**International Journal of Sports Science and Physical Education**
2022; 7(2): 53-58
http://www.sciencepublishinggroup.com/j/ijsspe
doi: 10.11648/j.ijsspe.20220702.13
ISSN: 2575-226X (Print); ISSN: 2575-1611 (Online)

# Effects of Different Exercise Modes on Arterial Stiffness in Young People

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**To cite this article:**
Jianchang Ren, Haili Xiao, Ping Wang. Effects of Different Exercise Modes on Arterial Stiffness in Young People. *International Journal of Sports Science and Physical Education*. Vol. 7, No. 2, 2022, pp. 53-58. doi: 10.11648/j.ijsspe.20220702.13

**Received**: May 28, 2022; **Accepted**: June 15, 2022; **Published**: June 27, 2022

**Abstract:** Arterial stiffness is an index of disease, and it is also an independent predictor of cardiovascular events. Different exercise programs may have different effects on arterial stiffness. We designed to use aortic pulse wave velocity (PWV, an index of arterial stiffness) to evaluate human arterial stiffness and observed the effects of swimming, martial arts and badminton on systemic arterial stiffness in 30 healthy male college students (19-22 years). Subjects participated in three groups in random order (swimming, martial arts, badminton). Subjects participated in swimming, martial arts, and badminton for 30min. The intensity was set at 35% heart rate reserve. Arterial stiffness was measured at baseline (BL), 0min, 30min, and 60min post-exercise. In the swimming group, heart-ankle pulse wave velocity (haPWV) was significantly lower immediately after exercise and 30 minutes before exercise ($p < 0.05$). In the martial arts group, brachial-ankle pulse wave velocity (baPWV) immediately after exercise was significantly higher than that before exercise ($p < 0.05$). In the badminton group, baPWV and haPWV were significantly lower than their pre-exercise levels at 30 minutes after exercise ($p < 0.05$). In all the exercise groups, the arterial stiffness indexes returned to the pre-exercise level 60 minutes after exercise. These results suggest that different muscle groups participating in contraction in the process of different sports may cause different changes in arterial stiffness in different parts.

**Keywords:** Arterial Stiffness, Exercise Modes, Young People

## 1. Introduction

Cardiovascular disease (CVD) has a serious impact on human health [1]. Arterial stiffness is an important step in the process of CVD development and progression. Arterial stiffness has become an important target for the prevention and treatment of CVD [2]. Exercise has been shown to improve vascular function [3-4]. Since the pathological process of atherosclerosis begins in youth, interventions to stop the increase of atherosclerosis in healthy young people can lead to effective prevention of CVD.

Pulse-wave velocity (PWV) is widely used as an index of arterial stiffness [5, 6], and increased arterial stiffness has been identified as an independent risk factor for future CVD [7]. Studies have reported that PWV can increase 2.5-fold with age from age 20 to 91 years [8]. For every 1 m/s increase in PWV, the risk of cardiovascular events and all-cause mortality will increase by 15% [9]. Even in young people without any symptoms, poor lifestyle habits or obesity can accelerate the process of atherosclerosis. Scientific and reasonable exercise training can effectively reduce arterial stiffness and increase arterial elasticity, thus reducing cardiological tube risk. Exercise can improve cardiovascular health and is an important tool in the prevention and treatment of CVD [10, 11]. Numerous studies have confirmed that long-term regular aerobic exercise, such as walking, jogging, cycling, and swimming, can reduce arterial stiffness [12]. Even a week of sustained aerobic exercise can change arterial stiffness. The benefits of long-term aerobic exercise on arteries are well established, but the hemodynamic mechanisms by which long-term aerobic exercise improves arterial elasticity remain unclear. Kingwell et al. [13] found that acute aerobic exercise decreased central artery vascular stiffness, whereas Naka et al. [14] concluded that acute aerobic training increased central artery stiffness and Heffernan et al. [15] concluded that acute aerobic exercise did not alter central artery stiffness. Although moderate exercise intensity is the most commonly recommended exercise prescription, the American College of

Sports Medicine suggests that even when engaging in low recommended amounts of exercise, corresponding health benefits can be obtained as a result of exercise [16]. However, not all exercise has a beneficial effect on arterial stiffness. The present study was designed to evaluate human arterial stiffness using PWV and to observe the acute effects of the low-intensity exercise of different sports on systemic arterial stiffness in healthy youth.

# 2. Methods

### *2.1. Subjects*

Thirty healthy college students, male, aged 19-22 years, with or without previous professional exercise, without diabetes, hypertension, and dyslipidemia, without cardiovascular disease, and without medication. The subjects were informed about the experiment and the experimental procedure before the experiment, and they voluntarily participated in the experiment after reading and signing the informed consent form. The ethics committee of Lingnan normal college-approved all procedures, and the study was carried out according to the Declaration of Helsinki.

### *2.2. Design*

Using a self-control design, subjects participated in three groups in random order (swimming, martial arts, badminton). The trials were performed between 8:00 AM and 11:00 AM following an overnight fast. Arterial stiffness was measured at baseline (BL), 0min, 30min, and 60min post-exercise in the supine position. In the control trial (CON), the subjects sat quietly except for the measurements.

### *2.3. Exercise*

Subjects participated in swimming, martial arts, and badminton for 30min. The intensity was set at 35% heart rate reserve. The targeted heart rates were calculated using the Karvonen formula, which is: targeted heart rate= (220-age-resting heart rate) ×35%+resting heart rate. During exercise, the heart rate of the participant was monitored by a polo heart rate monitor.

### *2.4. Measurement*

Using the Omron atherosclerosis detector (BP-203RPEIII; Omron Colin, Tokyo, Japan), arterial stiffness was evaluated in Pulse-wave velocity (PWV), an index of systemic arterial stiffness. Arterial stiffness was derived from brachial-ankle pulse wave velocity (baPWV) and heart-ankle pulse wave velocity (haPWV). With the subjects in the supine position, pulse waveforms were recorded simultaneously from the brachial and anterior tibial arteries. A microphone overlying the left edge of the recorded the heart sounds while ECG leads, attached to both arms, recorded heart rate. PWV was evaluated by recording a phonocardiogram (set in the third intercostal space on the left side of the sternum through a microphone), pressure waveform of the brachial artery, and posterior tibial artery on the right side of the body (by air plethysmography) for about 10 seconds. The time intervals between the second heart sound and the re-beat notch of the brachial artery pulse wave (Thb), and the time interval between the brachial artery and the start points of ankle systolic elevation (Tba). The average of the right and left PWV was calculated. Measurements of blood pressure and heart rate were made simultaneously by the Omron atherosclerosis detector. Arterial path lengths from the heart to the brachial position (Lhb) and ankle position (Lha) were estimated by the following formulas in the vascular test device from the height of the subject.

baPWV and haPWV were calculated as *the* following equation:

$$\text{baPWV} = (\text{Lha}-\text{Lhb})/\text{Tba},$$

$$\text{haPWV} = \text{Lha}/\ (\text{Thb} + \text{Tba}).$$

### *2.5. Statistical Analysis*

All data are expressed as means±SD if not mentioned otherwise. To observe the time course of PWV dynamics in the trial, one-way ANOVA with repeated measures with Bonferroni post-test was performed. The statistical significance level was set at $P<0.05$. origin Pro (version 2022b) was used for data analysis.

# 3. Results

### *3.1. Characteristics of Participants (Baseline)*

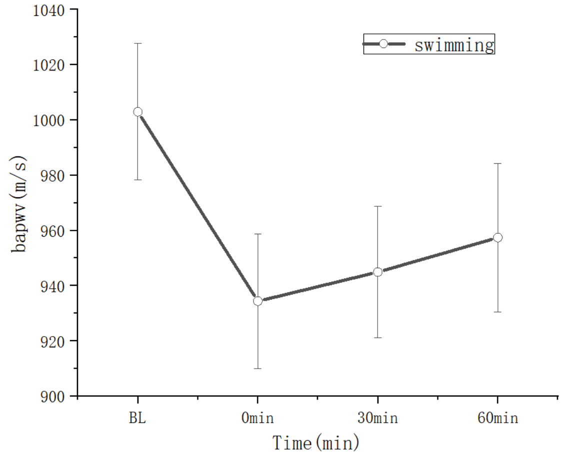
Table 1 shows the subject's baseline characteristics including age, height, weight, body mass index, and blood pressure. According to Omron's atherosclerosis detector, the subject's arteries were as old as their real ages. There was no difference in baPWV, haPWV between the swimming group, martial arts group, and badminton group.

***Table 1.*** *Characteristics of participants (baseline).*

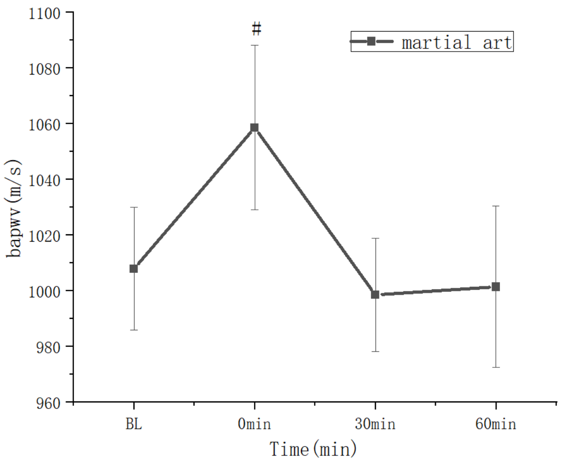
| | Swimming (n=10) | Martial arts (n=10) | Badminton (n=10) | p |
|---|---|---|---|---|
| Age (years) | 20.82±1.32 | 21.75±1.04 | 21.44±0.53 | 0.16 |
| Height (m) | 170.36±7.84 | 167.50±7.58 | 172.777±6.37 | 0.35 |
| Weight (kg) | 69.272±11.87 | 65.13±11.34 | 66.722±11.55 | 0.74 |
| Body mass index | 23.76±3.23 | 23.19±3.69 | 22.200±3.08 | 0.58 |
| Resting systolic blood pressure (mmHg) | 115.36±11.26 | 110.50±14.22 | 118.333±10.71 | 0.41 |
| Resting baPWV (m/s) | 991.14±83.87 | 1001.00±59.87 | 1094.94±144.48 | 0.07 |
| Resting haPWV (m/s) | 688.27±62.84 | 695.94±53.42 | 732.944±78.26 | 0.31 |

* baPWV. brachial-ankle pulse wave velocity. haPWV, heart-ankle pulse wave velocity.

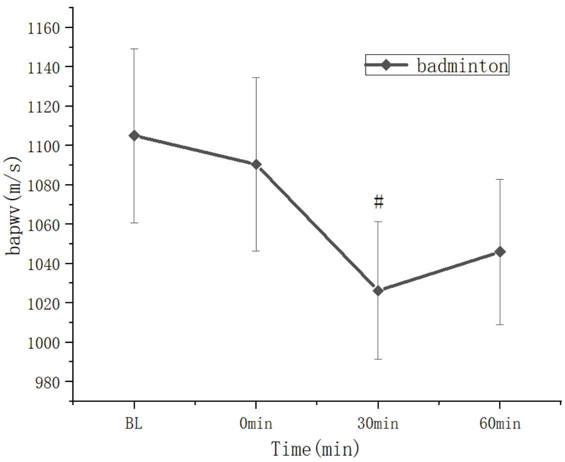
### *3.2. Changes of baPWV and haPWV with Time in Swimming, Martial Arts, Badminton Exercise Trials*




(a)

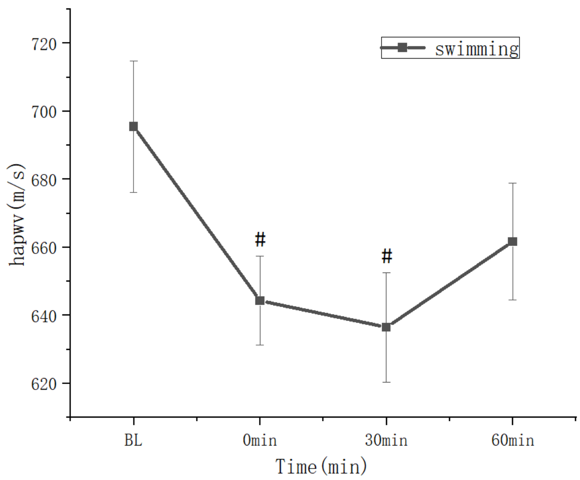



(b)

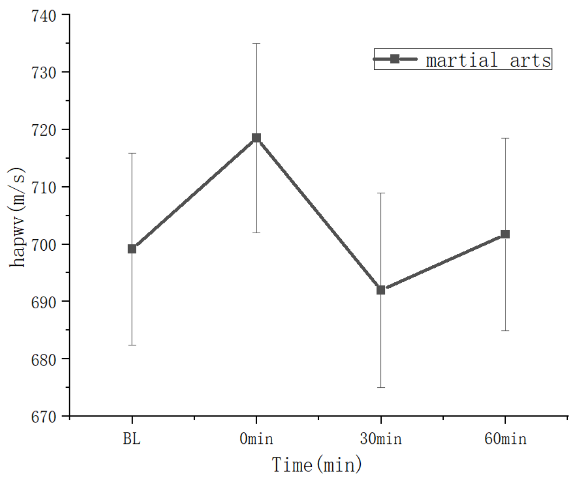



(c)

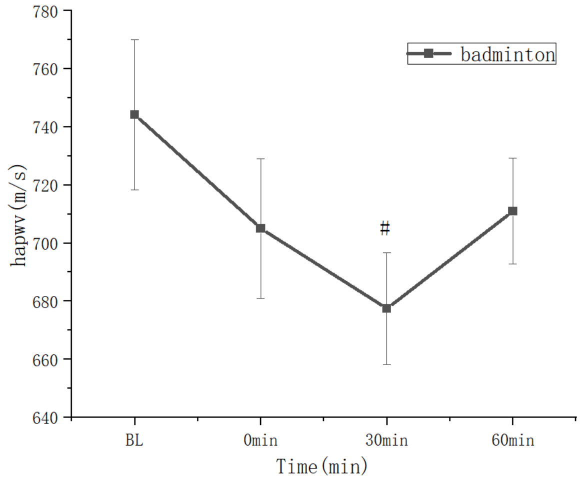
***Figure 1.*** *Changes of bapwv with time in swimming (a), martial arts (b), badminton (c) exercise trials. One-way ANOVA with repeated measures with Bonferroni's multiple comparison test was used in the data analysis. The data are means±SE, n=30. #P<0.05 vs BL. BL baseline, 0min immediately after the completion of exercise, 30min 30min after the completion of exercise, 60min 60min after the completion of exercise.*




(a)




(b)




(c)

***Figure 2.*** *Observation of the change in hapwv over time in swimming (a), martial arts (b), and badminton (c) exercise trials. One-way ANOVA with repeated measurements with Bonferroni's multiple comparisons was used to analyze the data. The data are means±SE, n=30. #P<0.05 vs BL. BL baseline, 0min immediately after the completion of the exercise, 30min 30min after the completion of the exercise, 60min 60min after the completion of the exercise.*

The mean (±SE) changes of baPWV in swimming, martial arts, badmintand on exercises were presented in Figure 1. Bapwv unaltered in the swimming exercise group (1002.95±24.72, 934.4±24.43, 944.95±23.79, 957.4±26.87 at BL, 0min, 30min, and 60min, respectively). BaPWV changed in the martial arts exercise group (1007.95±22.03, 1058.6±29.56 at BL, 0min, respectively). BaPWV changed in the badminton exercise group (1105.1±44.26, 1026.3±34.97 at BL, 30min, respectively).

The mean (±SE) changes of haPWV in swimming, martial arts, and badminton exercise were presented in Figure 2. HaPWV changed in the swimming exercise group (695.5±19.36, 644.3±13.04, 636.5±16.13 at BL, 0min, and 30min respectively). HaPWV was unaltered in the martial arts exercise group (699.15±16.69, 718.5±16.48, 692±16.98, 701.7±16.802 at BL, 0min, 30min, and 60min, respectively). BaPWV changed in the badminton exercise group (744.2±25.91, 677.45±19.21 at BL, 30min).

In Figure 1 and Figure 2, Bonferroni post-test shows that baPWV in mean±SD increased significantly from 1007.95±22.03 at baseline (BL) to 1058.6±29.56 at 0min in the martial arts exercise group. BaPWV in mean±SD decreased significantly from 1105.1±44.26 at baseline (BL) to 1026.3±34.97 at 30min in the badminton exercise group. HaPWV in mean±SD decreased significantly from 695.5±19.36 at baseline (BL) to 644.3±13.04 at 0min and 636.5±16.13 at 30min in the swimming exercise group. HaPWV in mean±SD decreased significantly from 744.2±25.91 at baseline (BL) to 677.45±19.21 at 30min in the badminton exercise group.

## 4. Discussion

The main finding of this study was that swimming and badminton for 30 minutes can reduce arterial stiffness, but martial arts for 30 minutes can increase arterial stiffness. After 60 minutes of exercise, the arterial stiffness of swimming, martial arts, and badminton groups returned to the pre-exercise level.

This is consistent with the results of previous studies. Aerobic exercise reduces arterial stiffness, while resistance exercise increases arterial stiffness. Moderate energy circulation for 30 minutes can reduce arterial stiffness [17]. A meta-analysis suggests that resistance training stand-alone does not elicit changes in AS in healthy subjects, but the high heterogeneity suggests an influence of training protocol and/or personal characteristics that should be investigated in the future [18].

Acute low-intensity aerobic exercise can reduce arterial stiffness, but different types of exercise have different acute effects on arterial stiffness. The arterial stiffness was significantly decreased in the swimming group immediately after exercise (Figure 2a), but it was significantly decreased in the badminton group 30 minutes after exercise (Figure 1c, Figure 2c). Static muscle contraction during martial arts may temporarily increase the stiffness of arteries (Figure 1b).

In this case, PWV (heart-ankle PWV, haPWV) from the heart to the ankle, measured by the cuff blood pressure measurements, includes the proximal aorta in addition to the same artery segment of baPWV. Different sports have different effects on the indexes of baPWV and haPWV. In this study, swimming had no significant effect on bapw, but it has a significant effect on haPWV, which was still significantly lower immediately after swimming and 30 minutes after swimming. Badminton had a significant effect on both baPWV and haPWV, but it was lower than the pre-exercise level only 30 minutes after exercise, and it was not significantly lower than the pre-exercise level immediately after exercise, indicating that badminton had a delayed effect on the impact of arterial hardness. According to Tomato, the stiffness of the proximal aorta has a greater impact on aerobic capacity than that of the distal aorta [19]. Cheung reported that the central vascular system of excellent water athletes varies from discipline to discipline [20]. According to previous studies and this study, aerobic exercise is beneficial to improve arterial stiffness, and different exercises have different effects on arterial stiffness. The above results suggest that a variety of sports should be selected for daily exercise.

Acute resistance movement can temporarily increase arterial stiffness (Figure 1b). The effect of resistance training on arterial stiffness has not been consistent in previous studies. Werner reported that chronic resistance training does not seem to affect the stiffness of the central artery, regardless of the amount and load of training [21]. However, a review showed that low-intensity and high-intensity radiotherapy may not affect arterial stiffness, while low-intensity radiotherapy may reduce systemic arterial stiffness (brachial artery stiffness) in young healthy adults, or may not affect arterial stiffness in middle-aged and old people [22]. The results of research on the effect of resistance exercise on arterial hardness are inconsistent, which may be due to the different effects of resistance exercise in different parts of the body on arterial hardness. With regard to the main muscle groups used in strength intervention (upper body, lower body, or full body), Okamoto specifically compared the differences between vigorous-intensity combined resistance training protocols for the upper and lower body [23]. The results showed that the arterial stiffness in the upper body increased greatly, but that of the lower body decreased slightly. This can be explained by the fact that resistance training of upper body muscle groups increases arterial stiffness, which can be proved by the increase of the concentration of norepinephrine in plasma. In this study, there are a lot of static contractions in the muscles of the whole body during martial arts, which might be the reason for the temporary increase of baPWV index after martial arts.

Tomato observed in regularly highly-trained endurance athletes that haPWV and baPWV significantly increased following a one-week vigorous training camp characterized by greater training volume. Interestingly, the individual response of haPWV, but not baPWV, correlated with the corresponding changes in myocardial contractility [24]. In this study, swimming had no significant effect on baPWV, but it had a significant effect on haPWV. Badminton has a significant influence on both baPWV and haPWV.

This means that different muscle groups participating in contraction in the process of different sports may cause different changes in arterial stiffness in different parts. In order to keep healthy, we should take part in various sports activities.

Future research should expand the sample size to study the effect of different exercise programs on arterial stiffness in different ages and different populations.

# 5. Conclusion

We designed to use aortic pulse wave velocity (PWV, an index of arterial stiffness) to evaluate human arterial stiffness and observed the effects of swimming, martial arts, and badminton on systemic arterial stiffness in healthy male college students. We found that swimming and badminton for 30 minutes can reduce arterial stiffness, but martial arts for 30 minutes can increase arterial stiffness. After 60 minutes of exercise, the arterial stiffness of swimming, martial arts, and badminton groups returned to the pre-exercise level.

# Acknowledgements

This work was funded by the Philosophy and Social Science Planning Project of Guangdong Province (GD19CTY10).

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