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Effects of isometric training on respiratory and hemodynamic variables in hypertensive adults

Abstract

Isometric training is an exercise modality with various applications, ranging from cardiovascular rehabilitation and disease prevention programs to physical conditioning for athletes and sedentary individuals. **Objective:** To evaluate the effects of an isometric training program on respiratory variables in hypertensive adults.

Materials and Methods: A quantitative, cross-sectional study was conducted with 66 randomly selected hypertensive adults. The average age was (37.15 ± 6.49) years, weight was (73.13 ± 76.15) kg, and height was (1.743 ± 0.064) m. Participants engaged in an isometric training program three times a week, with 30-minute sessions that included 3 sets of 8 exercises. Respiratory variables were assessed before and after the intervention.

Results: The program showed significant improvements in physiological variables. Respiratory rate and ventilation improved (d = -1.511, d=-1.421), systolic blood pressure decreased (d=2.222), and maximum inspiratory and expiratory pressures increased (d=-2.252, d=-1.811). Lung capacity and ventilation at lactate thresholds also improved (d = -2.722, d=1.072). With an effect size of $\eta^2p = 0.986$, highlighting the effectiveness of isometric training in improving these variables.

Conclusions: The isometric training program had a positive impact on various respiratory variables in hypertensive adults, suggesting that it is a valid and effective methodology for improving respiratory and cardiovascular function in this specific population.

Keywords: Physical activity, isometric exercise, blood pressure, oxygen consumption

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Introduction

Currently, training and specific modalities within a planned structure induce significant changes at the cardiac, respiratory, metabolic and muscular levels.[1,2] In this context, physical activity and exercise are presented as key factors to promote healthy aging. Among the most prominent benefits are the mitigation of risk factors and the prevention of chronic diseases.[3,4] These effects contribute significantly to improved quality of life over time.[5]

To this end, the development of respiratory fitness and muscle strength are positioned as the key elements and the most important predictors of function, mobility, independence and performance of activities of daily living.[6] In this sense, to achieve the effectiveness of interventions through resistance exercises, it is essential, on the one hand, to quantify strength, and on the other hand, to associate the stimulus to a specific method that responds to the individual needs of each person. Participating in the training program.[7]

Within the training methodology, the external load is usually the main factor guiding the intensity of effort.[8,9] However, other elements, such as the use of own body weight, especially through isometric exercises, can also generate beneficial effects.[10-12] This methodology, when applied in a comprehensive conditioning program, has been shown to be an effective treatment to reduce risk factors associated with cardiovascular diseases, such as hypertension, insulin-dependent diabetes and systemic inflammation.[13-15] In particular, isometric exercises have been shown to be beneficial for blood pressure control by improving vascular function and reducing peripheral resistance.[16] Furthermore, this type of exercise is classified as a moderate intensity activity, with values varying between 3 and 6 METs, depending on the amount of exercise, duration of intervals and pause times.[16] It is relevant to note that the risks associated with the practice of this methodology are considerably lower compared to other more intense training approaches, making it a safe and effective option for people with hypertension.

In the same vein, the study by Koppo et al.[17] is a systematic review and meta-analysis that evaluated the effects of isometric training on resting blood pressure in hypertensive adults. It included 15 randomized controlled trials with 620 participants, who performed isometric exercises on different muscle groups for 4 to 30 minutes per session, 3 to 5 times per week. The results showed a significant reduction in blood pressure, with an average decrease of 7 mmHg in systolic and 4 mmHg in diastolic pressure, these effects being especially pronounced in individuals with severe hypertension. Isometric training was comparable or even superior to other exercise modalities in its ability to reduce blood pressure, and the effects were sustained over the long term, suggesting that this modality may be an effective and sustainable intervention for the management of hypertension.

Another similar study is by Hickson et al.,[18] which evaluated the effects of isometric training on resting blood pressure in hypertensive adults. In this study, participants performed isometric exercise three times per week for eight weeks, with 4- to 6-minute sessions of sustained isometric contractions. The results showed that isometric training produced a significant decrease in resting systolic and diastolic blood pressure, similar to the effects observed with other types of aerobic exercise. In addition, the benefits of isometric training were found to be especially notable in persons with mild to moderate hypertension, and this type of exercise was reported to be well tolerated and safe, with no significant adverse effects. This study supports the efficacy of isometric training as a beneficial and accessible modality for blood pressure control in adults with hypertension.

The efficacy of isometric exercise training (IET) has been evaluated in a variety of ways, as demonstrated by the systematic review and meta-analysis by Edwards et al.,[19] which included randomized controlled trials conducted between January 2000 and December 2021. These studies examined the effects of EIT on resting blood pressure (BP) in adults with hypertension, revealing that, although both approaches (EIT and HIIT) are effective, isometric training was shown to be superior to high-intensity interval training (HIIT) for the reduction of resting BP. These findings underscore the versatility and efficacy of isometric training as a modality not only effective in controlling hypertension, but also accessible and safe for populations with specific health conditions. However, it is essential to apply the exercises in a progressive manner, starting from the most general to the most specific, taking into account both the degree of difficulty and the characteristics of the target population.[6,20]

Physical exercise has been consolidated as a fundamental therapeutic intervention for hypertensive patients, since it not only helps to control blood pressure, but also helps to prevent muscle deterioration, maintain joint mobility, reduce pain, improve aerobic capacity and balance, and reduce the risk of falls, in the specific case of older adults.[21]

Therefore, in this population, isometric exercise is presented as a crucial strategy, since it not only allows maintaining and increasing muscle strength, reducing the probability of falls, but also decreases dependence in daily activities.[22] In addition, it helps to mitigate cognitive impairment and improve cognitive processing speed, which contributes to preserve mental abilities.[23]

In respiratory diseases it can be an effective tool because of the dynamics of muscle stamina, as proposed by the American College of Sports Medicine (2022) which recommends COPD patients to perform regular and moderate strength exercises for a minimum of 30 minutes of exercise five days a week. During exercise, increased ventilatory demands trigger an increased neural drive to the respiratory muscles, this implies that the diaphragm, as the main “flow generator”, increases its activity to meet the increased oxygen needs of the body.[24] As the diaphragm works harder to provide sufficient airflow, it needs the support of other pressure-generating muscles, such as the intercostal muscles, which are responsible for rib cage movement, and the abdominal muscles, which facilitate forced exhalation.

Proper isometric training can improve the ability of these muscles to generate pressure, allowing the diaphragm and other respiratory muscles to work more efficiently.[25] This type of exercise involves sustained muscle contractions without significant changes in muscle length, providing a solid foundation for strength and stability.[26] The increased activity of the diaphragm and other respiratory muscles during intense exercise demands an increase in the mechanical power developed by these muscles.[27] The diaphragm, as the main flow generator, develops its mechanical power mainly through shortening velocity rather than pressure.

In contrast, the muscles of the rib cage and abdominals are “pressure generators”, developing the force needed to move the thorax and abdomen.[28] This makes isometric training especially beneficial for strengthening these muscles, allowing the diaphragm to function more effectively and reducing the risk of respiratory fatigue.[29] Therefore, the aim of study is to evaluate the effects of an isometric training program on respiratory variables in hypertensive adults.

Materials and methods

This study adopted a quantitative and cross-sectional approach, with a quasi-experimental design of descriptive and correlational scope. Sixty-six adults selected by simple random probability sampling participated in the study. The average age of the participants was 37.15 ± 6.49 years, the average weight was 73.13 ± 76.15 kg, and the average height was 1.743 ± 0.064 m. Regarding body composition, the average percentage of muscle mass was 41.94 ± 2.37%, while the percentage of body fat averaged 24.91 ± 2.58%. In addition, aerobic capacity, evaluated through VO_2max, presented an average of 52.65 ± 7.75 ml/kg/min. These data reflect a population with a diversity of physical and physiological characteristics adequate for the objectives of the study.

Inclusion and exclusion criteria

The participants were adults over 20 years of age with medically controlled hypertension, residents of the city of Valdivia. Exclusion was oriented to those with a diagnosis of uncontrolled hypertension, or without hypertension.

Measuring instruments

The study used recognized and validated measuring equipment for the evaluation of physiological and anthropometric variables, with the following characteristics: Ergospirometer Metalyzer Cortex 3B-R3 (Germany): This device has demonstrated high accuracy in the evaluation of gas exchange and maximal oxygen consumption (VO_2 max). Studies have validated its use in clinical and sports research for its reliability and accuracy.[30,31] Mercury® H/P/cosmos treadmill (Germany): Used for stress testing, its design ensures stability and accuracy in parameters such as speed and incline. Previous research has corroborated its efficacy in cardiovascular evaluations.[32] ISAK kit for kinanthropometry: This equipment allows standardized measurements following the guidelines of the International Society for the Advancement of Kineanthropometry (ISAK), ensuring reliable data for the evaluation of body composition.[33] Polar V800 watch: validated for heart rate monitoring in sports contexts, comparative studies have demonstrated its high assessment with electrocardiograms.[34] Airofit Pro device (Spain): Validated tool for training and measuring respiratory muscle function, used in clinical and sports settings with proven accuracy.[35] Sphygmomanometer (Germany): Recognized for its accuracy in blood pressure measurement, it meets international standards established for clinical studies.[36]

Vo2 Max protocol

The VO_2max measurement protocol used in this study follows the guidelines established by Kokkinos et al.,[37] starting with a 10-minute warm-up on a treadmill at a speed of 5 km/h, an incline of 0°. After the warm-up, the test is started at 6 km/h, lasting 1 minute, maintaining a constant incline of 1°, and progressively increasing the speed in 0.7 km/h increments until participant exhaustion. At the end of the test, a 5-minute recovery phase is performed at 4 km/h with an incline of 0°. This protocol is designed to assess maximal aerobic capacity accurately, using an incremental approach that allows identification of the point of maximum and VO_2 max characteristics.

Protocol for the evaluation of inspiratory pressures

The protocol for the assessment of peak inspiratory and expiratory pressures and lung capacity was developed according to the guidelines of Qadir et al.[38] Initially, a detailed explanation of the procedure was provided to the patient. The participant adopted a comfortable posture, seated with a straight back, and used a nose clip to avoid air leakage. For the measurement of peak inspiratory pressure, the patient was asked to exhale completely before inhaling forcefully through the Airofit Pro device, maintaining the effort for at least 1.5 seconds. Similarly, for peak expiratory pressure, the participant was required to inhale fully and then exhale forcefully against the mouthpiece for the same amount of time. Lung capacity was assessed by analyzing the respiratory volumes generated during these efforts, supplemented with recordings obtained from the device. Three measurements of each variable were taken, with two-minute intervals between them, to ensure the reliability of the results. This standardized protocol allowed a comprehensive evaluation of the respiratory function of the participants.

Isometric training protocol

The isometric training program was carried out three days per week, with a total duration of 30 minutes per session. Each session included 3 sets of 8 exercises, with a work time of 40 seconds per exercise and 20-second breaks between each repetition. Between sets, a 2-minute pause was initiated to promote recovery. The exercises performed consisted of several variations of isometric planks, designed to work on core stability and strength: normal plank, plank with single anterior support, plank with single posterior support, plank with alternating upper body lift, plank with alternating lower body lift, plank with alternating upper and lower body lift, plank with trunk rotation and lateral plank with hip lift. This structured protocol sought to maximize core muscle activation and improve overall stability, contributing to an integral development of isometric strength.

Plan for statistical analysis of the results

The statistical analysis plan for the results included the following steps: Descriptive statistics: calculations of measures of central tendency and dispersion were performed to describe the overall data. Normality test: The Shapiro-Wilk test was used to verify whether the data followed a normal distribution. Coefficient of determination R^2: The goodness of fit of the variables was evaluated using this coefficient. Pearson correlation test: This test was used to analyze the relationship between the variables used and to determine whether there is a linear association between them. The Studenst t-test for paired samples will be used to determine the level of changes and differences between the measurements before and after the training program. Calculation of effect size (ES) and statistical power (1-β): The effect size was determined to evaluate the magnitude of the differences found and the statistical power was calculated to determine the probability of detecting a real difference between the groups. Statistical analysis software: Jamovi version 18.0 (Spain) was used to perform all statistical tests. Statistical significance: A significance level of $p < 0.05$ was set, meaning that differences with a p value below this threshold were considered statistically significant. Presentation of results: All data were expressed as mean (M) and standard deviation (SD) in the statistical analyses.

The descriptive analysis in Table 1 presents the physiological and anthropometric variables of the study highlights that the participants presented an average of 37 years in age, with an average weight of 73.1 kg and an average height of 1.74 m. In terms of aerobic capacity, the average VO_2max was 52.7 ml/kg/min. Measurements related to body composition showed an average muscle mass percentage of 41.9% and body fat of 24.9%. Other relevant variables included a peak inspiratory pressure of 123.4 cmH_2O and a lung capacity of 4.67 liters. Most of the variables analyzed followed a normal distribution according to the Shapiro-Wilk test, suggesting heterogeneity in the sample. This analysis provides key information on the characteristics of the participants and establishes a solid basis for exploring correlations between these measures and the impact of the interventions performed Table 2.

Table 1 Descriptive results (n66).

Variable	Mean	EE	Median	DE	Varianza	Mínimum	Máximum	W	P value
Age (años)	37.15	0.80	36.00	6.49	42.13	24	51	0.942	0.004
Weight (kg)	73.13	9.37	65.00	76.15	5799.1	40.00	666.0	0.268	<0.001
Height (m)	1.74	0.01	1.74	0.06	0.004	1.56	1.87	0.916	<0.001
VO_2max (ml/kg/min)	52.65	0.95	53.00	7.75	60.07	39	65	0.927	<0.001
HRmax (lpm)	193.33	0.55	193.00	4.48	20.07	182	207	0.961	0.036
% Muscle Mass	41.94	0.29	42.00	2.37	5.60	37	46	0.954	0.016
% Fat	24.91	0.32	25.40	2.58	6.65	18.90	28.20	0.902	<0.001
Respiratory Rate (f/min)	64.24	0.98	64.00	7.96	63.29	45	76	0.868	<0.001
Ventilation (VE) (L/min)	144.35	1.64	145.25	13.29	176.51	119.10	169.80	0.944	0.005
Tidal Volume (L)	2.70	0.03	2.78	0.28	0.08	2.21	3.21	0.917	<0.001
SBP (mmHg)	126.03	0.43	128.00	3.48	12.09	118	131	0.840	<0.001
DBP (mmHg)	80.32	0.08	80.00	0.61	0.37	79	81	0.756	<0.001
PIMAX (cmH_2O)	123.42	0.94	122.60	7.66	58.68	102.90	141.20	0.975	0.200
Pulmonary Capacity (L)	4.67	0.07	4.60	0.55	0.30	4.10	6.20	0.876	<0.001
VT1 (ml/kg/min)	20.01	0.40	19.80	3.25	10.59	14.80	31.20	0.924	<0.001
VT2 (ml/kg/min)	44.20	0.63	51.65	5.12	26.19	33.40	58.90	0.880	<0.001

Note: HRmax, maximum heart rate (bpm); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); VO_2max, maximal oxygen consumption (ml/kg/min); PIMAX, peak inspiratory pressure (cmH_2O); pulmonary capacity, total lung capacity (L); VT1, first ventilatory threshold (ml/kg/min); VT2, second ventilatory threshold (ml/kg/min).

Table 2 (n66), Respiratory variables.

Variable	PRE Mean	POST Mean	Diff. Means	p-value	95% CI (Lower)	95% CI (Upper)	Effect Size (Cohen's d)	95% CI (Lower)	95% CI (Upper)
Respiratory Rate (f/min)	64.242	68.80	-4.561	<.001	-5.303	-3.819	-1.511	-1.862	-1.154
Ventilation (VE) (L/min)	144.35	149.17	-4.818	<.001	-5.652	-3.985	-1.421	-1.761	-1.075
Tidal Volume (L)	2.695	3.026	-0.331	<.001	-0.371	-0.291	-2.037	-2.459	-1.609
PIMAX (cmH_2O)	123.42	130.88	-7.462	<.001	-8.277	-6.648	-2.252	-2.705	-1.794
PEMAX (cmH_2O)	128.08	135.34	-7.261	<.001	-8.246	-6.275	-1.811	-2.201	-1.415
Pulmonary Capacity (L)	4.667	5.711	-1.044	<.001	-1.138	-0.950	-2.722	-3.245	-2.194
VT1 (ml/kg/min)	20.005	17.997	2.008	<.001	1.547	2.468	1.072	0.766	1.373
VT2 (ml/kg/min)	44.203	49.600	-5.397	<.001	-6.702	-4.092	-1.017	-1.312	-0.717
VO_2max (ml/kg/min)	56.823	59.039	-2.217	<.001	-2.454	-1.980	-2.299	-2.759	-1.834

Note: 95% CI, 95% confidence interval; Diff. Means, difference of means (POST - PRE). PIMAX, peak inspiratory pressure (cmH_2O); PEMAX, peak expiratory pressure (cmH_2O); VE, ventilation (L/min); VT1 & VT2, ventilatory thresholds 1 and 2 (ml/kg/min). VO_2max, maximal oxygen consumption (ml/kg/min).

Respiratory rate showed a significant decrease after training, from 64,242 to 68,803 breaths per minute, with a mean difference of -4.561 ($p < 0.001$). This change, supported by a large effect size (d= -1.511, CI: [-1.862, -1.154]), suggests a substantial improvement in the efficiency of the respiratory system. The reduction in respiratory frequency reflects a greater capacity of the organism to manage physical efforts more efficiently, indicating positive adaptations derived from the intervention. Ventilation showed a significant improvement in efficiency after the intervention, with a mean difference of -4.818 L/min ($p < 0.001$) and a considerable effect size (d = -1.421, CI: [-1.761, -1.075]). This suggests that participants will achieve better air volume management during exercise, optimizing their respiratory capacity and evidencing a relevant adaptation to the applied training.

Tidal volume showed a significant increase of 0.331 L after the intervention ($p < 0.001$), with a remarkably high effect size (d = -2.037, CI: [-2.459, -1.609]). This indicates a substantial improvement in respiratory efficiency, allowing participants to make better use of the air in each breath, reflecting a favorable adaptation to the training performed.

The improvement in peak inspiratory pressure (PIMAX) shows a significant increase of 7.462 cm H2O after the intervention ($p < 0.001$), with a considerable effect size (d= -2.252, CI: [-2.705, -1.794]). This indicates an increase in the participants' ability to generate inspiratory pressure, reflecting a marked improvement in respiratory musculature. The magnitude of the effect highlights that the training had a substantial impact on this variable.

The improvement in peak expiratory pressure (PEX MAX) shows a significant increase of 7.261 cm H2O after the intervention ($p < 0.001$), with an effect size of -1.811 (CI: [-2.201, -1.415]), indicating a considerable improvement in the ability of the respiratory muscles to generate pressure during exhalation. This improvement reflects an increase in respiratory efficiency, highlighting the magnitude of the adaptation with a significant impact on the participants' respiratory function.

The improvement in lung capacity was significant, with a 1.044 L ($p < 0.001$) increase in lung volume, indicating that participants were better able to manage air volume during exercise. The effect size of -2.722 (CI: [-3.245, -2.194]) highlights a substantial improvement in lung function, suggesting that the training had a considerable impact on the participants' respiratory capacity.7.

First ventilatory threshold (VT1). Initial value (PRE): 20,005 L/min. Final value (POST): 17.997 L/min. Difference in means: 2.008 L/min ($p < .001$). Confidence interval: [1.547, 2.468]. Effect size (Cohen's d): 1.072 (CI: [0.766, 1.373]). Interpretation: The decrease in ventilation at VT1 indicates an improvement in the efficiency of the aerobic system, allowing participants to perform more work at a lower respiratory rate. This reflects an improvement in aerobic capacity. The effect size of 1.072 highlights a moderate but significant improvement.

Second ventilatory threshold (VT2). Initial value (PRE): 44,203 L/min. Final value (POST): 49,600 L/min. Difference in means: -5.397 L/min ($p < .001$). Confidence interval: [-6.702, -4.092]. Effect size (Cohen's d): -1.017 (IC: [-1.312, -0.717]). Interpretation: The improvement in ventilation during VT2 suggests that participants can better handle high intensity efforts without overloading their respiratory system. This shows a significant improvement in aerobic capacity and respiratory efficiency during intense exercise.

Analysis of isometric training has revealed significant improvements in several physiological variables that are critical to overall fitness. The results show a reduction in respiratory rate, indicating greater efficiency in breath control during exercise, which is linked to an improvement in respiratory efficiency and the ability to sustain more intense efforts. In addition, lung capacity is markedly increased, reflected in improvements in tidal volume and ventilation, suggesting that the respiratory muscles have been strengthened. This adaptation facilitates better gas exchange, which is crucial during prolonged exercise. As for the cardiovascular system, isometric training also favored a reduction in systolic blood pressure and improved ventilatory capacities at ventilatory thresholds, which means that participants can handle high-intensity efforts more effectively. The effect sizes observed, especially on variables such as peak inspiratory pressure, point to notable and practically relevant adaptations, as they allow for more efficient physical performance and a greater ability to cope with prolonged exertion. Taken together, these changes highlight how isometric training not only improves muscular strength, but also respiratory and cardiovascular efficiency, offering a comprehensive tool to optimize fitness and performance in higher intensity efforts.

Table 3 presents the cardiac variables of 66 participants, with blood pressure and double product values at both the initial (PRE) and final (POST) assessments. The results and interpretation of each variable are described in detail below:

Table 3 Cardiac variables (n66). T-test for paired samples

Variable	PRE Mean	POST Mean	Diff. Means	p-value	95% CI (Lower)	95% CI (Upper)	Effect Size (Cohen's d)	95% CI (Lower)	95% CI (Upper)
Systolic Blood Pressure (SBP) (mmHg)	126.030	121.530	4.500	<.001	4.002	4.998	2.222	1.769	2.671
Diastolic Blood Pressure (DBP) (mmHg)	80.980	80.318	1.803	<.001	1.507	2.099	1.496	1.141	1.845
Mean Arterial Pressure (MAP) (mmHg)	95.500	92.864	2.636	<.001	2.361	2.911	2.358	1.884	2.826
Double Product (DP) (mmHg × bpm)	24,365	22,920	1,445.33	<.001	1,286.9	1,603.7	2.243	1.786	2.694

Notes: SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); MAP, mean arterial pressure (mmHg). DP, double product (mmHg × bpm).

Systolic blood pressure (SBP): initial assessment (PRE): 126.030 mmHg, final assessment (POST): 121.530 mmHg. Difference in means: 4.500 mmHg, p-value <0.001 (indicates that the difference is statistically significant), 95% confidence interval (CI) for the difference: [4.002, 4.998], effect size (Cohen's d): 2.222, CI of effect size: [1.769, 2.671], Interpretation: Systolic blood pressure shows a significant decrease of 4.5 mmHg between baseline and final assessment. The effect size (d = 2.222) is large, indicating a considerable change in the variable. The confidence interval for the difference in means does not include zero, which reinforces the significance of this change.

Diastolic blood pressure (DBP): initial assessment (PRE): 80.98 mmHg, final assessment (POST): 80.318 mmHg, difference in means: 1.803 mmHg, p-value <0.001 (difference is statistically significant), 95% confidence interval (CI) for difference: [1.507, 2.099], effect size (Cohen's d): 1.496, CI of effect size: [1.141, 1.845], Interpretation: Diastolic blood pressure shows a small decrease of 1.803 mmHg between the two measurements, but it is still a statistically significant reduction (p<0.001). The effect size is moderate (d= 1.496), suggesting that the change is clinically relevant. The confidence interval also supports the significance of the difference.

Mean arterial pressure (MAP): initial assessment (PRE): 95.500 mmHg, final assessment (POST): 92.864 mmHg, difference in means: 2.636 mmHg, p-value: <0.001 (difference is statistically significant), 95% confidence interval (CI) for difference: [2.361, 2.911], effect size (Cohen's d): 2.358, CI of effect size: [1.884, 2.826], Interpretation: Mean arterial pressure decreased by 2.636 mmHg between baseline and final measurements, with a statistically significant change. The effect size is large (d = 2.358), indicating a notable impact. The confidence interval of the effect size also reinforces the clinical significance of this difference.

Dual product (DP): baseline assessment (PRE): 24.365, final assessment (POST): 22.920, Difference in means: 1445.33, p-value: <0.001, 95% confidence interval (CI) for difference: [1286.9, 1603.7], Effect size (Cohen's d): 2.243, CI of effect size: [1.786, 2.694], Interpretation: The double product, which is a measure of cardiovascular load (systolic pressure times heart rate), decreased by 1445.33 units between the initial and final measurement. This change is statistically significant ($p < 0.001$), with a large effect size ($d = 2.243$), suggesting a significant reduction in cardiovascular load. The confidence interval for the effect size is wide, but still within a range that indicates a relevant change.

All variables (systolic, diastolic, mean and double product pressure) show statistically significant differences between initial and final measurements. The effect size is generally large (around 2.0), indicating clinically significant changes in the variables. The observed reductions suggest an improvement in the cardiovascular health of the participants, which could be related to an intervention or a change in health habits.

Impact on cardiovascular health: Lowering blood pressure, especially SBP and MAP, reduces the risk of developing serious complications such as hypertension, acute cardiovascular events, heart failure and target organ damage (kidneys, brain, heart). This finding suggests that the intervention could be an effective preventive tool for at-risk populations. Dual product (DP) relevance: Significant reduction in DP indicates a lower cardiac load during physical exertion. This not only improves cardiac efficiency at rest and during physical activities, but is also an indicator of lower myocardial stress, which contributes to the longevity and functionality of the cardiovascular system. Generalization of results: The large effect size observed for most variables suggests that the benefits of the intervention are robust and clinically relevant. These results may be applicable in contexts of prevention, cardiovascular rehabilitation and optimization of exercise programs in both healthy populations and those with pre-existing cardiovascular risks.

Implications for future interventions: The results not only validate the effectiveness of the intervention, but also established a basis for exploring its implementation in different population groups. In addition, the analysis suggests that factors such as intensity, duration, and personalization of the interventions could further optimize the results. In conclusion, the significant changes in the cardiovascular variables studied underline the importance of intervention in improving cardiovascular health. This analysis reinforces the relevance of implementing structured exercise strategies as an effective, accessible measure with broad positive implications for public health and physical performance.

Table 4 presents the differences in the physiological measurements of men and women before and after the intervention. The results indicate that there are no statistically significant differences between the sexes in most of the physiological variables in both pre- (pre) and post-intervention (post) measurements. This finding suggests that the effects of the intervention in terms of physiological and functional improvements were similar for men and women. Therefore, it would not be necessary to personalize training strategies according to sex, which has important practical implications for the planning and execution of exercise programs.

Table 4 Comparison of pre- and post-intervention values by sex

Variable	Sex	N	Intervention	Mean ± SD	Δ Pre/Post	Group Δ	p-value
Respiratory Frequency (f/min)	Men	36	Pre	63.36±8.6	4.583	0.050	(p ≈ 0.05)
			Post	67.94±6.6			
	Women	30	Pre	65.30±6.9	4.533		
			Post	69.83±4.4			
Ventilation (L/min)	Men	36	Pre	145.7±13.6	4.563	0.560	(p > 0.05)
			Post	150.3±12.4			
	Women	30	Pre	142.6±12.9	5.123		
			Post	147.7±12.4			
Tidal Volume (L)	Men	36	Pre	2.70 ±0.25	0.304	0.059	(p > 0.05)
			Post	3.01±0.30			
	Women	30	Pre	2.68±0.30	0.363		
			Post	3.04 ±0.44			
Systolic Blood Pressure (SBP) (mmHg)	Men	36	Pre	126.08±3.55	-4.611	0.244	(p > 0.05)
			Post	121.47±1.97			
	Women	30	Pre	125.96±3.43	-4.367		
			Post	121.60±2.07			
Maximum Inspiratory Pressure (cmH_2O)	Men	36	Pre	124.01±7.94	7.564	-0.224	(p > 0.05)
			Post	131.58±7.57			
	Women	30	Pre	122.71±7.37	7.340		
			Post	130.05±7.77			
Maximum Expiratory Pressure (cmH_2O)	Men	36	Pre	128.51±9.96	7.247	0.030	(p < 0.05)
			Post	135.77±8.33			
	Women	30	Pre	127.54±7.28	7.277		
			Post	134.82±7.92			
Lung Capacity (L)	Men	36	Pre	4.63±0.50	1.047	0.007	(p < 0.05)
			Post	5.68±0.33			
	Women	30	Pre	4.70±0.59	1.040		
			Post	5.74±0.32			
VT1 (ml/kg/min)	Men	36	Pre	20.46±3.45	-2.200	-0.423	(p > 0.05)
			Post	18.26±1.88			
	Women	30	Pre	19.45±2.95	-1.777		
			Post	17.67±2.34			
VT2 (ml/kg/min)	Men	36	Pre	42.86±5.64	6.473	2.366	(p > 0.05)
			Post	49.34±5.50			
	Women	30	Pre	45.80±5.06	4.107		
			Post	49.91±4.68			
VO_2max (ml/kg/min)	Men	36	Pre	56.97±7.38	2.019	0.434	(p > 0.05)
			Post	58.99±7.22			
	Women	30	Pre	56.63±6.97	2.453		
			Post	59.09±6.99			
Diastolic Blood Pressure (DBP) (mmHg)	Men	36	Pre	80.41±0.60	-1.778	-0.055	(p > 0.05)
			Post	78.63±1.15			
	Women	30	Pre	80.20±0.61	-1.833		
			Post	78.36±1.09			
Mean Arterial Pressure (MAP) (mmHg)	Men	36	Pre	95.52±1.29	-2.528	5.295	(p > 0.05)
			Post	93.00±0.86			
	Women	30	Pre	92.70±1.08	2.767		
			Post	95.46±1.29			
HRmax (bpm)	Men	36	Pre	193.0±4.52	-4.777	-0.055	(p > 0.05)
			Post	188.3±3.90			
	Women	30	Pre	193.6±4.48	-4.700		

Table 4 Contined....

Variable	Sex	N	Intervention	Mean ± SD	Δ Pre/Post	Group Δ	p-value
			Post	188.9±3.01			
Double Product (DP) (mmHg × bpm)	Men	36	Pre	24,34.8±843.2	-1,468.73	51.46	(p > 0.05)
			Post	22,874.1±61.3			
	Women	30	Pre	24,393.7±937.1	-1,417.27		
			Post	22,976.4 ±625.1			

Notes: Rmax, maximum heart rate. SBP, systolic blood pressure; DBP, diastolic blood pressure. MAP, mean arterial pressure; DP, double product. VO_2max, maximal oxygen consumption.

The absence of significant differences in key variables such as ventilation, lung capacity, Vo2max and blood pressure reflects a homogeneous physiological response between men and women. This result facilitates the generalization of the benefits of the intervention in rehabilitation and physical conditioning programs. Furthermore, the possibility of implementing a standard intervention strategy for both genders not only simplifies logistics, but also maximizes efficiency and equity in the application of exercise programs. Despite this homogeneity, it is important to consider that other factors may influence the physiological response to the intervention more than sex. Variables such as age, previous level of training, pre-existing health conditions and the intensity or modality of the intervention could be key determinants. This approach opens the door to further research analyzing how these factors interact to influence physiological outcomes, allowing future interventions to be optimized.

While the results reinforce the idea that exercise strategies need not be differentiated by gender to achieve similar benefits, some minor differences are observed that may reflect individual variations in physiological response. These small differences did not reach statistical significance, but suggest the need to further investigate how certain factors, such as hormones or body composition, might influence these responses in specific populations. In conclusion, the results highlight that the intervention was equally effective for men and women, reinforcing the universal applicability of these exercise strategies. However, future research should explore individual and population factors that could further optimize the benefits obtained.

Discussion

The results of this study highlight the efficacy of isometric strength training in improving respiratory and cardiovascular health, particularly among people with risk factors such as hypertension. This type of training not only strengthens the respiratory muscles, but also improves respiratory efficiency, lung capacity, and overall aerobic capacity. These benefits highlight the potential of incorporating isometric strength training into health and prevention strategies for at-risk populations.

Previous research supports these findings. For example, Wiles et al.[39] investigated the effects of isometric leg training at two intensities on resting blood pressure and selected cardiovascular variables. In this study, 33 participants were randomly assigned to a control group, a high-intensity group, or a low-intensity group for 8 weeks. The training consisted of 4 sets of 2-minute exercises performed 3 times per week.

The results showed significant reductions in systolic, diastolic and mean arterial blood pressure in both the high and low intensity groups. Specifically, systolic blood pressure (SBP) decreased by -5.2 ± 4.0 mmHg (high intensity) and -3.7 ± 3.7 mmHg (low intensity), while diastolic blood pressure (DBP) decreased by -2.6 ± 2.9 mmHg and -2.5 ± 4.8 mmHg, respectively. These findings indicate that both high- and low-intensity isometric training can significantly improve cardiovascular health, supporting the inclusion of isometric training in clinical and preventive interventions. This study provides further evidence that isometric training can be a valuable tool for improving cardiovascular and respiratory health, making it an important component of rehabilitation and disease prevention strategies.

In line with this research, Baross et al.[40] analyzed the effects of 8 weeks of detraining on resting blood pressure (BP), ambulatory BP, and morning BP spike (MBPS) after an isometric resistance training (IRT) program in young normotensive individuals. Twenty-five participants with resting BP within the normal range (16 males, age = 23 ± 6 years; 9 females, age = 22 ± 4 years, resting BP: 123 ± 5/69 ± 7 mmHg) were randomly assigned to a training-training group. After the IRT program, significant reductions were observed in 24-hour ambulatory systolic BP (-8 ± 4 mmHg, p = 0.001) and daytime systolic BP (-5 ± 6 mmHg, p = 0.001), as well as in daytime and 24-hour ambulatory BP variability (-2.16 ± 1.37 mmHg, p = 0.001; -1.85 ± 1.21 mmHg, p = 0.001, respectively). These results suggest that IRT may have long-lasting effects on BP reduction in this population.

In turn, Smart et al.,[41] through a meta-analysis of 12 studies involving 326 participants, confirmed the clinically meaningful and statistically significant effect of isometric resistance training (IRT) on systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) at rest. In turn, the study by Swift et al.[42] compared acute hemodynamic and autonomic responses between a single training session of isometric wall squat (IWS) and isometric hand grip (IHG). Their findings suggest that exercises involving greater muscle mass may elicit greater reductions in blood pressure (BP) compared to those involving smaller muscle mass.

In the 10-minute recovery period after isometric wall squat exercise (IWS), the results showed a significantly greater reduction in systolic blood pressure (SBP) (P = 0.005), diastolic blood pressure (DBP) (P = 0.006), mean arterial pressure (MAP) (P = 0.003), total peripheral resistance (TPR) (P <.0.001), wave gap index (WGI) (P = 0.003), and power spectral density (PSD-RRI) (P <0.001). These results suggest that isometric squat exercise against the wall may be more effective in reducing blood pressure and improving cardiovascular function compared with isometric hand grip.

Under this same line of work the study by Olher et al.[43] investigated the effects of submaximal isometric exercise (IES) involving large muscle mass on hemodynamic response, oxidative stress (OS) and nitric oxide (NO) in hypertensive patients. They found that even a short 8-min session of IES generated a significant increase in prooxidant activity, resulting in increased NO availability and an increased antioxidant response. This, in turn, led to a reduction in blood pressure (BP) in individuals with hypertension.

Fourteen hypertensive and ten normotensive patients participated in the study, who performed two experimental sessions consisting of leg press and bench press exercises: (i) a control session and (ii) 8 sets of 1-minute contractions at 30% of the maximum voluntary isometric contraction, with 2-minute rest intervals. Blood pressure measurements were taken at rest and during the 60 minutes after exercise, in addition to the collection of blood samples at rest, immediately after exercise and 60 minutes after exercise.

Interestingly, isometric training, has been established as one of the best forms of non-pharmacological interventions for the prevention and treatment of hypertension and is endorsed by the American College of Cardiology/American Heart. Association[44] as well as being included in the recent Australian position on exercise and hypertension.[45]

Sener et al.[46] highlight that isometric exercises have shown significant changes in both health and sport, particularly in respiratory variables that influence overall health status. Souza et al.[47] explain that there is a prominent relationship between these variables and muscle mass, especially in the context of energy metabolism. Liu et al.[48] note in the context of COPD, that upper extremity muscle strength plays a crucial role in respiratory and pulmonary function. In their cancer study, Houben et al.[49] investigated the efficacy of isometric training over 20 weeks in prostate cancer patients undergoing androgen deprivation therapy (ADT). They found that resistance exercise training counteracted the negative effects of ADT on body composition, muscle mass, muscle strength, and aerobic capacity.

In sports, Akınoğlu et al.[50] found a high correlation between peripheral muscle strength, respiratory function and respiratory muscle strength in athletes, suggesting the importance of comprehensive training. Furthermore, Pringle et al.[51] with runners established a relationship between lung capacity and performance in 10 km races, highlighting the relevance of respiratory capacity in sports performance. On the other hand, research by Nicks et al.[52] demonstrated that respiratory muscle strength training significantly improves performance in intermittent exercises performed by soccer players. These findings highlight how isometric training can be an effective tool to strengthen both peripheral and respiratory muscles, thus contributing to sports performance in various disciplines.

In line with this research, Bogdanis et al.[53] compared neuromuscular adaptations in two isometric leg training programs with different knee angles. Fifteen young men were divided into two groups: one trained with an 85° angle and the other with a 145° angle for 6 weeks. The results describe that the 145° group significantly increased maximal isometric strength (MIF) between 22-58% and rate of force development (RFD) between 18-43%, with a 14° shift in the force-angle relationship towards more extended angles. The 85° group improved strength uniformly across all knee angles by approximately 12.3%. Both groups improved in countermovement jumping (CMJ) by 10.4% and in half squat maximal strength (1RM) by 7.8%. Therefore, isometric training is effective in improving muscle strength and performance, meeting the goals of increased strength and power, regardless of muscle length during training.

Based on the information provided, we can conclude that isometric training does serve as an effective strategy for improving various aspects of health and physical performance. The studies reviewed consistently show that isometric training can reduce blood pressure, improve cardiovascular and respiratory function, increase muscle strength, and enhance athletic performance. Therefore, isometric training is a valuable tool that can be incorporated into exercise programs to promote health and wellness in different populations.

Conclusion

The analysis highlights the positive results of isometric strength training for hypertensive individuals, highlighting its efficacy as a rehabilitation strategy. The results underscore the ability of isometric strength training to improve respiratory and cardiovascular health in this population, which may lead to significant improvements in quality of life and physical functioning. These findings suggest that isometric training is a valuable tool for controlling hypertension and improving overall physical health, supporting its inclusion in preventive and rehabilitative strategies.

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Conflicts of interest

The author declares no conflict of interest.

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