness in peripheral arteries (upper arm-forearm arteries).

2. Methods

2.1. Subjects

The subjects were 14 healthy postmenopausal elderly women aged between 56 and 65. Six women who did not perform regular exercise (age 61±3) made up the control group, while eight women who regular exercised using a leg cycle ergometer (age 62±1) made up a training group. All the subjects neither smoke nor take regular medication and are normotensives (<140/90 mmHg) without any obvious signs of ill health and are all right-handed. The training group had participated in aerobic exercise training for the lower limbs on a cycle ergometer (80% intensity of ventilatory threshold (VT), 5 days/wk, 30-40min/day) for more than one year.

The study was approved by the Ethical Committees of the Institute of Health and Sport Sciences of the University of Tsukuba. The Study conformed with the principles outlined in the Helsinki Declaration, and all subjects gave their written informed consent before inclusion in the study.

2.2. Protocol

Measurements of all the subjects were taken in the morning. After more than a 30-minute rest period in a seated position, blood pressure and pulse wave velocity (PWV) were measured. The subjects in the training group rested for at least one day prior to the test in order to rule out an acute effect of the most recent bout of exercise.

2.3. Measurement of PWV

Using the volume plethysmographic apparatus (form PWV/ABI manufactured in Japan by the Colin Company), the pulse wave velocity of brachial arteries and radial arteries of the subjects was recorded while in a supine resting position to calculate PWV (b-r PWV) from brachial arteries to radial arteries. The waveform of brachial arteries and radial arteries was recorded continuously for 8 seconds, with the lower end of a plethysmogram recording cuff applied to the upper arm and forearm at the respective lower end positions. At the same time, an electrocardiogram was carried out using the tri-electric pole method. To calculate b-r PWV, the distance between the upper and lower end of the cuff, placed around the upper arm and forearm, was divided by the surge time difference, shown in systole of waveform, between the brachial arteries and the radial arteries. The distance was measured using a cloth measure.

2.4. Statistics

The value is given in mean-value ± standard deviation. Student’s unpaired t-test was used for
3. Results

Table 1. shows the age, height, body weight, body mass index, and blood pressure in exercise and control groups

<table>
<thead>
<tr>
<th></th>
<th>Control (n=6)</th>
<th>Exercise (n=8)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>61.2 ± 3.3</td>
<td>62.4 ± 1.3</td>
<td>NS</td>
</tr>
<tr>
<td>Height, cm</td>
<td>150.2 ± 3.9</td>
<td>153.5 ± 3.0</td>
<td>NS</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>52.8 ± 4.4</td>
<td>53.7 ± 1.9</td>
<td>NS</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23.4 ± 1.2</td>
<td>22.8 ± 1.1</td>
<td>NS</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>116.8 ± 10.0</td>
<td>111.1 ± 13.1</td>
<td>NS</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>72.0 ± 5.1</td>
<td>66.5 ± 8.7</td>
<td>NS</td>
</tr>
</tbody>
</table>

BMI: body mass index
SBP: systolic blood pressure
DBP: diastolic blood pressure
Values are means ± SD. NS, not significant.

the significant difference test between the control group and the training group. The level of statistical significance was set below 5%.

4. Discussion

Our study has found that measured PWV is in proportion to Young’s modulus of arterial walls or stiffness, therefore our findings suggest that relatively mild leg cycle training in elderly women reduces stiffness in upper limb arteries to which loads are not expected to be applied during training.

The present study has shown that relatively mild leg cycle training in elderly women reduces stiffness in upper limb arteries to which less amount of loads are to be applied. In contrast, Tanaka et al. (1998) conclude that upper limb stiffness is less subject to physical activities in women who are in a similar age group (aged 59±2) as our subjects. Tanaka et al. measured upper limb stiffness in women who participated in intensive aerobic exercise over an extended period of time (average 13±1 years). In the present study, we measured upper limb arterial stiffness in forearm arteries and brachial arteries which include peripheral arteries in women who participated in relatively mild training for more than one year (specifically a year and several months). As previously described, the research conducted by Tanaka et al. and the current research has differences in the type of training, and the intensity and duration of the exercise, and may have used somewhat different measuring points. However, the exact causes of the differences in findings are unknown. Prior findings have shown that brachial arteries in competitive cyclists, who participated in intensive exercise, are in agreement with the present research findings [Kool et al., (1992)]. In addition, research findings suggest that adaptability to exercise can also be generated in relatively mild training.

If it can be assumed that cycling exercise that mainly uses lower limbs can locally change the tonus in vascular smooth muscles, which is a functional factor governing the degree of elasticity in artery walls, it can be inferred that arterial stiffness can be reduced in upper limb arteries which are not directly involved in exercise. The tonus in vascular smooth muscles is locally affected by such factors as vascular endothelium function. Concerning the effect of aerobic training on vascular endothelium function, it has been reported that blood concentration of nitrite/nitrate (NOx), an endothelium-derived relaxing
substance, increases significantly after training [Maeda et al. (2001)] and blood concentration of endothelin-1, a endothelium-derived constricting substance, is reduced significantly [Maeda et al., (2001); Maeda et al.,(2003)]. Furthermore, findings from animal experiments have shown that aerobic exercise training increases mRNA and protein of NO synthase in aortic tissues [Delp and Laughlin, (1997); Tanabe et al., (2003)]. Therefore, it is suggested that exercise is effective in reducing the tonus in vascular smooth muscles through the changes in vascular endothelial functions. Also it has been reported that the endothelium-dependent and endothelium-independent vasodilation of the upper limb artery diameter increases in late middle-aged men who continue to do intensive exercise that mainly utilizes the lower limbs [Rywik et al., (1999)]. It has also been demonstrated that a significant correlation was found between the amount of physical activity and the endothelium-dependent vasodilation of the upper limb arteries in postmenopausal women [McKechnie et al., (2001)]. Therefore, it is possible that aerobic exercise can help to reduce the tonus in vascular smooth muscles by changing vascular endothelial functions, leading to the reduction of stiffness.

Share stress applied to endothelial cells accelerates synthesis and release of NO [Rubanyi et al., (1986)], therefore increased blood flow in active muscles due to acute exercise may serve as a stimulus to endothelial cells in peripheral arteries. It is reasonable to suggest that exercising lower limbs on cycle ergometer increase the blood flow in the lower limbs, but recent studies have shown that this type of exercise increases blood flow in the forearm and vessel diameter, but administration of NO-syntase inhibitors (L-NMMA) depresses these increments [Green et al., (2002)]. Therefore, it is possible that lower limb exercise increases blood flow in upper limbs, and that increased NO production in peripheral arteries accelerates blood flow. Changes in endothelium function in upper limb arteries may be produced by the recurrent stimulus from exercise. It is presumed that if regular leg cycle exercise can reduce the tonus in vascular smooth muscles through the changes in endothelium function in upper limb arteries (change in endothelium-derived vasoactive substances and the like), arterial in upper limbs can be reduced.

The present study has investigated whether relatively mild leg cycle training in postmenopausal elderly women could be effective in reducing stiffness in the peripheral arteries. Relatively mild leg cycle training in this age group of women reduces stiffness in peripheral arteries. It is interesting to note that the positive effect on peripheral arteries can be seen in arteries where lesser loads are applied. Reduced arterial stiffness helps to reduce systolic arterial pressure and improve blood flow efficiency. Improving arterial stiffness through aerobic exercise training may help to prevent lifestyle restrictions imposed by cardiovascular disorders or cerebral apoplexy, improve motor functions, thus serving the purpose of physical or mental independence and improvement in QOL.

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References
Exercise Training and Arterial Stiffness in Elderly Women


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