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Comparative Effects of Four Exercise Management Models on Blood Pressure and BMI in Adults with Prehypertension: A 12-Week Randomized Controlled Trial

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Research Article

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Abstract

Purpose

Physical exercise is widely recognized for its potential to lower hypertension risk in adults with prehypertension. However, evidence remains limited regarding the comparative efficacy of structured exercise management models, especially those that integrate digital monitoring and progressive intensity progression. This randomized controlled trial aimed to compare four distinct exercise management approaches on systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), and pulse rate in young and middle-aged adults with high-normal blood pressure.

Methods

A total of 120 adults (aged 30–50 years) with high-normal blood pressure (SBP 120–139 mmHg and/or DBP 80–89 mmHg) were randomly allocated to four groups for a 12-week exercise intervention. Group 1 followed a standard unsupervised exercise prescription. Group 2 adhered to the same prescription but used the “Weidong Manager” platform for real-time monitoring and reporting. Group 3 followed the same monitored protocol but performed daily aerobic exercise in two 20-minute sessions. Group 4 combined monitoring with a monthly progressive increase in aerobic intensity from 40% to 60% $\dot{V}O_2$max. Resting SBP, DBP, BMI, and pulse rate were assessed before and after the intervention.

Results

All groups showed significant reductions in SBP, DBP, and pulse rate from baseline (all $P < 0.05$). Between-group analyses indicated that Group 4 achieved the greatest reductions in both SBP and DBP, while Group 1 showed the smallest improvements. BMI decreased significantly in Groups 2–4 but not in Group 1. Exercise segmentation did not lead to significant differences in any outcome when compared with a single continuous session under equivalent monitoring conditions.

Conclusions

Exercise management that incorporates digital supervision and gradual intensity progression appears most effective for improving blood pressure and BMI in adults with prehypertension. Segmenting exercise into shorter bouts does not diminish effectiveness, supporting its practical utility for individuals with limited time. These results underline the value of structured, technology-supported exercise programs in early hypertension prevention.

Summary Table

What is known about the topic:

· Regular physical exercise is an established non-pharmacological strategy to lower blood pressure and reduce the risk of progression from prehypertension to hypertension.

· Digital health platforms can enhance adherence to lifestyle interventions, but their comparative effectiveness within structured exercise programs for blood pressure management is not well-defined.

·Whether segmenting daily exercise into multiple short bouts offers similar cardiovascular benefits to a single continuous session in individuals with prehypertension lacks clear evidence.

What this study adds:

· This 12-week RCT demonstrates that an exercise program combining real-time digital supervision with monthly progressive intensity escalation yields the greatest reduction in both systolic and diastolic blood pressure among adults with prehypertension.

· It provides evidence that segmenting aerobic exercise into two 20-minute sessions per day is equally effective as one 40-minute session for lowering blood pressure, supporting a flexible approach for individuals with time constraints.

· The findings highlight that structured, technology-supported exercise management is a superior strategy to standard prescription alone for improving both blood pressure and BMI in this population, offering a practical model for early intervention.

1. Introduction

According to the latest data from the Chinese Hypertension Survey, the prevalence of hypertension among adults aged 18 years and above in China reached 27.9% between 2012 and 2015(Wang et al., 2014). Hypertension has become an extremely common health issue among Chinese adults. As one of the most prevalent chronic diseases worldwide, hypertension is the primary risk factor for heart disease, cerebrovascular disease, kidney disease, and related deaths, which poses a serious threat to the health of Chinese residents(Tsao et al., 2023).In this study, we defined prehypertension as high-normal blood pressure, consistent with SBP 120–139 mmHg and/or DBP 80–89 mmHg. Although terminology varies across guidelines, this category represents a clinically important risk state with a substantial likelihood of progression to overt hypertension. Studies have shown that individuals with high-normal blood pressure (systolic blood pressure 120–139 mmHg, diastolic blood pressure 80–89 mmHg) have a risk as high as 52% of developing hypertension within 4 years(Julius et al., 2006). In China, the prevalence of high-normal blood pressure among adults has exceeded 30%, and its proportion in the young and middle-aged population is on the rise(Li et al., 2024). "Primordial prevention" implemented for this population is a fundamental measure to prevent the occurrence and progression of hypertension by blocking the progression of hypertension, this preventive measure is of great significance for reducing the subsequent disease burden.

Hypertension management includes pharmacological and non-pharmacological therapies. Compared with pharmacological approaches, non-pharmacological therapies are safer and more cost-effective such as dietary adjustment, exercise intervention(Zhu et al., 2025). Exercise can regulate blood pressure through mechanisms such as improving vascular elasticity, adjusting autonomic nervous function, and reducing body weight. Currently, exercise therapy has been recommended as a first-line non-pharmacological treatment for hypertension in domestic and international guidelines(John et al., 2022). Early exercise intervention in young and middle-aged adults with high-normal blood pressure identified during physical examinations is crucial for preventing hypertension and cardio-cerebrovascular diseases.

Therefore, this study aimed to compare the effectiveness of four exercise management models—differing in digital monitoring/supervision, session segmentation, and progressive intensity adjustment—on SBP, DBP, BMI, and pulse rate in young and middle-aged adults with high-normal blood pressure identified during routine health examinations.

2. Methods

2.1. Study Participants

This study was conducted at a university-affiliated hospital in Northwest China. The study subjects were 120 individuals with high-normal blood pressure selected from those who underwent physical examinations in our department from November to December 2020 following pre-exercise screening and voluntary enrollment. Inclusion criteria comprised both genders aged between 30 and 50 years with a systolic blood pressure between 120 and 139 mmHg and/or diastolic blood pressure between 80 and 89 mmHg who were physically inactive had no history of antihypertensive medication use and had no concurrent heart lung liver or kidney diseases. Before the intervention there were no statistically significant differences in systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), or pulse rate among the four groups (all $P > 0.05$).

All participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki.

2.2 Exercise Management intervention Protocols

A management team, with exercise specialists as the core members, was established to oversee the implementation of the exercise intervention and data collection throughout the study period. The 12-week exercise intervention was conducted from March to June 2021, with group-specific protocols as follows. Group 1 participants received individualized exercise prescriptions consisting of 5 sessions/week of aerobic exercise at 40% maximal oxygen consumption ($\dot{V}O_2max$) and 2 sessions/week of resistance exercise, with 40 minutes of effective exercise per session; they were instructed to exercise according to the prescription, measure and record resting blood pressure, heart rate, and body weight weekly, with data compiled monthly by exercise specialists. Group 2 followed the

same exercise prescription as Group 1 but with additional monitoring of prescription adherence, effective exercise duration, and intensity via the "Weidong Manager" platform, and participants uploaded weekly measurements to exercise specialists. Group 3 used the same exercise intensity, frequency, and monitoring protocol as Group 2, except that daily aerobic exercise was split into 2 sessions of 20 minutes each. Group 4 initially followed the same prescription and monitoring as Group 2, with aerobic exercise intensity gradually increased monthly to 60% $\dot{V}O_2$max, and participants uploaded weekly measurements to exercise specialists.

2.3 Data Collection

Body weight, SBP, DBP, and pulse rate were collected regularly using standardized protocols. For blood pressure measurement, participants rested quietly for at least 5 minutes before seated upper-arm measurements, with the arm positioned at heart level; a validated upper-arm medical electronic sphygmomanometer was used, and measurements were taken on the same limb, with heart rate recorded simultaneously. Body weight was measured every Sunday morning immediately after waking up, with a fixed measurement time to ensure consistency.

2.4 Statistical Analysis

All data were processed using the Statistical Package for Social Science (SPSS) version 26.0. The Shapiro–Wilk test was first performed to verify the normality of the data, which confirmed that variables including systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), and pulse rate were normally distributed across all groups at baseline (all $P > 0.05$). One-way analysis of variance (ANOVA) was used to assess between-group differences, with Duncan's multiple range test applied for post-hoc comparisons. Paired t-tests were used to compare within-group differences before and after the intervention. All experimental data are presented as mean ± pooled standard error of the mean (SEM). A two-sided $P < 0.05$ was considered statistically significant.

3. Results

3.1 Changes in Systolic Blood Pressure

The changes in systolic blood pressure among the four groups before and after exercise management intervention are presented in Table 1. Significant differences were observed in systolic blood pressure across groups ($F = 4.094$, $P = 0.009$), with notable reductions over time ($F = 361.059$, $P < 0.001$) and a significant interaction between group and time ($F = 37.517$, $P < 0.001$). No significant baseline differences were found among the four groups, but post-intervention differences were significant. All groups showed significant reductions in systolic blood pressure from baseline, with the fourth group achieving the largest reduction (11.00 ± 4.71 mmHg) and the first group the smallest (3.15 ± 2.34 mmHg), indicating the fourth group had the optimal effect.

3.2 Changes in Diastolic Blood Pressure(DBP)

The changes in DBP among the four groups before and after exercise management intervention are presented in Table 2. There were significant differences in DBP across groups ($F = 17.715$, $P < 0.001$), with significant reductions over time ($F = 521.832$, $P < 0.001$) and a significant group-by-time interaction ($F = 23.472$, $P < 0.001$). Baseline DBP was comparable among the four groups, but post-intervention differences were significant. Further simple effect analysis showed that there were no significant DBP differences among four groups before intervention; DBP differences among four groups were with statistical significance after intervention. All groups showed significant reductions in DBP, with the fourth group achieving the largest reduction (9.61 ± 3.99 mmHg) and the first group the smallest (3.85 ± 1.52 mmHg), consistent with the trend in systolic blood pressure. Paired sample *t*-test were performed in four groups before and after intervention. Except group1, DBP differences among other three groups were with statistical significance before and after intervention ($P < 0.001$).

3.3 Changes in Body Mass Index (BMI)

The changes in BMI among the four groups before and after exercise management intervention are presented in Table 3. No significant differences in BMI were found across groups ($F = 1.292$, $P = 0.281$), but significant reductions were observed over time ($F = 91.738$, $P < 0.001$) with a significant group-by-time interaction ($F = 4.433$, $P < 0.001$). Baseline BMI was similar among the four groups, but post-intervention differences were significant. The second, third, and fourth groups showed significant reductions in BMI ($P < 0.001$), while the first group had no significant change ($P = 0.051$). No significant differences in BMI reduction were observed among the second, third, and fourth groups.

3.4 Changes in Pulse Rate

The changes in pulse rate among the four groups before and after exercise management intervention are presented in Table 4. No significant differences in pulse rate were found across groups ($F = 0.672$, $P = 0.571$) or in the group-by-time interaction ($F = 2.434$, $P = 0.069$), but significant reductions were observed over time ($F = 85.122$, $P < 0.001$). Pulse rate was comparable among the four groups at baseline and post-intervention. All groups showed significant reductions in pulse rate after intervention (all $P \leq 0.001$), with no significant differences in the magnitude of reduction among groups.

4. Discussion

This study evaluated the effects of four different exercise management modalities on blood pressure, BMI, and pulse rate in young and middle-aged adults with prehypertension. The results showed that regular exercise management could effectively reduce systolic blood pressure, diastolic blood pressure, and pulse rate in this population. Our findings support the implementation of structured exercise interventions for individuals with prehypertension as a key strategy to prevent progression to hypertension and reduce cardiovascular risk(Tian et al., 2025; Williamson et al., 2016).

The most notable finding of this study is that exercise management modalities incorporating real-time monitoring and supervision (Group 2) or progressive intensity increase (Group 4) resulted in greater blood pressure reduction than standard exercise prescription alone (Group 1). Specifically, Group 4,

which combined real-time monitoring with progressively increased exercise intensity, achieved the largest reductions in both systolic blood pressure (14.2 mmHg) and diastolic blood pressure (9.8 mmHg). These reductions are clinically meaningful and consistent with the benefits observed in pharmacological interventions for hypertension(Caminiti et al., 2021). Additionally, the finding that splitting daily exercise time into multiple sessions (Group 3) had no significant impact on blood pressure outcomes compared with completing the entire exercise session at one time (Group 2) has important practical implications. This suggests that busy young and middle-aged adults can obtain similar benefits from exercise regardless of whether they complete their exercise in one session or multiple shorter sessions throughout the day. Such flexibility may help improve exercise adherence in this population.

The significant improvements in Group 2 indicate that using exercise management software for real-time follow-up and supervision can enhance the effectiveness of exercise interventions in individuals with prehypertension. This approach may be particularly beneficial for young and middle-aged adults who are familiar with technology and likely to respond well to digital health interventions(Dedov & Dedova, 2015). The excellent results achieved by Group 4 highlight the importance of gradually increasing exercise intensity over time. This approach can help individuals build physical fitness progressively while maintaining motivation and reducing the risk of injury or burnout. The lack of significant difference between Group 2 and Group 3 suggests that healthcare providers can offer flexibility in exercise timing without compromising outcomes. This flexibility can help accommodate the busy schedules of young and middle-aged adults, potentially improving adherence to exercise recommendations(Jae et al., 2025). The effectiveness of exercise interventions in this study supports the importance of identifying and intervening in individuals with prehypertension at an early stage. Early intervention may help prevent or delay the progression to hypertension, potentially reducing the burden of cardiovascular disease in this population(Sun et al., 2024).

Our findings are consistent with previous studies that have demonstrated the benefits of exercise for blood pressure management. A meta-analysis of randomized controlled trials showed that resistance training could reduce systolic blood pressure by 4–6 mmHg and diastolic blood pressure by 3–4 mmHg(Cornelissen & Smart, 2013). Our study extends these findings by demonstrating that more intensive exercise management modalities can achieve even greater blood pressure reduction, especially when combined with real-time monitoring and progressive intensity increase.

The significant improvements in Group 2 (real-time monitoring) are consistent with the results of a pilot randomized controlled trial that examined the use of activity trackers to improve blood pressure in young people at risk of cardiovascular disease. Although that study found no significant effect on blood pressure, it did demonstrate the feasibility of using such devices to promote physical activity(Bicki et al., 2024). Our study builds on this by incorporating more comprehensive real-time monitoring and supervision, which may explain the more positive results. As an effective and low-cost non-pharmacological treatment method, exercise combined with different exercise intervention modalities to improve treatment effects has clinical significance(Pescatello et al., 2019).

Due to the specificity of exercise intervention, the limited sample size, and the restricted indicators collected in this study, future research should further expand the sample size, add other hypertension-related test indicators, and continue to refine this research. Additionally, future studies should explore effective methods to improve exercise intervention adherence in young and middle-aged adults with prehypertension, identify appropriate exercise intervention techniques to prevent the progression of prehypertension to hypertension, and lay a foundation for the comprehensive prevention and treatment of prehypertension using exercise therapy in subsequent work.

5. Conclusions

Software-monitored exercise with progressive intensity adjustment is optimal for reducing SBP and DBP in young and middle-aged adults with high-normal blood pressure. Software supervision also contributes to BMI improvement, whereas segmented exercise and one-time exercise as two forms of exercise timing have no impact on intervention outcomes. These findings provide practical strategies for preventing hypertension progression.

Abbreviations

SBP
Systolic blood pressure
DBP
Diastolic blood pressure
BMI
Body mass index
$\dot{V}O_2max$
Maximal oxygen consumption
h
Hour
min
Minute
SD
Standard deviation

Declarations

Submission statement

All authors have read and agree with manuscript content.

Ethical approval statement

All family members participating in this study signed informed consent. We adhered to the Declaration of Helsinki (World Medical Association, revised in 2013), the study protocol was approved by the local Institutional Review Board.

Conflict of interest

All authors declare that they have no competing interests.

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Tables

Tables are available in the Supplementary Files section.

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