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Effect of home-based isometric handgrip training on vascular function in middle-aged women with elevated pulse pressure

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ABSTRACT

Background: Wide pulse pressure (PP) is a significant predictor of cardiovascular events. Isometric handgrip exercise (IHG) is a form of exercise used to manage blood pressure (BP). However, research on its effects in individuals with above-normal pulse pressure remains limited.

Objectives: This study aimed to examine the impact of a home-IHG program on arterial stiffness and blood pressure in middle-aged individuals with prehypertension or stage 1 hypertension and elevated PP.

Materials and methods: Twenty-eight participants were randomly assigned to either the IHG group (IHG, N=14) or the control group (CON, N=14). The IHG group performed IHG at 30% of their maximum voluntary contraction, using a modified mercury sphygmomanometer as the exercise device, 3 times/week, for 8 weeks. Brachial-ankle pulse wave velocity (baPWV) and BP were assessed at baseline and post-intervention.

Results: The results demonstrated an improvement in vascular function following IHG implementation, indicated by a significant decrease in baPWV in the IHG group compared with the control group (IHG: 1240±121 cm/s vs CON: 1365±159 cm/s; $p<0.05$). IHG also significantly reduced systolic blood pressure (SBP) compared with the control group (IHG: 119.86±5.26 mmHg vs CON: 131.21±3.64 mmHg; $p<0.05$). Moreover, changes in baPWV were positively correlated with changes in SBP ($r=0.65$, $p<0.001$) and PP ($r=0.52$, $p<0.01$).

Conclusion: An 8-week home-based IHG program using a mercury sphygmomanometer for training reduced BP and arterial stiffness in middle-aged women with elevated PP.

Introduction

Elevated BP, even at a marginal level, is a significant clinical concern and increased cardiovascular morbidity and mortality.[1] Therefore, appropriate BP control is crucial. Age-related changes in BP are characterized by an increase in SBP and a stable or mildly decreasing diastolic pressure (DBP), resulting in higher PP. Notably, elevated PP is related to vascular elasticity and serves as an index of arterial stiffness.[2] The European Society of Hypertension also acknowledges that a widened PP is a distinct risk factor, independent of elevated SBP.

Guidelines from health organizations recommend at least 150 minutes/week of moderate-intensity aerobic exercise as a first-line non-pharmacological strategy for the prevention, management, and lowering of hypertension (HTN).[3,4] A recent systematic review and meta-analysis

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demonstrated that aerobic training reduced SBP and DBP by approximately 4 and 3 mmHg, respectively.[5] Despite the established benefits of regular exercise, in Thailand, 43% of adults do not meet recommended exercise levels.[6] Lack of time is frequently cited as a barrier to engaging in aerobic exercise,[7] highlighting the need for time-efficient alternative approaches to BP management.

IHG has gained attention for its simplicity, short exercise duration, and efficacy in reducing BP.[8-10] Previous studies have demonstrated the anti-hypertensive effects of IHG interventions, with durations ranging from 3 to 12 weeks across diverse populations, with average BP reductions comparable to those achieved with standard exercise recommendations.[8,10] Nevertheless, only a limited number of trials have explored the effect of IHG on vascular adaptation, yielding inconsistent results.[11-13] Prior IHG implementation typically required specialized equipment, potentially impeding exercise accessibility. Hence, to overcome this limitation, this research employed a modified mercury sphygmomanometer as an accessible tool for grip strength exercises.[14-16]

Therefore, the aims of this study were to investigate the effect of an 8-week IHG intervention on vascular function BP in middle-aged individuals with pre-HTN and stage 1 HTN who exhibited elevated PP. We hypothesized that IHG would lead to improved vascular function, with a concomitant decrease in BP.

Materials and methods

Participants

Women aged 40-59 years with elevated BP or stage 1 HTN (resting SBP ≥120-139 mmHg and/or DBP ≥80-89 mmHg) were recruited from Samliam sub-district Health Promoting Hospital and Nong Kung sub-district Health Promoting Hospital, Khon Kaen province, Thailand. The inclusion criteria were: 1) PP of 50-79 mmHg, 2) body mass index (BMI) of 18.5-24.9 kg/m², and 3) sedentary behavior, defined as a low level of physical activity assessed using the Thai version of the short-form International Physical Activity Questionnaire (IPAQ-SF). Exclusion criteria included: 1) a diagnosis of heart disease, diabetes mellitus, kidney disease, pulmonary disease, or neurological conditions;,2) use of regular medications, supplements, or hormone replacement therapy within the 12 months prior to study enrollment, 3) upper extremity fracture within the past 6 months, 4) upper extremity deformity that could impair IHG, 5) moderate to severe pain, 6) current regular smoking or alcohol consumption, and 7) participation in any other exercise programs within 12 months prior to trial enrollment.

The sample size was calculated based on a previous study[17] using the formula for the comparison of two independent means. A sample size of 14 participants per group was required to achieve a statistical power of 0.80 with an alpha (α) level of 0.05. Consequently, a total of 28 participants were randomly assigned to the study groups.

Modified mercury sphygmomanometer

This study employed a modified mercury sphygmomanometer (SPIRIT, CK-101, Germany) for both measurement and training device (Figure 1). Previous research has demonstrated a correlation between grip strength values obtained using mercury sphygmomanometers and standard dynamometers in various populations. This evidence supports the use of modified sphygmomanometers as a reliable and alternative method for assessing handgrip strength.[14-16] As previously described, the sphygmomanometer was adapted using the bag method, which involved folding the inflatable bladder cuff into a cylindrical form with an approximate circumference of 7 inches and encasing it in a soft, non-slip, non-stretch fabric.[15,16] The modified mercury sphygmomanometer was calibrated and validation prior to data collection to ensure accuracy. The calibration results confirmed the validity for research application, with high measurement reliability at 95% confidence, complying with international standards (EA-4/02 and GUM).

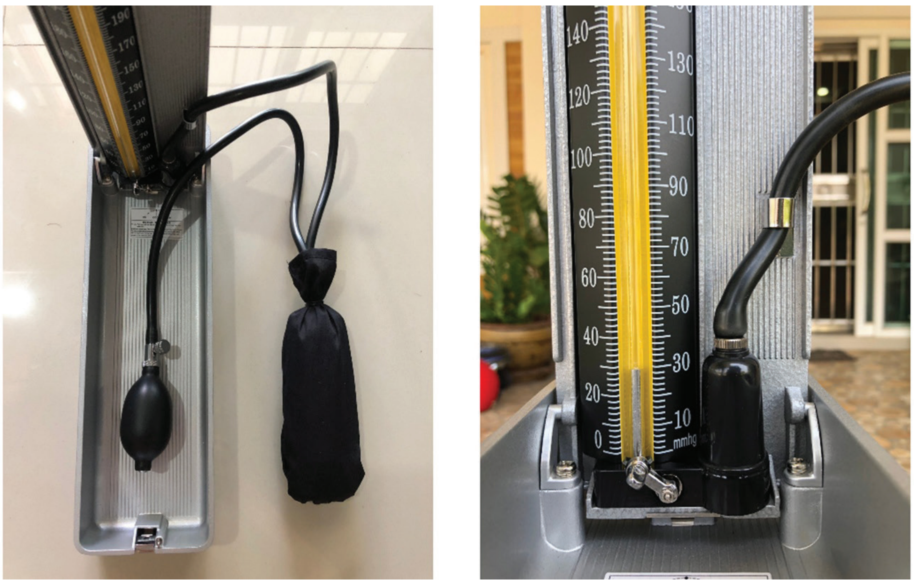

Figure 1. *Modified mercury sphygmomanometer.*

Procedure

The maximal voluntary contraction (MVC) of the dominant hand was assessed using a modified mercury sphygmomanometer, consistent with the recommendations of the American Society of Hand Therapists.[18] All measurements were performed by a trained physiotherapist. Following a familiarization session, the MVC test was conducted with participants in a seated position, maintaining the shoulder in a neutral position and elbow flexion at 90°. Each participant performed two trials with a minimum rest period of 1 minute between attempts. The higher value of the two trials, recorded in mmHg, was used as the participant's MVC.

Isometric handgrip training protocol

In the initial 2 weeks, participants performed exercises under the closed supervision of a physical therapist and received an instructional exercise booklet for continued practice. Furthermore, the participants were informed of the precautions and the indications for stopping exercise. For the subsequent 6 weeks, participants independently conducted home-based training. The IHG program, performed 3 times/week for 8 weeks, consisted of four sets of two-minute contractions using a modified mercury sphygmomanometer with the dominant hand, maintaining a target pressure at 30% of the participant's MVC, with one-minute rest periods between each set.[8] The MVC was reassessed every two weeks to adjust the exercise load. Throughout the study, participants were asked to maintain their routine activities and record each home exercise session in an exercise diary. Adherence to the home-based exercise program was monitored through weekly phone calls and researcher home visits every two weeks. All of participants in the IHG group completed all 24 scheduled exercise sessions.

Control group

Participants in the control group maintained their usual daily activities during the study period and received no additional interventions.

Measurements

Before testing, subjects were instructed to avoid strenuous exercise for 24 hours and to abstain from smoking, alcohol, and caffeine for 4 hours. A minimum 10-minute rest period was required prior to data collection. All assessments were conducted in a quiet, temperature-controlled environment. Outcome measurements were collected at baseline and after the 8-week program. Post-intervention assessments were conducted 48 hours after the final exercise session to minimize the influence of immediate exercise responses. All data were collected by the same investigator who blinded to group allocation. After a 10-minute rest, brachial SBP and DBP were measured using a calibrated, automated device (Masimo, WelchAllyn Vonnex Spot Monitor, USA) following a standardized protocol.[19] The mean of two readings was recorded for analysis, PP was then calculated from SBP and DBP.

Vascular function

baPWV was determined using a data acquisition system (Arterial Compliance Monitor, Bart's and The London School of Medicine and Dentistry, UK) with Doppler probes (Dopplex MDII, Huntleigh Healthcare, Cardiff, UK). Two consecutive waveform tracings were obtained for each participant, and the mean value was used for subsequent analysis. The arterial path length was estimated based on participant height.[20]

Statistical analysis

All data are expressed as mean±SD. Statistical analyses were performed using Statistical software (SPSS version 28.0.1.0 (142)). The Shapiro-Wilk test was used to assess the normality of data distribution. For within-group comparisons, paired samples T-tests were applied to evaluate differences between baseline and post-intervention values. Between-group differences in outcome variables were analyzed using independent samples t-tests. Pearson's correlation coefficient was calculated to assess the relationship between changes in vascular function and BP parameters. A <0.05 was considered statistically significant for all analyses.

Results

Baseline characteristics

Twenty-eight middle-aged women (age range: 43-57 years, mean age: 50.57±3.90 years) participated in this study. At baseline, there were no significant differences in demographic characteristics between the IHG and control groups (Table 1).

Table 1. Participant's characteristics.

Variables	Control group (N=14)	IHG group (N=14)
Age (year)	49.23±4.14	51.24±3.68
Weight (kg)	56.77±5.27	56.55±6.67
Height (cm)	161.14±4.53	158.50±6.37
BMI (kg/m^2)	21.84±1.50	22.45±1.52

Note: *IHG group: isometric handgrip exercise group, kg: kilogram, cm: centimeter, BMI: body mass index, m: meter. Data are expressed as mean±SD.*

Blood pressure

The 8-week IHG program significantly reduced SBP by approximately 10 mmHg and PP by approximately 8 mmHg from baseline. (Table 2). Following the intervention, SBP and PP were significantly lower in the exercise group compared to the control group (*p*<0.05). However, DBP did not change significantly over the 8-week period.

Initial baPWV did not differ significantly between the IHG and control groups (*p*>0.05; Figure 2). After 8 weeks, baPWV in the IHG group decreased significantly by 117 cm/s from baseline values (*p*<0.05). Furthermore, arterial function significantly improved in the IHG group, as evidenced by a lower baPWV compared to the control group at the post-intervention assessment (*p*<0.05).

Table 2. Changes in blood pressure before and after 8-weeks of intervention.

Variables	**Control group (N=14)**		**IHG group (N=14)**	
	Baseline	8 weeks	Baseline	8 weeks
SBP (mmHg)	130.79±4.89	131.21±3.64	130.75±4.51	119.86±5.26*,#
DBP (mmHg)	76.43±3.13	77.50±5.50	77.57±3.37	75.21±4.90
PP (mmHg)	54.36±3.82	53.71±7.05	53.18±3.24	44.64±4.57*,#

Note: *IHG group: isometric handgrip exercise group, SBP: systolic blood pressure, mmHg: millimeter of mercury, DBP: diastolic blood pressure, PP: pulse pressure, *significant different from baseline (p<0.05), #significant different from control group (p<0.05). Data are express as mean±SD*

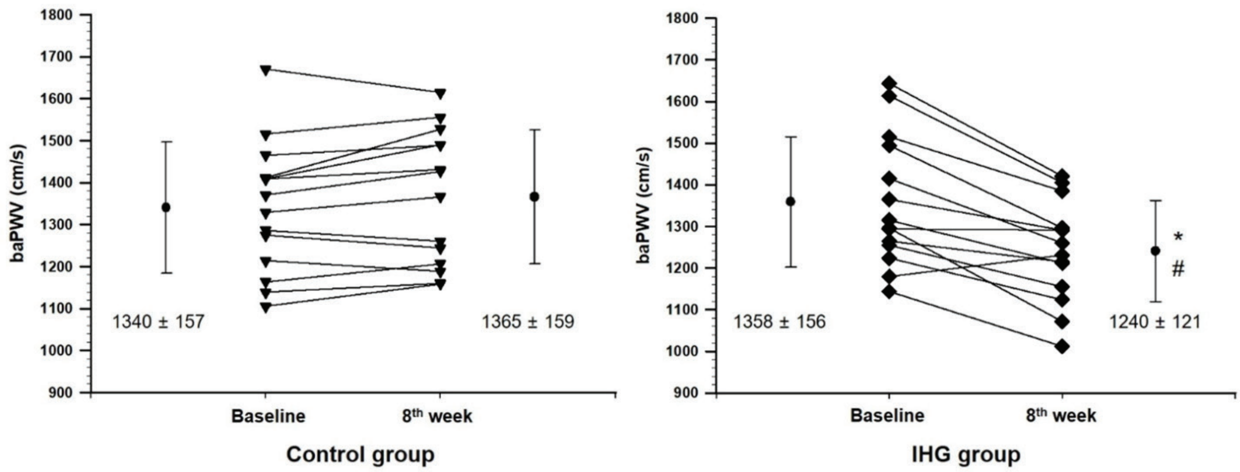

Figure 2. *Individual changes and mean baPWV before and after 8-weeks of intervention.*
*IHG group: isometric handgrip exercise group, baPWV: brachial ankle pulse wave velocity, cm: centimeter, s: second, * significant different from baseline (p<0.05), # significant different from control group (p<0.05).*

Pearson correlation analysis was conducted to examine the relationship between changes in arterial stiffness and BP parameters. There was a significant positive association between changes in baPWV and changes in SBP (r=0.65, p<0.001; Figure 3A). Similarly, alterations in baPWV were significantly correlated with changes in PP (r=0.52, p<0.01; Figure 3B).

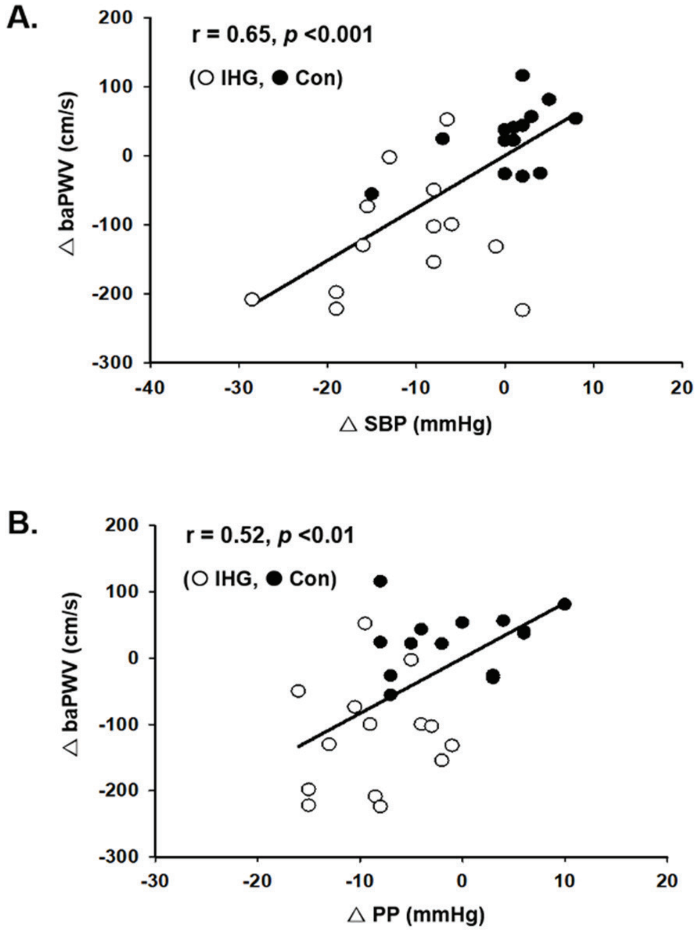

Figure 3. *Relationship between changes in brachial-ankle pulse wave velocity (baPWV) and changes in systolic blood pressure (A) and PP (B) all participants.*
IHG: isometric handgrip exercise group, Con: control group, baPWV: brachial ankle pulse wave velocity, cm: centimeter, s: second, SBP: systolic blood pressure, mmHg: millimeter of mercury, PP: pulse pressure.

Discussion

In this cohort of middle-aged women with elevated PP an 8-week home-based IHG program demonstrated beneficial effects on vascular function and reduced BP. Increased arterial stiffness is a recognized characteristic in HTN patients. In the present study, baPWV was used to assess arterial stiffness. A significant reduction in baPWV (approximately 100 cm/s) was observed following the implementation of IHG exercise. This magnitude of PWV reduction is considered clinically meaningful.[21] This finding aligns with a study by Patil *et al.*,[22] which demonstrated an alleviation of arterial stiffness (both carotid-femoral pulse wave velocity: cfPWV and baPWV) following a yoga intervention in elderly subjects with elevated PP. Similarly, previous research has shown a significant decrease in cfPWV after 12 weeks of IHG in elderly hypertensive patients. However, they reported no significant change in peripheral arterial stiffness, assessed via leg PWV.[23] IHG-induced vascular adaptations may involve several mechanisms, including enhanced local endothelium-dependent vasodilation, vascular remodeling, and/or modulation of autonomic vasomotor control.[8]

In the current study, a 8-week IHG training resulted in a clinically significant reduction in resting SBP by approximately 10 mmHg.[24] Following the intervention, 35% of participants in the handgrip group achieved optimal SBP levels (<120 mmHg). Additionally, 85% of participants achieved a PP less than 50 mmHg, a level associated with reduced cardiovascular risk.[25] Our findings align with a previous systematic review of low- to moderate-intensity IHG training programs which reported a mean reduction in SBP of 5 mmHg.[26] These findings support the efficacy of IHG for lowering BP in pre-HTN and stage 1 HTN middle-aged adults with above-normal PP. Indeed, the magnitude of BP reduction following IHG exercise appears to be related to the participants' baseline clinical characteristics and the IHG exercise protocol. Millar et al.[27] reported a positive correlation between baseline SBP and the magnitude of SBP reduction after IHG training, indicating greater benefits in individuals with higher initial SBP levels. Regarding the

IHG prescription, prior meta-analyses suggest that IHG training durations exceeding 8 weeks may yield larger BP reductions.[28]

The present study found that handgrip training had no significant effect on DBP. Our findings are consistent with prior research and likely attributed to the baseline characteristics of our participants, the majority of whom presented with DBP values within the normal range prior to the intervention. Therefore, any additional decrease in DBP was limited by a physiological floor effect.[28,29] This lack of a significant DBP change aligns with findings from a systematic review and meta-analysis by Almeida et al., which also reported no significant diastolic reductions following 8-10 weeks of IHG training in individuals with normotensive baseline DBP. The researchers proposed that IHG training mainly influences SBP by decreasing vascular resistance, leading to a greater impact on systolic blood pressure.[30] Conversely, DBP is primarily determined by cardiac output, which appear to be less responsive to this form of exercise training.[31]

Elevated BP accelerates structural and functional vascular changes, leading to reducing arterial distensibility. Conversely, increased arterial stiffness elevates BP by enhancing vascular resistance, establishing a bidirectional relationship.[27,28] In the present study, a positive association between reductions in BP and PWV was observed, suggesting that BP lowering following IHG training was proportional to improvements in vascular function. SBP has been demonstrated to be associated with arterial stiffness. Supporting this relationship, a large cross-sectional study (N=12,517) by Tomiyama *et al*. revealed that systolic blood pressure was correlated with baPWV among both male (r=0.61, p<0.01) and female participants (r=0.75, p<0.01).[34] This association has also been observed in intervention studies. Prior research in individuals with chronic obstructive pulmonary disease reported a significant positive association between changes in baPWV and changes in SBP (r=0.79, p=0.004) after a 4-week aerobic exercise program.[35] Similarly, Figueroa et.al., found correlations between decrease in baPWV and reductions in both radial systolic blood pressure (r=0.57, p<0.01) and aortic systolic blood pressure (r=0.64, p<0.01) following 6 weeks of watermelon supplementation in post-menopausal women.[36] These findings suggest that the intervention-induced reductions in systolic blood pressure may be accompanied by concurrent decreases in arterial stiffness.

The potential mechanisms underlying the BP-lowering effects of handgrip exercise might be involved an attenuation of vascular resistance by enhanced nitric oxide (NO)-induced vasodilation.[8] Although our study did not directly measure NO levels, the assessed flow-mediated dilation (FMD) as an indicator of endothelium-dependent, NO-mediated vasodilation in response to IHG. Consistent with this, Javidi et al. reported an enhancement in brachial artery %FMD in IHG training group, implying increased NO bioavailability after the IHG intervention.[37] Further supporting this mechanism, improvements in endothelial function after IHG have been demonstrated by a reduction in shear rate area under the curve after occlusion in hypertensive patient.[23]

Limitations

This study has several limitations. The absence of measurements for nitric oxide, oxidative stress, or inflammatory markers limits our ability to fully elucidate the mechanisms underlying the BP reductions observed following IHG. Further research is needed to explore the mechanistic pathways. Additionally, studies with longer durations and larger sample sizes are warranted to confirm the long-term benefits of IHG training and only specific for middle aged women.

Conclusion

Moderate-intensity IHG using a modified sphygmomanometer significantly reduced BP and arterial stiffness, potentially lowering cardiovascular risk. These findings suggest that IHG exercise may serve as a therapeutic adjunct for improving BP control and vascular function in middle-aged women with pre-HTN or stage 1 HTN and elevated PP.

Ethical approval

The research procedures were approved by the Khon Kaen University Ethics Committee for Human Research (HE661093), in accordance with the Declaration of Helsinki and the Good Clinical Practice Guidelines. Written informed consent was obtained from all participants before their enrollment.

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Conflict of interest

The authors have no conflicts of interest associated with the material presented in this paper.

CRedit authorship contribution statement

Worrawut Usupharach: data collection, formal analysis, data curation, initial drafting; **Hataichanok Boonpim:** formal analysis, data curation, initial drafting; **Sawitri Wanpen:** formal analysis, data curation; **Raoyrin Chanavirut:** conceptualized and designed, formal analysis; **Ponlapat Yonglitthipagon:** conceptualized and designed, formal analysis; **Saowanee Nakmareong:** conceptualized and designed, writing – review and editing, project administration and funding acquisition. All authors approved the final version of the manuscript.

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