

Isometric exercise training and blood pressure control: exploring the dose-response to training frequency in a randomised controlled trial

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ABSTRACT

Background Isometric exercise training (IET) is a time-efficient intervention that consistently demonstrates clinically meaningful reductions in resting blood pressure (BP). The optimal frequency required to maintain these benefits has not been established. This study aimed to (1) examine the dose-response relationship between training frequency and the maintenance of BP reductions following an initial 4-week IET period and (2) investigate the physiological mechanisms underpinning any observed changes in BP.

Methods Adults (n=100) with normal to high-normal BP were randomised into five groups: 3×, 2×, 1× or 0× IET sessions/week following an initial 4-week lower-body IET protocol (3×/week), or control. Haemodynamic and cardiac autonomic variables, including resting BP, total peripheral resistance (TPR), heart rate variability (HRV) and baroreceptor reflex sensitivity (BRS) were assessed at baseline, following the initial intervention (week 4), and following the maintenance period (week 8).

Results All intervention groups showed significant reductions in systolic BP (sBP), diastolic BP and mean arterial pressure (MAP) after 4 weeks compared with control (-9.45 ± 6.69 mm Hg, $p < 0.001$, -5.47 ± 9.92 mm Hg, $p = 0.007$ and -6.80 ± 7.77 mm Hg, $p < 0.001$, respectively). At week 8, the 1×, 2× and 3×/week groups maintained sBP and MAP reductions, although the magnitude of these reductions was significantly greater in the 3×/week group ($p < 0.001$). The 0×/week group showed reversal of BP reductions to levels not significantly different from control. Only the 3×/week group maintained improvements in TPR, HRV and BRS.

Conclusions A reduction in IET frequency to 1–2 sessions per week can partially attenuate the rate at which BP adaptations regress during short-term reductions in training frequency.

INTRODUCTION

Isometric exercise training (IET) is an effective lifestyle intervention for the reduction of resting blood pressure (BP). The magnitude of BP reduction seen following IET has been shown to be greater than other forms of exercise training, and also the same as,

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Isometric exercise training (IET) is a time-efficient intervention that reduces resting blood pressure (BP), with effects similar to, or greater than, some pharmacological therapies.
- ⇒ The minimum training frequency required to maintain these benefits, and the consequences of stopping training, are not well established.

WHAT THIS STUDY ADDS

- ⇒ Provides the first robust evidence of a frequency-dependent dose-response to IET, showing how different training doses affect both BP and the underlying cardiovascular mechanisms.
- ⇒ Demonstrates that while lower-frequency IET may be sufficient to maintain BP reductions over the short term, higher frequencies are required to preserve these benefits and the associated vascular and cardiac autonomic adaptations.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Offers evidence that lower-frequency IET can help maintain short-term BP reductions, providing a pragmatic option for individuals with limited time or adherence challenges.
- ⇒ May inform policy discussions around feasible, scalable exercise interventions for populations with low adherence or limited exercise tolerance.

or sometimes greater than pharmacological interventions.¹ Despite promising long-term adherence rates seen following long-term IET training,² it is realistic to expect that periods of training cessation or inactivity will occur (eg, holiday trips, short-term illness or fluctuations in motivation or routine) when exercise training programmes are integrated into everyday life.³ However, the minimal IET maintenance dose required to preserve haemodynamic adaptations during likely training interruptions has yet to be established. Moreover, the application of exercise training programmes without sufficient

understanding of the dose–response relationship could result in unrealistic expectations and inefficient exercise therapy.⁴ A better understanding of the dose–response relationship in IET could help to optimise therapeutic efficacy, minimise patient burden and provide individualised programmes that balance benefit with long-term adherence.

The positive effects of an exercise training programme are normally only achieved if the recommended exercise prescription (eg, volume, intensity) is strictly adhered to.⁴ However, studies that have used a reduced training frequency during a follow-up period of training have been shown to delay reversibility in cardiorespiratory, metabolic, muscular and hormonal functions.^{5–8} Baross *et al*⁹ and Cohen *et al*¹⁰ also demonstrated that BP reductions following IET may be maintained with reduced training frequency. However, both have notable methodological limitations. First, neither included a detraining control group or monitored physical activity levels during the follow-up period, making it difficult to attribute maintained BP reductions specifically to continued training. Additionally, the sole use of a single maintenance condition (1×/week) in both studies limits any meaningful interpretation of dose–response effects. Moreover, Cohen *et al*¹⁰ used an intensity during the maintenance phase that was greater than the average initial training load which may have influenced BP maintenance. Finally, the sample size used by Baross *et al*⁹ (n=22) was based on effect sizes from initial IET studies without accounting for potentially smaller effects during a maintenance period, limiting both statistical power and generalisability.

While group-level changes in BP are consistently reported following IET,¹¹ the specific physiological mechanisms driving these changes and the extent to which they directly contribute to BP reductions remain insufficiently understood.¹² The majority of prior research has inferred mechanistic involvement based on group trends, yet this approach cannot determine whether individual improvements in vascular or autonomic function actually track with BP outcomes. To address this, exploratory correlation analyses could be used to evaluate whether individual changes in key physiological markers are associated with changes in resting BP. This would allow for a more nuanced understanding of which mechanisms are most closely linked to BP reduction and offer insight into how these adaptations are affected by training frequency.

Therefore, the primary aim of this study was to investigate the dose–response relationship between training frequency and the maintenance of resting BP reductions following IET, with the secondary aim to explore the associated physiological mechanisms that correspond with any BP changes during the maintenance period of training.

METHOD

The study was registered with the ISRCTN (ISRCTN62287921) and reported according to Consolidated Standards of Reporting Trials (CONSORT),

Template for Intervention Description and Replication (TIDieR), and CHecklist for statistical Assessment of Medical Papers (CHAMP) guidelines.

Participants

Male and female participants with normal to high-normal systolic BP (sBP) (range 120–140 mm Hg) and a total weekly physical activity below 150 min of moderate activity (≤ 600 metabolic equivalent of task (MET)-minutes/week based on light-intensity activities only) were recruited. Participants were excluded if they reported any structured exercise ≥ 4 METs for ≥ 10 min, had injuries or illnesses, were taking or had previously taken antihypertensive medication, were smokers, or consumed more than 14 units of alcohol per week. Screening was conducted using a standard Physical Activity Readiness Questionnaire.

Study procedures

Recruitment was conducted on a rolling basis to achieve the target sample size of 100 participants. The sample size calculation was primarily designed to assess differences in BP across intervention groups with varying training frequencies (3×, 2×, 1× and 0×/week, plus a control). Power calculations conducted using G*Power, with an alpha level of 0.05, a type II error rate of 20% (80% power), five groups, and one covariate (baseline BP), determined that a total sample size of 100 participants would be sufficient to detect a small to medium effect size of 0.35 (Cohen's f).¹³ The sample size considering drop-out (Nd) was estimated at 125 participants.¹⁴ Participants were randomised by the lead researcher (HTS) using the RAND function in Microsoft Excel into 1 of 5 groups: 3×, 2×, 1×, 0×/week or control (figure 1). Randomisation was stratified by sex using a block randomisation approach, with block sizes of 10 (one male and one female per group per block). Due to the nature of the intervention, blinding of participants and the researcher was not possible and allocation was not concealed.

Training condition

Participants attended three separate laboratory visits prior to the IET intervention: a familiarisation session; a baseline physiological data collection session; and an incremental lower-body IET test to determine the knee joint angle used during training.¹⁵ The individual knee joint angle was established to elicit a training intensity of 95% HR_{peak} during home-based sessions (HR_{peak} relates to the mean HR during the final 30 s of the incremental test). Following the incremental lower-body IET test, experimental participants were required to complete an initial 4-week home-based lower-body IET programme,¹⁵ comprising 4 bouts of isometric wall-squat exercise, separated by 2 min of seated rest, 3×/week, with 48 hours between each session.

Following the first 4-week training period, participants attended the laboratory for mid-training resting measures (visit 4). The experimental participants were

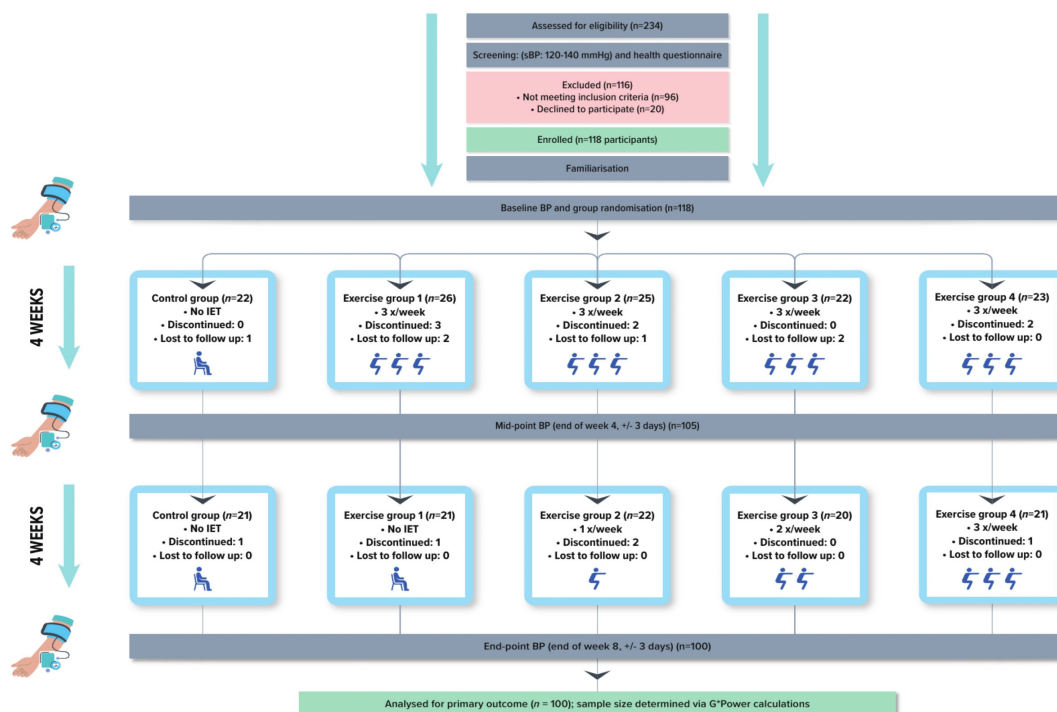


Figure 1 CONSORT flow diagram illustrating participant progression through the isometric exercise training trial, including screening, randomisation, group allocation and follow-up over 8 weeks. BP, blood pressure; CONSORT, Consolidated Standards of Reporting Trials; IET, isometric exercise training; sBP, systolic blood pressure.

then informed of their group allocation and subsequent training frequency for the second 4-week period. Participants began their second 4-week training period the day directly following their mid-point laboratory visit. Following the full 8-week period, participants were required to attend the laboratory again for post-training resting measures (visit 5).

During IET sessions, participants recorded their HR during the last 30s of each exercise bout using a wrist-mounted HR monitor and a Polar H10 chest strap (Polar Electro Oy, Kempele, Finland). If the HR data fell outside a target heart rate (HR) zone for more than two sessions, the knee angle was reduced or increased by 5° to ensure that the HR fell back within the correct range.¹⁶ Training adherence was confirmed by downloading HR data from the participants' watch at the end of each 4-week period. During the first 4-week period, the adherence threshold was 10 out of 12 sessions. During the second 4-week period, adherence to all IET sessions in all groups was required due to the predicted small differences and need for accurate comparisons between the various training frequencies. All participants were also required to fill in a physical activity training log to confirm that any additional physical activity levels remained below the required threshold.

Control group participants were requested to maintain their habitual dietary and daily routines for an 8-week period. Adherence to these conditions was verbally confirmed during each laboratory session. Control participants were also required to fill in a physical activity

training log to validate that their physical activity levels remained below the required threshold.

Resting measures

Resting haemodynamic and cardiac autonomic measures were measured using a Task Force Monitor (TFM; CNSystems, Medizintechnik, Graz, Austria).^{17 18} Following 15 min of seated rest, haemodynamic and cardiac autonomic function was measured continuously in the seated position for 5 min in a temperature-controlled room, with the mean for each variable calculated offline. The TFM allows for the observation of beat-to-beat changes in arterial BP using a vascular unloading technique at the proximal limb of the index or middle finger, which is then adjusted in accordance with oscillometric BP values from the brachial artery of the contralateral arm. HR was recorded using a 6-channel ECG. Beat-to-beat stroke volume (SV) was measured with impedance cardiography. Cardiac output (Q) was calculated as the product of HR and SV. Total peripheral resistance (TPR) was measured according to Ohm's law as a function of mean arterial pressure (MAP) and Q. R-R intervals were used to calculate real-time HR variability (HRV) via an autoregressive model. High (HF) (predominantly parasympathetic outflow) and low (LF) (predominantly sympathetic outflow) frequency parameters of HRV were automatically calculated. Baroreceptor reflex sensitivity (BRS) was calculated via the sequence method.

Data analysis

Data were checked for normality and homogeneity of variances. If parametric, a one-way analysis of covariance (ANCOVA) using baseline measures as the covariate was carried out. If statistically significant, a least significant difference (LSD) post-hoc test was used to explore any differences detected between the experimental and control groups at the 8-week mark. For analysis at the 4-week time point, an ANCOVA was used with all experimental data collated ($n=80$) compared against the control group ($n=20$). A one-way analysis of variance was also conducted to assess baseline differences in BP, age, body mass, height and non-exercise physical activity (MET-mins). Where data were not normally distributed, a Quade non-parametric ANCOVA was used. To examine the relationship between changes in BP and key physiological variables, a repeated-measures correlation approach was used.¹⁹ An alpha level of 0.05 was set as the threshold for statistical significance. Data analysis was performed with IBM SPSS Statistics for Windows (V.29.0; IBM).

Patient and public involvement

Participants were not involved in the study design, conduct or dissemination of outcomes.

RESULTS

From July 2020 to September 2023, 100 participants (45% female) completed the study (37 ± 11 years; 79 ± 14 kg; 173 ± 9 cm; [table 1](#)). During the first 4-week period, 77 out of 80 experimental participants completed all 12 training sessions and 3 missed 1 session, completing 11 training sessions over the 4 weeks. During the second 4-week period (weeks 4–8), all prescribed IET sessions were adhered to for all groups. Full resting haemodynamic and cardiac autonomic data were obtained for all participants at all time

points. No harms or unintended effects were observed in any group during the study.

Baseline comparisons across groups revealed no significant differences in sBP ($p=0.26$) and diastolic BP (dBP) ($p=0.69$). There were no differences in body mass ($p=0.744$), height ($p=0.087$) or age ($p=0.25$). Non-exercise physical activity differed between groups ($p<0.001$). The 1×/week group showed the highest activity levels, exceeding all other groups (all $p\leq 0.012$). The 2×/week group was higher than 0×/week and 3×/week (both $p<0.001$), and the control group exceeded 0×/week ($p=0.002$).

Resting BP

After 4 weeks of IET, sBP ($p<0.001$), dBP ($p=0.007$) and MAP ($p<0.001$) were reduced versus control. By 8 weeks, significant group effects remained for sBP and MAP (both $p<0.001$). Pairwise comparisons showed that sBP was lower in the 3× ($p<0.001$), 2× ($p<0.001$), and 1×/week ($p=0.003$) groups versus control ([figure 2](#)). MAP followed the same pattern, with reductions in 3× ($p<0.001$), 2× ($p=0.013$), and 1×/week ($p=0.027$) compared with control. There was no main group effect for dBP ($p=0.06$). Mean values can be seen in [table 2](#).

Post hoc comparisons revealed that sBP was lower in the 3×/week group compared with both 2×/week ($p=0.003$) and 1×/week ($p<0.001$), while 2× and 1×/week did not differ ($p=0.629$). For MAP, 3×/week was lower than 1×/week ($p=0.045$), but not 2×/week ($p=0.086$); no difference was observed between 2× and 1×/week ($p=0.766$).

Resting cardiac output, TPR, HR and SV

After 4 weeks, TPR and TPRi were reduced versus control ($p=0.007$, $p=0.002$), with no changes in HR, $\dot{Q}$, $\dot{Q}_i$, SV or Si. At week 8, there were significant group effects for TPR ($p=0.025$) and TPRi ($p=0.008$). Post hoc analyses showed lower TPR in the 3×/week group, and lower TPRi in both 3× and 2×/week versus control (all $p<0.05$). No differences were observed for HR, $\dot{Q}$, $\dot{Q}_i$, SV or Si. Full data are reported in online supplemental table S1.

Resting HRV and baroreceptor sensitivity

At 4 weeks, IET increased power spectral density of RR intervals (PSD-RRi) ($p=0.025$) and HF power ($p=0.006$), while LF showed no change ($p=0.47$). These adaptations were accompanied by a lower LF:HF ratio ($p<0.001$), higher HFnu, lower LFnu (both $p=0.03$), and an increase in BRS ($p=0.028$) compared with control. By 8 weeks, group effects were evident for all autonomic indices (all $p<0.05$). Post hoc analyses confirmed that only the 3×/week group remained significantly different from control across all measures (all $p<0.05$). Mean values can be seen in the online supplemental table S2.

Correlation analysis between BP and mechanistic variables

Significant correlations were observed between BP changes and indices of vascular resistance (TPR, TPRi)

Table 1 Participant demographics for all experimental and control groups (mean $\pm$ 1 SD)

Variable	Control	0×/week	1×/week	2×/week	3×/week
Sex (M:F)	12:8	11:9	10:10	11:9	11:9
Age (years)	34 ± 7	40 ± 9	40 ± 13	38 ± 10	35 ± 13
Body mass (kg)	74 ± 12	78 ± 9	82 ± 16	80 ± 11	83 ± 15
Height (cm)	174 ± 8	172 ± 10	173 ± 8	175 ± 10	175 ± 10
Baseline BP (mm Hg)	128/81	132/83	130/85	129/84	131/84
MET-mins/week	512 ± 12	485 ± 32	548 ± 22	526 ± 24	496 ± 19

BP, blood pressure; F, female; M, male; MET, metabolic equivalent of task.

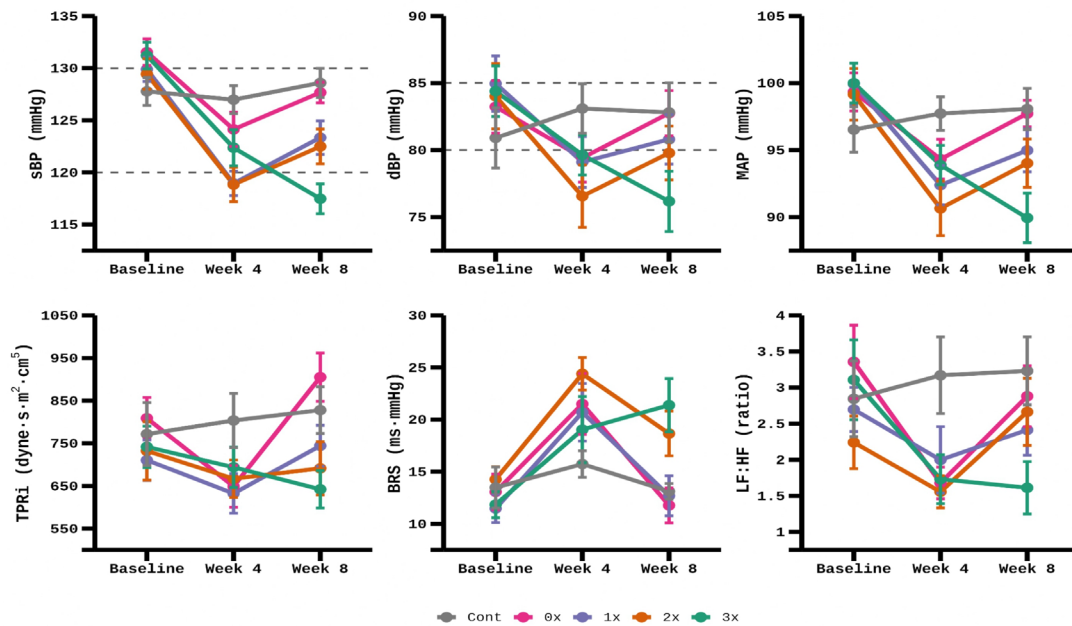


Figure 2 Mean values for systolic blood pressure (sBP), diastolic blood pressure (dBP), mean arterial pressure (MAP), total peripheral resistance index (TPRi), low-to-high frequency ratio (LF:HF) and baroreceptor reflex sensitivity (BRS) over the 8-week training period across all groups (3x/week, 2x/week, 1x/week, 0x/week and control). Error bars indicate SEM. Grey dashed horizontal lines indicate context thresholds: for sBP, 120 mm Hg (optimal/normal) and 130 mm Hg (normal/high-normal); for dBP, 80 mm Hg (optimal/normal) and 85 mm Hg (normal/high-normal).

and autonomic function (HRV measures and BRS). The strongest associations were between sBP and BRS ($r=0.38$, $p<0.001$) and HRV indices (LFnu/HFnu, $r=0.37$, $p<0.001$). Similar patterns were seen for dBP and MAP. Full correlation coefficients are shown in figure 3.

DISCUSSION

The impact of IET frequency on resting BP

The primary aim of this study was to examine the dose-response relationship between training frequency and the maintenance of resting BP reductions during a follow-up

Table 2 Mean values for systolic (sBP), diastolic (dBP) and mean arterial blood pressure (MAP) in each group

Group		Baseline (mm Hg)	95% CI	Week 4 (mm Hg)	95% CI	Week 8 (mm Hg)	95% CI
3x/week	sBP	131.20±5.74	128.51 to 133.89	122.37±7.77	118.89 to 125.85	117.47±6.39**	114.61 to 120.33
	dBP	84.39±8.45	80.61 to 88.17	79.64±6.71	76.64 to 82.64	76.17±10.04	71.68 to 80.66
	MAP	100.00±6.61	97.04 to 102.96	93.88±6.57	90.94 to 96.82	89.94±8.25**	86.24 to 93.64
2x/week	sBP	129.44±6.53	126.52 to 132.36	118.84±7.36	115.59 to 122.09	122.49±7.48**	119.14 to 125.84
	dBP	84.02±10.91	79.14 to 88.90	76.56±10.42	71.90 to 81.22	79.78±8.96	75.88 to 83.68
	MAP	99.16±8.62	95.32 to 103.00	90.65±9.09	86.52 to 94.59	94.02±8.04*	90.43 to 97.61
1x/week	sBP	129.89±5.25	127.54 to 132.24	118.94±5.25	116.59 to 121.29	123.33±7.19*	120.11 to 126.55
	dBP	84.96±9.23	80.84 to 89.08	79.11±8.47	75.33 to 82.89	80.80±8.24	77.12 to 84.48
	MAP	99.94±6.94	96.84 to 103.04	92.39±6.56	89.37 to 95.21	94.98±7.15*	91.78 to 98.18
0x/week	sBP	131.54±5.70	128.99 to 134.09	124.13±7.36	120.88 to 127.40	127.66±4.40	125.69 to 129.63
	dBP	83.23±8.75	79.32 to 87.14	79.42±8.10	75.75 to 83.09	82.75±7.53	79.39 to 86.11
	MAP	99.33±6.37	96.48 to 102.18	94.32±6.62	91.49 to 97.15	97.72±4.44	95.73 to 99.71
Control	sBP	127.77±5.99	125.25 to 130.29	126.98±6.00	124.25 to 129.61	128.59±6.27	125.79 to 131.39
	dBP	80.91±10.08	76.49 to 85.53	83.10±8.25	79.31 to 86.69	82.80±9.91	78.37 to 87.23
	MAP	96.53±7.56	93.15 to 100.05	97.73±5.60	95.22 to 100.18	98.06±6.89	94.91 to 101.09

Data are presented as mean±1 SD, and 95% CIs for resting sBP, dBP and MAP blood pressure at baseline, week 4 and week 8 in the training and control conditions.

* $p<0.05$ and ** $p<0.001$ for difference to control conditions at week 8.

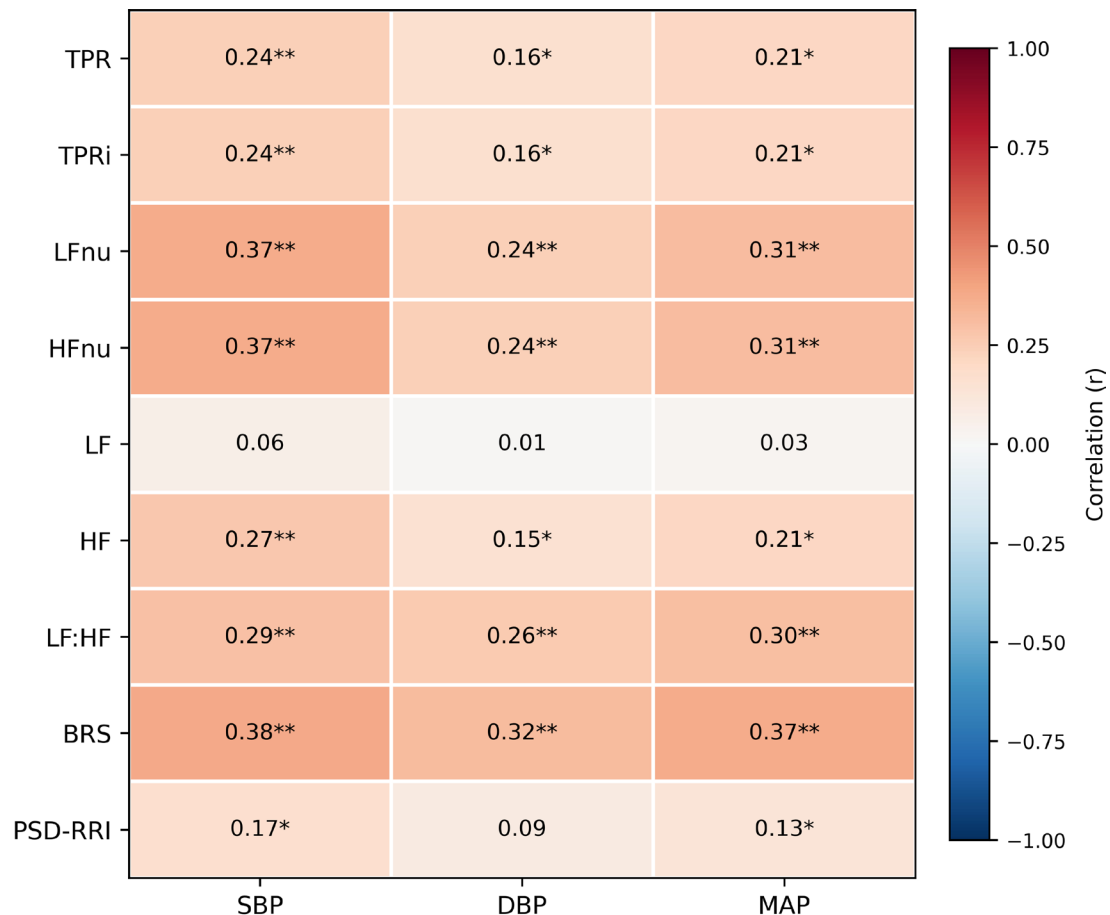


Figure 3 Heatmap of within-subject correlation coefficients (r) between changes in blood pressure (systolic blood pressure (sBP), diastolic blood pressure (dBP) and mean arterial (MAP)) and physiological variables following isometric exercise training. Positive correlations are shown in shades of red, negative correlations in shades of blue. Asterisks (*, **) indicate statistically significant correlations ($p < 0.05$, $p < 0.001$, respectively). Variables include total peripheral resistance (TPR), indexed TPR (TPRI), heart rate variability measures (low frequency (LF), high frequency (HF), LF/HF ratio, normalised LF (LFnu) and HF (HFnu)), power spectral density of RR intervals (PSD-RRI) and baroreceptor reflex sensitivity (BRS).

period of IET. All participants initially completed 4 weeks of lower-body IET, 3x/week. Consistent with previous research,^{15 20–23} significant reductions in sBP, dBP and MAP were observed compared with the control group at this time.

Participants who continued IET at 1 or 2x/week during the subsequent 4-week follow-up were able to maintain significant reductions in sBP and MAP, but not dBP, relative to the control group. These findings align with prior work by Cohen *et al*,¹⁰ who found that after 12 weeks of lower-body IET at 3x/week, BP reductions were maintained at 1x/week. Similarly, Baross *et al*⁹ reported that ambulatory BP reductions from 8 weeks of IET were preserved during an 8-week follow-up with 1x/week. However, these previous studies did not elucidate the dose-response effect. Our data show that participants continuing IET at 3x/week achieved the greatest reductions in resting sBP compared with baseline (−13.73 mm Hg), followed by 2x/week (−6.95 mm Hg), and then 1x/week (−6.56 mm Hg). Notably, no significant differences were seen between 1x and 2x/week, suggesting no added benefit over 1x/week unless training is maintained at 3x/

week. In contrast, the cessation of IET led to BP reductions not significantly different from control within 4 weeks, confirming ≥ 1 x/week is needed to sustain benefits.

Observation of the BP trajectories in the 1x and 2x/week groups suggests early signs of upward drift, indicating that while these lower frequencies may slow the loss of training-induced reductions, they do not fully prevent the gradual reversal of BP improvements during short periods of reduced training. From an applied perspective, these findings imply that reduced frequencies may help buffer short-term lapses in training, but reinstating a 3x/week schedule is likely required to fully preserve adaptations over time. These findings provide the dose-response evidence needed to underpin more pragmatic IET protocols, where training frequency can be periodised in response to real-world adherence constraints. The field must now progress towards hybrid effectiveness-implementation designs to establish whether IET translates to clinically meaningful BP reductions outside the laboratory.

Possible mechanisms underpinning resting BP reduction following IET

The inclusion of multiple comparative groups enables a nuanced evaluation of physiological adaptations within a clearly defined dose–response framework. The 3×/week group not only demonstrated the greatest reductions in sBP and MAP but also the largest improvements in vascular (TPR_i) and autonomic (LF:HF, BRS) function. In contrast, these adaptations were attenuated in the 2×/week group and absent in the 1× and 0×/week groups.

Significant correlations were identified between changes in BP and several mechanistic markers, including TPR, TPR_i, HRV indices (LFnu, HFnu, LF:HF and PSD-RRI) and BRS (figure 3). Importantly, no single physiological variable was found to explain BP changes in isolation. Rather, the pattern of multiple moderate correlations across distinct domains of vascular and autonomic function suggests a redundant, integrative physiological response to training. This redundancy likely reflects the complexity of cardiovascular regulation, with BP reductions arising from synergistic rather than single mechanisms.

Consistent with the findings of Edwards *et al.*¹² the present data further implicate autonomic modulation and vascular resistance as primary mechanisms underlying IET-induced reductions in BP. Reductions in TPR likely reflect enhanced endothelium-dependent vasodilation, increased nitric oxide bioavailability and reduced sympathetic vasoconstrictor activity. Concurrent changes in HRV, specifically increases in HFnu, reductions in LFnu and LF:HF ratio, suggest a shift towards greater parasympathetic influence and reduced sympathetic drive at the sinus node, while increases in BRS indicate enhanced reflex regulation of BP. Importantly, these autonomic adaptations occurred without significant changes in resting HR, indicating that (as a function of Ohm's law) the BP-lowering effect was likely driven by altered vascular function rather than altered cardiac output. Furthermore, as the mechanistic changes observed in these groups mirror the patterns seen in the BP outcomes, these results likely indicate that partial or complete reversal of BP reductions in the 2×, 1× and 0×/week groups was due to the corresponding decline in these same mechanistic variables. While causality cannot be confirmed, the observed alignment between the mechanistic decline and the loss of BP reduction suggests that training frequency plays a critical role in sustaining the cardiovascular adaptations necessary for BP control following IET.

Our data also suggest that total training duration plays an important role in the durability of cardiovascular adaptations. Previous studies¹⁰ have shown greater maintenance of BP reductions following longer intervention periods which may be attributable to the nature of vascular adaptations. IET performed for ≥8 weeks was shown to induce structural vascular changes, such as increased arterial diameter and reduced wall thickness. In contrast, shorter-duration intervention (≤4 weeks)

tends to elicit functional vascular adaptations, which have been shown to reverse rapidly on training cessation.^{24 25} This may explain the relatively quick regression of both BP and mechanistic variables observed in the lower-frequency groups of the present study.

Strengths and limitations

A key strength of this study is that it represents one of the largest investigations of its kind, with good balance between groups across the primary variables of interest. This study also included female participants, enhancing the generalisability of the findings. Moreover, to our knowledge, few studies have directly assessed the degree to which changes in physiological mechanisms are statistically associated with BP reductions following IET. While the majority of studies infer such mechanisms based on group-level trends,¹² the current study is among the first to apply formal correlation analyses across multiple training frequencies.

Although there were statistically significant differences in weekly MET-mins between groups at baseline, these differences fall within normal daily variation and are below thresholds typically associated with meaningful BP change.^{26 27}

A notable limitation of this study is that the follow-up period for the maintenance phase was restricted to 4 weeks. In terms of cardiovascular health and long-term pathophysiology, this is relatively short, and future trials should examine whether these BP trajectories persist beyond 4 weeks to better inform longer-term IET prescription.

CONCLUSIONS

Our findings provide evidence that sBP and MAP reductions can be maintained for up to 4 weeks with just 1 or 2 IET sessions/week. For individuals unable to commit to higher training frequencies, even minimal engagement (1×/week) can help maintain significant benefits for sBP and MAP over a short 4-week period. However, for optimal BP reductions and the maintenance of a broader range of physiological adaptations, a frequency of 3×/week may be recommended.

By establishing the minimum effective dose required to maintain BP reductions, the present study provides a critical evidence base on which more pragmatic and ecologically valid research can be built. We recommend the field must now progress from highly controlled efficacy trials towards hybrid effectiveness-implementation designs to evaluate long-term adherence and understand whether IET produces meaningful BP reductions under real-world conditions.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Canterbury Christ Church University (Ref: 19/SAS/12C). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The data supporting the findings of this study are available from the UK Data Service (ID: 857921). Access is subject to standard licensing and registration requirements.

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