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Research Article

Optimizing Exercise Interval for Arterial Stiffness Improve-Ment in Middle-Aged Adults

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Abstract

By decreasing the interval periods and increasing the frequency of exercise bouts, we were able to confirm our hypothesis that middle-aged adults could achieve a greater reduction in arterial stiffness through intermittent exercise. Thirty middle-aged males were randomly divided into a control group (CON), continuous exercise group (CE), interval exercise long-long group (IELL), interval exercise long-short group (IELS), and interval exercise short-short group (IESS). The subjects performed moderate-intensity exercise on the treadmill. Cardio-ankle vascular index (CAVI) was assessed before exercise, right after the session ended, and at 30 and 60 minutes into the recovery period. Changes in values from the baseline (ΔCAVI) during each measurement were used for analysis. The control group showed no significant change in ΔCAVI, while all exercise groups showed a significant decrease at 0, 30, and 60 minutes. The exercise groups had significantly lower ΔCAVI than the control group at 0 and 30 minutes. At 60 minutes, the IESS group had a significantly lower ΔCAVI than the control group. Additionally, at 0 and 30 minutes, the IELS and IESS groups had a significantly lower ΔCAVI than the CE group. Hence, interval exercise is more effective than continuous exercise regardless of the total duration, but the effectiveness depends on the interval duration and number of repetitions.

Keywords

Interval Exercise, Arterial Stiffness, Middle-Aged, Cardiovascular Disease

1. Introduction

Arterial stiffness is a well-established predictor of cardiovascular events, and age is one of the major contributing factors to its development. As cardiovascular disease (CVD) remains a leading cause of morbidity and mortality worldwide, identifying and managing arterial stiffness is crucial for effective prevention and treatment [1, 2]. Arterial stiffness refers to a decrease in arterial compliance due to aging and other factors [3]. This is because arterial stiffness contributes to an increase in systolic blood pressure and pulse wave velocity (PWV), both of which are associated with an elevated risk of CVD. Many studies have explored the correlation between arterial stiffness and CVD. For example, a study by Laurent et al. found that PWV was a strong predictor of CVD [4], independent of traditional risk factors such as age, sex, and blood pressure. Similarly, in a study by Vlachopoulos et al., middle-aged individuals with in-creased arterial stiffness had a higher incidence of CVD [5]. In regards to assessing arterial stiffness, the PWV has long been widely utilized as the gold standard [6], although it may be affected by changes in blood pressure, rendering accurate evaluation of arterial

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stiffness in response to exercise difficult. In recent years, the cardio-ankle vascular index (CAVI) [7, 8], which takes into account blood pressure factors, has gained attention for its application in evaluating arterial stiffness.

Numerous studies have confirmed that aerobic exercise positively impacts arterial stiffness [9-11]. Due to dose-response considerations, research on the effectiveness of different intensity levels and exercise modes (continuous and intermittent) in improving vascular stiffness has become a focus of attention. Studies have found that com-pared to continuous aerobic training sessions, interval training could result in more notable enhancements in respiratory parameters among healthy individuals, as well as patients with cardio-vascular or cardiorespiratory disease [12, 13]. A study has shown that, under the same exercise volume, interval exercise may be a more effective way of reducing arterial stiffness, and that high-intensity interval training (HIIT) has better effects in achieving this goal [14]. Similar research demonstrates that intermittent exercise is more effective in reducing arterial stiffness compared to continuous exercise and that individual differences and factors such as basal arterial stiffness, BMI, and cardiorespiratory fitness can all affect changes in arterial stiffness [15]. Another re-search suggests that among healthy elderly individuals, moderate-intensity continuous exercise has a beneficial impact on PWV, compared to sedentary control groups. In elderly individuals with varying levels of cardiorespiratory fitness, PWV values tend to be lower after high-intensity interval exercise compared to the control group [16].

The mechanism behind the beneficial effects of HIIT is not yet fully understood, whether due to the high intensity or the interval itself. Recently, we have demonstrated that in young healthy individuals, intermittent exercise leads to a more significant lowering of arterial stiffness compared to contin-uous exercise when exercise volume is held constant [17]. As the interval period increases, the acute superiority disappears, while increasing the number of exercise sessions can preserve the effect of interval exercise. This suggests that the efficacy of intermittent exercise is influenced by the interval period and the number of exercise bouts. As individuals age and various lifestyle factors shift, middle-aged adults are at an increased risk of developing atherosclerosis. Therefore, it is of paramount importance for this demographic to prioritize preventative measures against such an affliction. To further substantiate the superiority of interval training, we have de-vised a prescription for middle-aged individuals engaged in intermittent physical activity, which we have compared with an equally intense continuous exercise regimen. We postulate that augmenting exercise frequency and shortening interval duration may further enhance the efficacy of intermittent exercise, thereby producing a more advantageous impact on arterial stiffness that surpasses the effects of equally intense continuous exercise.

2. Materials and Methods

2.1. Participants

The participants of this experiment were recruited from a rehabilitation center and consisted of middle-aged men who underwent physical examinations. We have recruited 36 par-ticipants to take part in this study. However, due to personal circumstances, 3 participants were unable to complete the entire test. Furthermore, one participant withdrew from the study midway through the testing process, whereas the data of the remaining two participants was incomplete and therefore, they could not complete the supplementary testing. As a result, the final number of participants included in this study is 30. A total of 30 male middle-aged participants with an average age of 56.5 ±1.9 years (Table 1) were enrolled in the study. Prior to their involvement in the experiment, all participants were required to provide informed consent by signing a consent form. None of the subjects smoked, but all had blood pressure within normal high values. The study was ethically approved by the ethics committee of Lingnan normal university and was conducted in accordance with the Helsinki Declaration. For three days prior to the experiment, all participants refrained from intense exercise, alcohol, and caffeine intake. Partici-pants were instructed to fast and remain at rest for at least 30 minutes before taking the baseline measurement. All exper-iments were conducted at a cardiovascular health examination center, at a temperature between 22-26 degrees.

2.2. Study Design

The study utilized a balanced cross-over design with self-controlled measures. Each participant completed five treadmill tests, performed in a randomized sequence and spaced three days apart. The five tests comprised the follow-ing: (i) control (CON); (ii) 30-minute continuous exercise trial (CE); (iii) (IELL) two sets of 10-minute treadmill exer-cise sessions followed by a 10-minute rest period (IELL); (iv) two sets of 10-minute treadmill exercise sessions followed by a 5-minute rest period (IELS); and (v) four sets of 5-minute treadmill exercise sessions separated by 5-minute rest periods (IESS). These are depicted in Figure 1. Experimental proce-dures took place within the morning timeframe of 8:00 am to 12:00 pm. CAVI was measured at baseline (BL), as well as at 0, 30, and 60 minutes following the completion of every ex-ercise session. During the exercise tests, participants engaged in moderate-intensity treadmill exercise.

In order to track variations in ΔCAVI subsequent to each interval during the experimental group undergoing IESS, an additional three appraisals of ΔCAVI were administered prior to the B1, B2, and B3 5-minute exercise episodes, as illus-trated in Figure 1.

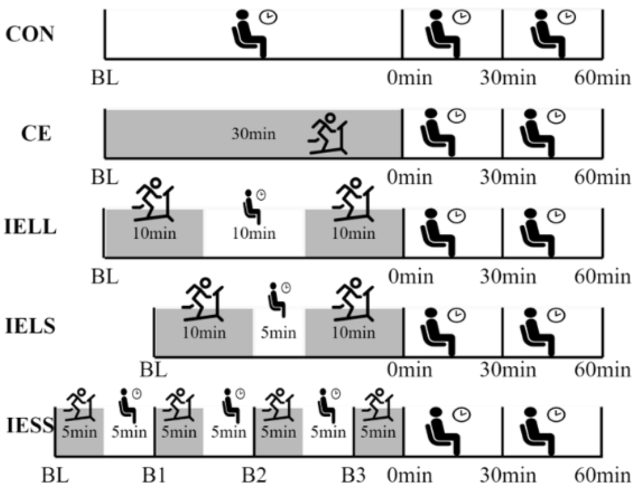

Figure 1. *Exercise design. This study entails five experiments: a control experiment (CON), a single 30-minute exercise experiment (CE), two 10-minute treadmill exercise experiments with a 10-minute rest period in between (IELL), two 10-minute treadmill exercise experiments with a 5-minute rest period in between (IELS), and four 5-minute treadmill exercise experiments with a 5-minute rest period in between (IESS). In the CE, IELL, IELS, and IESS experiments, time measurements were taken at baseline (BL), immediately after exercise (0 minutes), 30 minutes after exercise, and 60 minutes after exercise. Additionally, three additional CAVI measurements were taken before the second (B1), third (B2), and fourth (B3) 5-minute exercise sessions in the IESS experiment.*

2.3. Exercise Protocol

The exercise trials were carried out employing a treadmill (Quark C12, Cosmed Srl, Italy). Exercise intensity was determined using the following formula: target heart rate = [(220 - age - resting heart rate) × 45%] + resting heart rate, where 45% represents the desired exercise intensity level, and resting heart rate is the heart rate before exercising. While exercising on a treadmill, a heart rate monitor sensor was attached to the exerciser's body to track their heart rate. Based on this, the treadmill speed was carefully adjusted to maintain a consistent target heart rate throughout the workout.

2.4. Measurement

The CAVI measurements were obtained using the VS-1000 Arteriosclerosis Test Instrument, manufactured by Beijing Fukuda Electronic Medical Instruments Co., Ltd. Trained medical professionals performed the tests while participants lay supine on a bed, with their limbs straightened. An upper arm cuff was attached to the upper arm, positioned so the bottom edge was level with the elbow joint, and adjusted to fit snugly around one or two fingers. Lower extremity cuffs were placed above the ankle joint, and cushioning pads were placed under the elbows and heels for support. Electrocar-diogram electrodes were clipped onto both wrists, and a phonocardiographic sensor was placed near the sternum and adjusted until the heart signal could be clearly distinguished from the first and second heart sounds. The VS-1000 instrument then automatically measured the participant's CAVI. Mean CAVI values were calculated for both the right and left sides, and the difference (ΔCAVI) between these values and the baseline was calculated for subsequent analysis.

2.5. Statistical Analysis

The data were displayed as the means ± SE. Disparities in ΔCAVI among exercise regimens were evaluated via four distinct two-factor repeated-measures ANOVAs structured in a three (group) × four (time) model. The Bonferroni post hoc test was employed to identify significant variations within each trial, and Mauchly's sphericity test was performed to inspect the assumption of sphericity. To discern the time-varying patterns of ΔCAVI in the IESS experiment, a one-way ANOVA featuring repeatedly measured outcomes was conducted, and subsequent Bonferroni post hoc tests were implemented. A significance level of $p < 0.05$ was chosen, and Origin 2023b was utilized for data analysis.

3. Results

3.1. Subsection

Table 1 presents the initial attributes of the participants, including age, height, weight, body mass index (BMI), CAVI, and blood pressure. Furthermore, the participants exhibited arterial rigidity that was consistent with their chronological age as determined by the VS-1000 Arteriosclerosis Test Instrument system.

Table 1. *Participant characteristics (n = 30).*

	Value (Mean ± SE)
Age (years)	56.5 ± 1.9
Height (cm)	171.2 ± 4.3
Weight (kg)	80.3 ± 5.3
BMI (kg/m2)	27.2 ± 5.7
Systolic BP (mmHg)	132.3 ± 3.5
Diastolic BP (mmHg)	81.8 ± 2.7
CAVI	8.2 ± 0.6

BMI, body mass index; BP, blood pressure.

3.2. Arterial Stiffness

The changes of ΔCAVI in the experiment were exhibited in Figures 2 and 3. In the control group, ΔCAVI did not show significant changes over time (0.00 ±0.00 at base-line, -0.06 ±0.12 at 0 min, -0.045 ±0.05 at 30 min, -0.01 ±0.02 at 60 min). However, in the CE experimental group, Δ CAVI showed significant changes over time (0.00 ±0.00 at base-line, -0.63 ±0.23 at 0 min, -0.41 ±0.11 at 30 min, -0.03 ± 0.02 at 60 min). Similar changes were observed in the IELL experimental group (0.00 ±0.00 at baseline, -0.69 ±0.31 at 0 min, -0.44 ±0.20 at 30 min, -0.05 ±0.05 at 60 min), the IELS experimental group (0.00 ±0.00 at baseline, -0.78 ± 0.21 at 0 min, -0.54 ±0.12 at 30 min, -013 ±0.08 at 60 min), and the IESS experimental group (0.00 ±0.00 at baseline, -0.82 ±0.20 at 0 min, -0.61 ±0.12 at 30 min, -0.23 ±0.21 at 60 min).

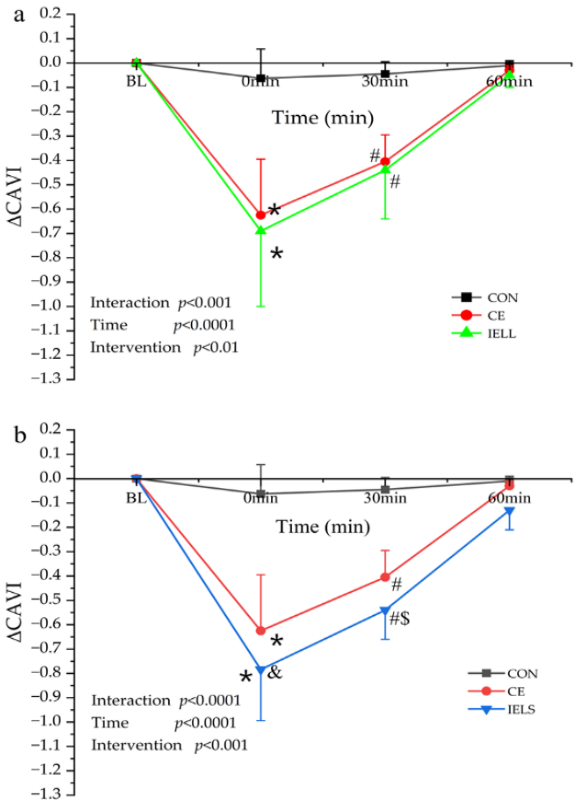

Figure 2. *Changes in ΔCAVI over time were observed during both intermittent exercise and continuous exercise experiments. The mean (±SD) is time-dependent ΔCAVI changes in CON, CE, and IELL trials (a) and CON, CE, and IELS trials (b). * p < 0.01, CE, IELL, and IELS vs. CON at 0 min. # p < 0.01, CE, IELL, and IELS vs. CON at 30 min. & p < 0.05, IELS vs. CE at 0 min. $p < 0.05, IELS vs. CE at 30 min. n = 30.*

As shown in Figure 2 and Figure 3, there was a significant interaction between intervention and time ($p < 0.001$ in Figure 2a, $p < 0.0001$ in Figure 2b; $p < 0.0001$ in Figure 3a and Figure 3b), indicating that the changes in ΔCAVI differed over time in each experiment. A significant main effect of time was also observed ($p < 0.0001$ in Figure 2a and Figure 2b; $p < 0.0001$ in Figure 3a and Figure 3b), suggesting that ΔCAVI under-went significant changes over time. The main effect of the intervention was also significant ($p< 0.01$ in Figure 2a, $p < 0.001$ in Figure 2b; $p < 0.0001$ in Figure 3a, $p< 0.001$ in Figure 3b).

The Bonferroni post-hoc test revealed that in Figure 2 and Figure 3, ΔCAVI in the exercise intervention group was significantly lower than in the control group at 0 min (*p < 0.01 for CE, IELL, IELS, IESS compared to the CON group) and at 30 min (#p < 0.01 for CE, IELL, IELS, IESS compared to the CON group). At 60 min, ΔCAVI in the IESS group was significantly lower than in the CON group (¥p < 0.01). In Figure 2b, ΔCAVI in the IELS group was significantly lower than in the CE group at 0 min and 30 min (&p < 0.05). In Figure 3a, ΔCAVI in the IESS group was significantly lower than in the CE group at 0 min and 30 min (&p < 0.05).

ΔCAVI in the IESS group showed a significant decrease from the baseline value of 0.00±0.00 to -0.50±0.41 at B1, -0.63±0.51 at B2, -0.7±0.44 at B3, -0.83±0.20 at 0 min, -0.61±0.12 at 30 min, and -0.23±0.21 at 60 min, as demonstrated in Figure 4.

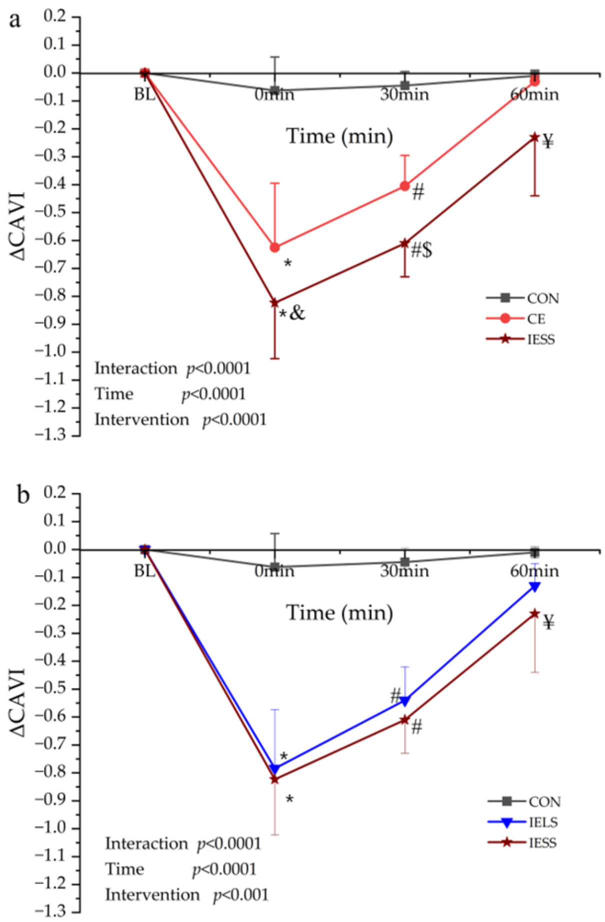

Figure 3. *Changes in ΔCAVI over time were observed during intermittent exercise experiments with different rest periods. The mean (±SD) ΔCAVI changes in CON, CE. and IESS trials (a) and CON, IELS, and IESS trials (b). * p < 0. 01, CE, IELS, and IESS vs. CON at 0 min. # p < 0.01, CE, IELS, and IELS vs. CON at 30 min. ¥p < 0.05, IESS vs. CON at 60 min. & p < 0.05, IESS vs. CE at 60 min. n = 30.*

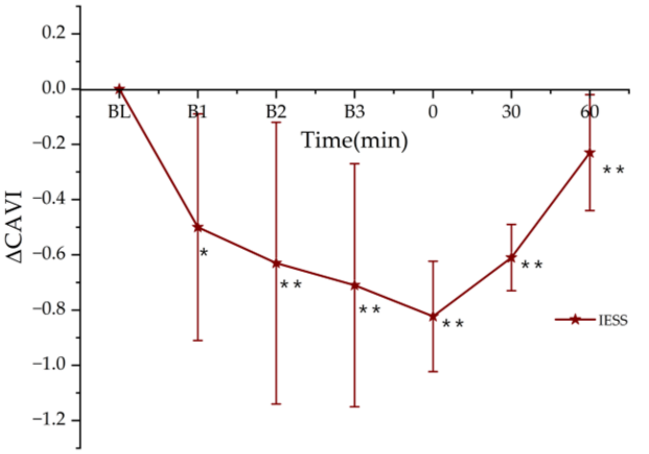

*Figure 4. The change of ΔCAVI over time in the IESS experiment. * $p < 0.05$ vs. BL; ** $p < 0.01$ vs. BL. n = 30.*

4. Discussion

A considerable amount of research has been conducted on the immediate and prolonged impacts of aerobic exercise on arterial stiffness [11, 18-20]. According to our study, middle-aged individuals may experience more favorable effects on arterial stiffness by engaging in intermittent exercise with shorter rest intervals compared to continuous exercise. These findings supplement the literature surrounding the improvement of cardiovascular health in middle-aged individuals through intermittent exercise and provide evidence supporting its viability as a practical exercise prescription.

4.1. Effects of Rest Intervals on Arterial Stiffness Changes During Exercise in Middle-Aged Individuals

HIIT is a calculated routine that comprises intense, short-lived exercises, alternating with periods of active recuperation. This form of training has been scientifically shown to deliver better results than traditional aerobic exercise, in less time. Numerous well-documented studies demonstrate that HIIT has a positive effect on arterial stiff-ness. For instance, just four weeks of high-intensity interval training can improve arterial stiffness among normal-weight, obese female university students [21]. Other re-search shows that HIIT has acute effects on vascular stiffness in healthy men; such as reducing the femoral-to-posterior-tibial artery pulse wave velocity [22]. Similarly, following high-intensity interval training, older adults experienced a decrease in the pulse wave propagation velocity.

Studies have also shown that HIIT surpasses moderate-intensity continuous training in improving cardiorespiratory fitness among obese and hypertensive populations [19, 23]. Recognizing the correlation between physical activity magnitude and cardiovascular reaction, it's imperative to distinguish whether the benefits of HIIT are due to its magnitude or rest interval. This study suggests that the effects of interval and continuous exercise of equal volume can be compared and that the impact of interval training can be independently evaluated.

Although high-intensity exercise is beneficial for cardiovascular health, it may not be suitable for certain populations and can be difficult to sustain. For most middle-aged and elderly individuals, especially those with underlying medical conditions, high-intensity exercise may not be the exercise of choice. Low-intensity activity has limited beneficial effects, and a recommended level of physical activity is engaging in moderate-intensity exercise, according to the guidelines [24]. The findings from this re-search indicate that engaging in two sets of 10-minute treadmill exercises with a 10-minute rest period can yield similar benefits to performing 30 minutes of continuous treadmill exercise in terms of arterial stiffness changes among middle-aged adults, as presented in Figures 1 and 2. Compared to continuous exercise, intermittent exercise with 10-minute rest intervals is more acceptable to the general population.

The reason why interval training may be superior to continuous exercise is likely due to the accumulation of effects. In other words, engaging in exercise during the beneficial effects produced by the previous exercise will cause these effects to accumulate. From our prior investigation, it was evident that short rest periods between exercise sessions produce superior results in enhancing arterial stiffness among young adults than in performing continuous exercise [17]. However, further research has shown that when the interval between two exercise sessions is too long, the advantages of interval training disappear [25]. Based on this, we can propose the hypothesis that an appropriate rest interval duration can amplify the benefits of exercise in terms of improving arterial stiffness (even though the ideal time for rest intervals has not been established yet). Our research results have shown that two 10-minute exercise sessions with a brief rest of 5 minutes in between have a greater effect on improving arterial stiffness in middle-aged adults than continuous exercise for 30 minutes (see Figure 1 and Figure 2b). Furthermore, after engaging in 30 minutes of continuous exercise or interval training, arterial stiffness in the lower limbs was reduced only in the case of interval training [14]. The author believes that this may be due to different reactions of peripheral blood vessels during exercise, where interval training can result in greater vascular adaptability stimulation, leading to the release of endothelial or metabolic vascular active factors. This also supports our hypothesis: the brief rest during interval training enhances the overall effect of exercise. Additionally, the brief rest increases public acceptance of exercise, making it easier to sustain.

4.2. Effects of Intermittent Frequency on Arterial Stiffness Changes During Exercise in Middleaged Individuals

Although it is commonly believed that short bouts of exercise have limited benefits for the body, some studies show that even short periods of exercise can have a positive effect on fitness, such as several consecutive 5-minute sessions [11, 26].

In the current research, we developed a more practical version of interval training by incorporating 5-minute workout intervals followed by a 5-minute rest, using a treadmill to facilitate the exercise routine (as in IESS in Figure 1). Our findings suggest that this method is more effective in improving arterial stiffness in middle-aged adults than continuous exercise for 30 minutes, which is consistent with our previous re-search on young individuals. We also compared the effects of four 5-minute exercise sessions with two 10-minute sessions on arterial stiffness improvement (as shown in Figure 1 and Figure 3b).

Within one hour, the arterial stiffness was observed to be considerably lower in the IESS group as compared to the IELS group, possibly due to the cumulative effects of four exercise sessions being more beneficial than two. The gradual reduction of ΔCAVI observed during exercise in the IESS group might be attributed to alterations in cardiovascular hemodynamics prompted by interval training, as well as the discharge of vascular endothelial active factors. At 60 minutes, only the IESS group showed a significant difference from the control group, which differs from our previous findings in healthy young participants, possibly due to individual differences in cardiorespiratory function and cardiovascular responses to exercise.

Our study has important implications for individuals who are unable to engage in high-intensity exercise and need to complete multiple physical workouts within a short time period. Fatigue is one of the factors that hinders people from engaging in physical activity regularly. Incorporating brief rest periods during exercise sessions and allowing individuals to accomplish more physical activities within an hour can enhance overall exercise adherence. Previous exercise regimens required low-intensity exercise during the intermission period, but we found that stopping exercise during the inter-mission period is easier to accept and execute, making this moderate-intensity interval exercise even more appropriate for reducing arterial stiffness. Based on our research on optimal interval length and exercise duration, we have developed a more practical and effective interval exercise prescription.

Future research could explore the precise biological mechanisms by which interval exercise improves arterial stiffness. This study has certain limitations, as it only included healthy middle-aged individuals and did not examine elderly individuals with chronic diseases. The main emphasis of the research was to examine the immediate effects of interval training and did not involve long-term intervention studies. Hence-forth, future research ought to investigate the impact of interval exercise at different intervention periods on arterial stiffness among elderly individuals. In this section, authors are advised to provide a thorough analysis of the results and make comparisons with relevant literature, not a short summary or conclusion. Any future research directions could also be stated in the discussion.

5. Conclusions

The primary findings of this investigation indicate that moderate-intensity aerobic exercise can temporarily reduce arterial stiffness in middle-aged individuals. Moreover, the impact of interval exercise on arterial stiffness improvement surpasses that of continuous exercise and is unaffected by total exercise duration. The duration of intervals in intermittent exercise and the number of exercise repetitions affect the effectiveness of interval exercise in improving arterial stiffness in middle-aged individuals.

Abbreviations

CVD	Cardiovascular Disease
CAVI	Cardio-ankle Vascular Index
PWV	Pulse Wave Velocity
BMI	Body Mass Index

Author Contributions

Haili Xiao: Conceptualization, Funding acquisition, Methodology, Writing – original draft

Jianchang Ren: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Writing – review & editing

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Laurent S, Cockcroft J, Van Bortel L, Boutouyrie P, Giannattasio C, Hayoz D, Pannier B, Vlachopoulos C, Wilkinson I, Struijker-Boudier H. Expert consensus document on arterial stiffness: methodological issues and clinical applications. Eur Heart J 2006; 27: 2588-605. https://doi.org/10.1093/eurheartj/ehl254

[2] Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. J Am Coll Cardiol 2010; 55: 1318-27. https://doi.org/10.1016/j.jacc.2009.10.061

[3] Mitchell GF, Hwang SJ, Vasan RS, Larson MG, Pencina MJ, Hamburg NM, Vita JA, Levy D, Benjamin EJ. Arterial stiffness and cardiovascular events: the Framingham Heart Study. Circulation 2010; 121: 505-11. https://doi.org/10.1161/CIRCULATIONAHA.109.886655

[4] Laurent S, Boutouyrie P, Asmar R, Gautier I, Laloux B, Guize L, Ducimetiere P, Benetos A. Aortic stiffness is an in-dependent predictor of all-cause and cardiovascular mortality in hypertensive patients. Hypertension 2001; 37: 1236-41. https://doi.org/10.1161/01.hyp.37.5.1236

[5] Vlachopoulos C, Aznaouridis K, Terentes-Printzios D, Ioakeimidis N, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with brachial-ankle elasticity index: a systematic review and meta-analysis. Hyper-tension 2012; 60: 556-62. https://doi.org/10.1161/HYPERTENSIONAHA.112.194779

[6] Blacher J, Asmar R, Djane S, London GM, Safar ME. Aortic pulse wave velocity as a marker of cardiovascular risk in hypertensive patients. Hypertension 1999; 33: 1111-7. https://doi.org/10.1161/01.hyp.33.5.1111

[7] Shirai K, Utino J, Otsuka K, Takata M. A novel blood pressure-independent arterial wall stiffness parameter; cardio-ankle vascular index (CAVI). J Atheroscler Thromb 2006; 13: 101-7. https://doi.org/10.5551/jat.13.101

[8] Koshiba H, Maeshima E. Effects of exercise intervention on arterial stiffness in middle-aged and older females: evaluation by measuring brachial-ankle pulse wave velocity and cardio-ankle vascular index. J Phys Ther Sci 2019; 31: 88-92. https://doi.org/10.1589/jpts.31.88

[9] Heil L, Oberhoffer R, Bohm B. Association Between Physical Activity Intensity Levels and Arterial Stiffness in Healthy Children. J Phys Act Health 2020; 17: 933-9. https://doi.org/10.1123/jpah.2019-0594

[10] Higaki Y, Yamato Y, Fujie S, Inoue K, Shimomura M, Kato S, Horii N, Ogoh S, Iemitsu M. Acute effects of the differ-ent relaxation periods during passive intermittent static stretching on arterial stiffness. Plos One 2021; 16: e259444. https://doi.org/10.1371/journal.pone.0259444

[11] Zhou Z, Hou L, Cui M, Mourot L, Zhu W. Acute effects of low-volume intermittent versus higher-volume continuous exercise on arterial stiffness in healthy young men. Sci Rep 2022; 12. https://doi.org/10.1038/s41598-022-05800-z

[12] Trapp EG, Chisholm DJ, Freund J, Boutcher SH. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. Int J Obes (Lond) 2008; 32: 684-91. https://doi.org/10.1038/sj.ijo.0803781

[13] Trapp EG, Chisholm DJ, Boutcher SH. Metabolic response of trained and untrained women during high-intensity intermittent cycle exercise. Am J Physiol Regul Integr Comp Physiol 2007; 293: R2370-5. https://doi.org/10.1152/ajpregu.00780.2006

[14] Tordi N, Mourot L, Colin E, Regnard J. Intermittent versus constant aerobic exercise: effects on arterial stiffness. Eur J Appl Physiol 2010; 108: 801-9. https://doi.org/10.1007/s00421-009-1285-1

[15] Peres D, Mourot L, Ménétrier A, Bouhaddi M, Degano B, Regnard J, Tordi N. Intermittent versus constant aerobic exercise in middle-aged males: acute effects on arterial stiffness and factors influencing the changes. Eur J Appl Physiol 2018; 118: 1625-33. https://doi.org/10.1007/s00421-018-3893-0

[16] Perissiou M, Bailey TG, Windsor M, Nam M, Greaves K, Leicht AS, Golledge J, Askew CD. Effects of exercise intensity and cardiorespiratory fitness on the acute response of arterial stiffness to exercise in older adults. Eur J Appl Physiol 2018; 118: 1673-88. https://doi.org/10.1007/s00421-018-3900-5

[17] Ren J, Xiao H, Wang P. Acute Effects of the Interval and Duration of Intermittent Exercise on Arterial Stiffness in Young Men. International Journal of Environmental Research and Public Health 2022; 19: 16847. https://doi.org/10.3390/ijerph192416847

[18] Sardeli AV, Gáspari AF, Chacon-Mikahil MP. Acute, short-, and long-term effects of different types of exercise in central arterial stiffness: a systematic review and meta-analysis. The Journal of Sports Medicine and Physical Fitness 2018; 58. https://doi.org/10.23736/S0022-4707.17.07486-2

[19] Hortmann K, Boutouyrie P, Locatelli JC, de Oliveira GH, Simões CF, de Souza Mendes VH, Reck HB, Okawa RTP, Lopes WA. Acute effects of high-intensity interval training and moderate-intensity continuous training on arterial stiffness in young obese women. Eur J Prev Cardiol 2021; 28: e7-10. https://doi.org/10.1177/2047487320909302

[20] Lopes S, Afreixo V, Teixeira M, Garcia C, Leitão C, Gouveia M, Figueiredo D, Alves AJ, Polonia J, Oliveira J, Mes-quita-Bastos J, Ribeiro F. Exercise training reduces arterial stiffness in adults with hypertension: a systematic review and meta-analysis. J Hypertens 2021; 39: 214-22. https://doi.org/10.1097/HJH.0000000000002619

[21] Hu J, Liu M, Yang R, Wang L, Liang L, Yang Y, Jia S, Chen R, Liu Q, Ren Y, Zhu L, Cai M. Effects of high-intensity interval training on improving arterial stiffness in Chinese female university students with normal weight obese: a pilot randomized controlled trial. J Transl Med 2022; 20: 60. https://doi.org/10.1186/s12967-022-03250-9

[22] Siasos G, Athanasiou D, Terzis G, Stasinaki A, Oikonomou E, Tsitkanou S, Kolokytha T, Spengos K, Papavassiliou AG, Tousoulis D. Acute effects of different types of aerobic exercise on endothelial function and arterial stiffness. Eur J Prev Cardiol 2016; 23: 1565-72. https://doi.org/10.1177/2047487316647185

[23] Krankel N, Bahls M, Van Craenenbroeck EM, Adams V, Serratosa L, Solberg EE, Hansen D, Dorr M, Kemps H. Exercise training to reduce cardiovascular risk in patients with metabolic syndrome and type 2 diabetes mellitus: How does it work? Eur J Prev Cardiol 2019; 26: 701-8. https://doi.org/10.1177/2047487318805158

[24] Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011; 43: 1334-59. https://doi.org/10.1249/MSS.0b013e318213fefb

[25] Zheng L, Zhang X, Zhu W, Chen X, Wu H, Yan S. Acute effects of moderate-intensity continuous and accumulated exercise on arterial stiffness in healthy young men. Eur J Appl Physiol 2015; 115: 177-85. https://doi.org/10.1007/s00421-014-3008-5

[26] Zhou Z, He Z, Yuan M, Yin Z, Dang X, Zhu J, Zhu W. Longer rest intervals do not attenuate the superior effects of accumulated exercise on arterial stiffness. Eur J Appl Physiol 2015; 115: 2149-57. https://doi.org/10.1007/s00421-015-3195-8