



QUALITY IN SPORT

eISSN 2450-3118 · Open Access · Peer-reviewed

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WIELOGÓRSKA, Aleksandra, ORŁOWSKA, Maria, SANOCKA, Maria, FALANA, Joanna, KAMIŃSKA, Agnieszka, KOZŁOWSKA, Jana, KWIATKOWSKA, Anna, PRZEPIÓRA, Agnieszka, TROJNAR, Karolina, ŻMIGRODZKA, Anna and CZERNIC-GOŁAWSKA, Klaudia. The Rising Role of Isometric Exercise in the Non-Pharmacological Management of Hypertension: A Review of Current Evidence and Clinical Guidelines. *Quality in Sport*. 2026;71:74822. <https://doi.org/10.12775/QS.2026.71.74822>

ARTICLE TIMELINE

Received: 31.07.2026. Revised: 15.08.2026. Accepted: 07.09.2026. Published: 13.09.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).

Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

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The Rising Role of Isometric Exercise in the Non-Pharmacological Management of Hypertension: A Review of Current Evidence and Clinical Guidelines

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Abstract

Background: Arterial hypertension is a major modifiable cardiovascular risk factor, which remains one of the most significant challenges of contemporary medicine. Despite the availability of effective pharmacotherapy, non-pharmacological interventions, such as physical activity, constitute an important element of hypertension management.

Aim: This paper aims to systematise the knowledge regarding the beneficial effects of physical activity on blood pressure control in hypertensive patients, taking into account physiological aspects, the type of physical exertion, and its dosage based on the latest guidelines.

Material and methods: A systematized review of the literature was conducted using PubMed and Google Scholar databases, covering the period from 2013 to 2026. The inclusion criteria

focused on large-scale meta-analyses, systematic reviews, and current clinical guidelines (ESC 2024, ESH 2023, PTNT 2024) evaluating the hypotensive efficacy of various physical exertion modalities in adult populations.

Results: Physical exercise reduces blood pressure by enhancing endothelial function (increased NO bioavailability, decreased ET-1), reducing oxidative stress and modulating autonomic nervous system. While aerobic exercise is the standard recommendation, recent data highlight isometric resistance training as the most effective intervention for lowering blood pressure, both systolic blood pressure (SBP) and diastolic blood pressure (DBP).

Conclusions:

Physical activity overall is effective in lowering blood pressure, with the most pronounced effect in hypertensive patients. All exercise modalities - aerobic, isometric, resistance, combined training - help to maintain blood pressure control. Isometric exercise demonstrates the most favourable outcomes in hypertension management. A finding that should be taken into account when formulating recommendations for hypertensive patients in clinical practice.

Key words: arterial hypertension, physical exercise, isometric training, aerobic training

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1. Introduction

Arterial hypertension is a modifiable cardiovascular risk factor. It is widely prevalent both globally and in Poland, where it affects approximately 30% of the adult population. Data from the Polish National Health Fund indicate that as many as 10 million adult Poles suffer from arterial hypertension, meaning it affects every third adult in Poland [1]. Globally, the number of adults living with arterial hypertension doubled from 650 million in 1990 to 1.3 billion in 2019 [2]. Untreated arterial hypertension leads to numerous adverse consequences within the body. Among other things, it leads to stroke, ischemic heart disease, heart failure, and renal failure. As a result, the treatment of these diseases and their sequelae generates an immense burden on the healthcare system.

Contemporary standards for the management of arterial hypertension are outlined in the 2023 guidelines of the European Society of Cardiology (ESC) and the 2024 guidelines of the Polish Society of Hypertension (PTNT). Both sets of guidelines emphasize non-pharmacological lifestyle modification as an essential component, regardless of the implemented pharmacotherapy [3, 4]. A key element, alongside weight reduction and a healthy diet, is regular physical activity.

The beneficial impact of physical exertion on the cardiovascular system is widely recognized; however, in clinical practice, recommendations regarding physical activity often remain too vague. Over the past few years, numerous scientific reports have emerged reshaping existing views on the role of specific training modalities. There is a growing emphasis on the role of resistance training and the favorable outcomes associated with isometric training [5].

The objective of this paper is to systematise current knowledge regarding the impact of various forms of physical exertion on blood pressure control in adults with arterial hypertension. To provide a comprehensive overview, this review is structured logically, starting with the modern diagnostic definitions of hypertension and the physiological mechanisms underlying exercise-induced blood pressure reduction. The central section of the paper evaluates the hypotensive efficacy of specific exercise modalities, highlighting the rising role of isometric training. Finally, the manuscript synthesizes these findings in the discussion section, bridging the gap between recent meta-analytical evidence and practical recommendations based on the 2023–2024 clinical guidelines.

2. Material and methods

A systematized literature search was conducted using PubMed and Google Scholar databases to identify relevant studies published between 2013 and 2026. The search strategy utilized a combination of Medical Subject Headings (MeSH) and specific text words, including terms such as "arterial hypertension", "elevated blood pressure", "physical activity", "aerobic exercise", "isometric training", "resistance training", and "clinical guidelines". To ensure high clinical relevance, inclusion criteria were strictly limited to recent major clinical guidelines concerning hypertension management (specifically ESC 2018 and 2024, ESH 2023, and PTNT 2024), as well as comprehensive systematic reviews and large-scale meta-analyses evaluating the hypotensive effects of various physical exertion modalities. The analysis focused exclusively on adult human populations (≥ 18 years old) and articles published in English or Polish. Studies conducted on animal models, case reports, editorials lacking a structured methodology, interventions focusing solely on pharmacotherapy without an exercise component, and articles without full-text availability were excluded. Following the initial search and removal of duplicates, potentially eligible articles were screened by title and abstract, followed by a full-text evaluation. Data extraction focused on the physiological mechanisms of post-exercise hypotension, the comparative efficacy of different exercise modalities (aerobic, dynamic resistance, isometric, and combined), and current clinical dosing recommendations. Due to the narrative nature of this review, which aimed to synthesize and juxtapose existing meta-analytical evidence with contemporary clinical guidelines, a descriptive synthesis of the findings was performed rather than a quantitative statistical pooling.

3. Background: Hypertension and Exercise Physiology

3. 1. Definition of Elevated Blood Pressure and Arterial Hypertension

The 2024 ESC guidelines continue to define arterial hypertension as office blood pressure values with a systolic pressure ≥ 140 mmHg or a diastolic pressure ≥ 90 mmHg. However, a new blood pressure category termed "elevated BP" has been introduced. Elevated BP is defined as an office systolic pressure (SBP) ranging from 120 - 139 mmHg or a diastolic pressure (DBP) between 70 - 89 mmHg [6].

The 2023 ESH guidelines build upon the earlier 2018 ESC/ESH recommendations regarding the diagnostic criteria for arterial hypertension. The diagnosis continues to rely on repeated office measurements where systolic blood pressure (SBP) reaches ≥ 140 mmHg and diastolic blood pressure (DBP) reaches ≥ 90 mmHg. It must be emphasized, however, that while these thresholds are arbitrary and primarily serve to simplify the diagnostic pathway, the risk of cardiovascular and renal events increases continuously starting from much lower values, i.e., $> 115/75$ mmHg [4, 7]. This approach remains fully consistent with the established definition of arterial hypertension. It defines this clinical entity as a condition in which - based on robust evidence from clinical trials, the therapeutic benefits derived from lowering blood pressure outweigh the potential risks associated with the implemented treatment [8].

The authors of the PTNT guidelines remain aligned with the European guidelines, indicating that the diagnosis of arterial hypertension begins at values of 140/90 mmHg in office measurements and corresponding out-of-office measurements. However, they emphasize that values in the range of 120 - 139/70 - 89 mmHg, which are classified as "elevated BP," require intensive lifestyle modifications and, in certain clinical situations, pharmacotherapy [3].

3. 2. Physiology

Improvement of Endothelial Function and Increased Bioavailability of Nitric Oxide (NO)

During physical exertion, an increase in cardiac output occurs. The elevated blood flow through the vessels creates shear stress, which acts as a mechanical stimuli on endothelial cells. Shear stress stimulates the endothelium to produce nitric oxide (NO), which exerts a vasodilatory effect. Simultaneously, the secretion of endothelin-1 (ET-1), which has a vasoconstrictive effect, is inhibited. Consequently, the dynamic balance between these two systems is restored [9].

Reduction of Oxidative Stress and Systemic Inflammation

At the molecular level, physical activity restores homeostasis between relaxing factors (NO synthesis) and constricting factors (ET-1). Under pathological conditions, there is an overexpression of NADPH oxidase, eNOS uncoupling, and an increased production of reactive oxygen species (ROS). Physical exertion effectively disrupts this cycle, reducing ROS levels and inhibiting ET-1 secretion, which leads to the restoration of the dynamic balance within the NO/ET-1 system. Furthermore, exercise-induced shear stress exhibits anti-inflammatory effects by decreasing the expression of adhesion molecules on the surface of endothelial cells. The aforementioned mechanisms result in an improved flow-mediated dilation (FMD) index and enhanced endothelium-dependent vasodilation, which directly translates to better skeletal muscle perfusion [9].

A meta-analysis from May 2024 confirms that exercise interventions improved endogenous nitric oxide activity, increased its utilization, and lowered plasma ET-1 concentrations in hypertensive patients. Moreover, a marked increase in the FMD index was observed in these patients, and vascular endothelial function significantly improved [9].

Modulation of the Autonomic Nervous System

Another critical aspect is the impact of physical activity on the modulation of the sympathetic nervous system (SNS). This occurs through a reduction in resting adrenergic tone. Systematic training not only improves heart rate variability, a primary measure of autonomic balance, but also counteracts the regression of the baroreflex associated with aging processes, directly translating to blood pressure stabilization. Furthermore, exercise induces cyclic stimulation of brainstem centers, including the ventrolateral medulla, which modifies central efferent signaling and limits excessive vasoconstriction of resistance vessels. Although literature data confirm the suppressive effect of sports on the SNS, it is worth noting that this effect may be less pronounced in young, healthy individuals. Ultimately, these neurohormonal adaptations facilitate better blood pressure control and yield a tangible improvement in microcirculatory efficiency [10].

3. 3. Hypotensive Efficacy of Physical Exercise

Increased physical activity constitutes a cornerstone of non-pharmacological blood pressure (BP) management, as confirmed by numerous clinical studies [11, 12]. Regular physical training is recognised as a highly effective hypotensive intervention [5, 13].

The key mechanism responsible for this effect is the phenomenon of post-exercise hypotension (PEH). It can be induced by various types and protocols of exercise, and the reduction in blood pressure values resulting from a single training session may persist for up to 24 hours [14].

4. Results: Efficacy of Specific Exercise Modalities

4. 1. Specific Forms of Training

Aerobic (oxygen) exercises involve rhythmic and continuous movements that cause an increase in heart rate, respiratory rate, and oxygen consumption by the body. Examples of this type of exertion include walking, running, cycling, swimming, and high-intensity interval training (HIIT) [12].

Aerobic training remains the foundation of non-pharmacological interventions, demonstrating efficacy in reducing both systolic blood pressure and diastolic blood pressure in hypertensive patients [12]. The average reduction in SBP in this group is 5 - 8 mmHg, while in normotensive individuals, it oscillates between 2 - 4 mmHg [11].

An crucial aspect is the impact of this form of exercise on blood pressure variability (BPV). Aerobic exercises show an advantage over other types of training in this regard, which is particularly marked concerning diastolic BPV [12].

Isometric exercises involve maintaining muscle contraction without changing its length [15] and without significant movement in the joint [12]. Examples of such exercises include the plank, wall squat, and static contractions involving pushing or pulling a stationary object [12]. Comparative analyses indicate that isometric exercises may generate greater reductions in resting blood pressure than traditional aerobic exercise [11]. In light of recent studies, isometric training is considered the most effective form for reducing both SBP and DBP [5].

Resistance exercises, such as strength training or weightlifting, involve using resistance or an external load to perform exercises based on repetitive muscle contractions, typically using free weights or resistance machines. It is performed with the help of free weights, such as dumbbells and barbells, strength machines, resistance bands, or one's own body weight [12]. Endurance and dynamic resistance training significantly lower both blood pressure values (SBP and DBP) [16].

Combined exercises are a comprehensive strength-and-conditioning program including core training, weightlifting, cardio training, gymnastic elements, and a range of additional exercises aimed at improving muscle tone and overall body composition. Examples include the combination of aerobic training with isometric or resistance training [12].

Combined training demonstrates a statistically significant reduction in DBP; however, its impact on SBP is sometimes less definitive in certain analyses [16].

Alongside traditional methods, an important role is attributed to HIIT. Both HIIT and other non-typical forms of physical activity may offer better clinical results in lowering blood pressure than standard exercise sets, though this hypothesis requires further verification through expanded scientific research [5, 17].

4. 2. The Rising Role of Isometric Training

A large-scale systematic review and network meta-analysis from 2023, covering 270 randomized controlled clinical trials, recognizes that aerobic, dynamic resistance, combined, and HIIT all demonstrate significant efficacy in reducing resting SBP and DBP blood pressure. However, isometric exercises demonstrate the greatest effectiveness in lowering both parameters [5]. While most forms of activity, both endurance and resistance training, measurably reduce DBP, the smallest effect (or lack thereof) regarding SBP is observed in combined training [16].

Modern scientific reports point to isometric exercise training as a highly effective and innovative non-pharmacological intervention in the area of blood pressure reduction. Although traditional forms of physical activity remain the standard in clinical guidelines, isometric exercise training shows a consistent advantage in hypotensive efficacy over currently recommended exercise models [15]. A 2013 meta-analysis already reported that the largest effect sizes were observed after isometric handgrip or lower limb exercises [16].

Individual patient data analysis confirms a clinically relevant and statistically significant impact of IRT on resting SBP, DBP, and mean arterial pressure (MAP). The blood pressure reductions observed after isometric training are greater than those reported in previous analyses regarding aerobic exercises [18].

The hypotensive potential of this method often exceeds the results obtained within standard physical activity recommendations, and in specific cases, this efficacy is comparable to or higher than the results achieved during standard antihypertensive monotherapy [15].

Meta-analyses and systematic reviews confirm that blood pressure reductions after isometric resistance training are consistent across all studied groups. The effect size supports the view that isometric training is comparable to or better than dynamic training (aerobic or resistance) and combined dynamic protocols in terms of SBP reduction. Although the drops in DBP and MAP may be relatively smaller than in the case of SBP, their values remain at least equivalent to the changes observed with other forms of physical activity [19].

Within isometric protocols, arm training (e.g., handgrip) appears to exceed the effectiveness of leg training. This difference is explained by the smaller active muscle mass in the upper limb, resulting in a lower threshold for arterial occlusion during contraction, thereby modifying the hemodynamic response [19].

In summary, isometric exercises are particularly effective, which determines their role as a potent intervention for lowering resting blood pressure [12], serving as a significant supplement or alternative to classical therapeutic models.

5. Discussion: Bridging the Gap Between Evidence and Clinical Practice

While current evidence highlights the superior efficacy of isometric training, translating these findings into clinical practice requires navigating established guidelines, safety considerations, and patient-specific factors.

5. 1. Recommendations According to ESC and PTNT Guidelines Regarding the Type and Frequency of Physical Exertion

According to the 2024 ESC guidelines, aerobic physical exercise lasting at least 150 minutes per week at moderate intensity, or 75 minutes per week at vigorous intensity, is recommended as a non-pharmacological intervention. Examples of this type of exertion include brisk walking, running, cycling, and swimming. Additionally, daily unstructured physical activity should be increased, accumulating more steps throughout the day, taking the stairs, walking, and commuting by bicycle. It is strongly recommended to avoid a sedentary lifestyle. Another core component of non-pharmacological interventions aimed at lowering blood pressure is dynamic or isometric training, which should supplement aerobic training 2 - 3 times a week. Isometric

training should be performed at a low to moderate intensity. Examples provided include 3 sets of 1 - 2 minute contractions, such as handgrip exercises, planks, and wall sits. Dynamic training should engage major muscle groups and be performed at a low to moderate intensity. Proposed regimen for this type of exertion includes 2 - 3 sets consisting of 10 - 15 repetitions of exercises like squats, push-ups, and crunches [6].

The PTNT guidelines clearly identify a lack of regular physical activity and sedentary lifestyle as primary risk factors for arterial hypertension. Simultaneously, they position non-pharmacological management as a cornerstone in the therapy of existing hypertension and as a crucial preventative measure against the development of hypertension in individuals with elevated blood pressure. For the non-pharmacological management of patients with arterial hypertension or elevated blood pressure, the following is recommended: aerobic physical exertion for 150 minutes or more per week at high intensity, alongside dynamic or isometric strength training 2 - 3 times a week at moderate intensity. [3]

Table 1. Characteristics, hypotensive efficacy, and current guideline status of various exercise modalities in hypertension management.

Exercise Modality	Impact on Blood Pressure (SBP/DBP)	Additional Characteristics	Position in 2024 PTNT and ESC Guidelines [3, 6]
Aerobic Training	Reduces both SBP, average 5–8 mmHg and DBP. Best impact on blood pressure variability [11,12].	Rhythmic, continuous movements e.g. running, cycling. Broad metabolic benefits [12].	Primary recommendation ≥ 150 min/week of moderate intensity or 75 min of vigorous intensity.
Isometric Training	Greatest effectiveness in lowering both resting SBP and DBP among all modalities [5].	High adherence, time-efficient 11-20 min/session, low cardiovascular load. Narrow metabolic benefits [15, 18, 19].	Supplemental pre recommendation 2–3 times a week at low-to-moderate intensity.
Dynamic Training	Significantly lowers both SBP and DBP [16].	Repetitive muscle contractions using external loads or body weight [12].	Supplemental recommendation 2–3 times a week at low-to-moderate intensity.
Combined Training	Significant reduction in DBP; impact on SBP is less	Comprehensive programs combining aerobic and	Recommended as a comprehensive approach,

	definitive in some analyses [16].	resistance/isometric elements [12].	combining primary and supplemental methods.
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Abbreviations: SBP - systolic blood pressure DBP - diastolic blood pressure PTNT - Polish Society of Hypertension; ; ESC - European Society of Cardiology. Note: Numbers in square brackets indicate the corresponding references in the bibliography.

5. 2. Advantages and Disadvantages of Isometric Training

A decisive advantage of isometric exercise is that it generates a smaller load on the cardiovascular system (lower rate-pressure product) compared to aerobic exertion [19]. Even protocols involving large muscle mass do not trigger excessive blood pressure reactions, and exercises of smaller muscle groups appear even safer [20].

Furthermore, the adherence rate is high. This is due to simplicity, low costs, and short session duration. Patients show a greater tendency to regularly continue training than in the case of conventional methods [19].

Additional advantages are time and place. Standard protocols require only 11 - 20 minutes per session, representing a significant time saving compared to aerobic or dynamic resistance training (30 - 60 min). The possibility of performing exercises in diverse conditions, including home and work environments, increases implementation versatility [15].

Moreover, the method is suitable for patients with motor deficits. It can be performed in a seated position and does not require specialised equipment (in the case of the wall squat protocol) or requires only a simple dynamometer (handgrip) [15, 18].

On the other hand, unlike dynamic aerobic exercises, the impact of isometric resistance training is mainly limited to blood pressure reduction, exhibiting a narrow spectrum of metabolic benefits. Isometric training does not affect other cardiovascular risk factors, such as body weight, insulin resistance, or lipid profile [18].

Sometimes, technical barriers may also arise in selected protocols. Certain forms of training, e.g., isometric leg extension, are difficult to access due to the need for expensive equipment, such as isokinetic dynamometers [15].

5. 3. Safety of Isometric Training

The selection of isometric exercise parameters in hypertension therapy should be strictly correlated with the patient's clinical state. In individuals with pharmacologically controlled

hypertension, engaging larger muscle groups is permitted, provided that breathing techniques excluding the Valsalva maneuver are followed. Although isometric exercise involving large muscle groups does not carry significant cardiovascular risk, the activity of smaller muscle groups induces a milder pressor response, constituting a safer hemodynamic alternative. This model is particularly indicated for patients with uncontrolled hypertension or comorbidities, where the priority is to minimise rapid spikes in blood pressure [20].

5. 4. Exercise Dosing

According to general guidelines, it is assumed that a greater training volume, the product of intensity, frequency, and duration, is associated with a more beneficial impact on health. However, in the case of endurance training, it was observed that the frequency and duration of a single session itself do not significantly affect the magnitude of the hypotensive response. Moreover, total exercise time exceeding 210 minutes per week results in the smallest drop in blood pressure. This phenomenon appears seemingly contradictory to the dose-response mechanism; however, a likely explanation is that programs with such a high time volume (>210 min/week) are compensatorily performed at a lower intensity [16].

Given the transient nature of cardiovascular changes, physical activity should be undertaken with high regularity, optimally every day. It is worth noting, however, that the precise combination of volume and intensity required to induce the PEH phenomenon remains to be definitively established [14].

In turn, regarding other forms of intervention, such as isometric resistance training, the optimization of the antihypertensive effect depends on the duration of the protocol. It is recognized that inducing optimal, desired changes in blood pressure values requires the implementation of an isometric resistance training intervention lasting at least 8 weeks [19].

5. 5. Different Patient Groups

Non-pharmacological therapeutic methods have been shown to be an effective model for supporting health development and optimizing blood pressure in middle-aged and elderly populations. Both aerobic training (including forms of activity such as jogging, walk-running, cycling, and intensive walking) and static/mixed training (including isometric exercises, stretching, and combined protocols) show significant effectiveness in reducing hypertension. Despite the proven efficacy of aerobic methods in lowering blood pressure in elderly and middle-aged individuals, comparative analysis based on the SUCRA (Surface Under

the Cumulative Ranking Curve) ranking indicates higher effectiveness of static exercises over aerobic training in terms of blood pressure reduction in this specific cohort [11].

Regarding the effect of training intervention, reports suggest that a greater drop in BP occurs in men with hypertension and in patients over 45 years of age [19]. Nevertheless, newer analyses do not provide evidence that gender, age, or BMI significantly modify the therapeutic response in terms of SBP, DBP, and MAP [18]. Furthermore, the reduction in blood pressure occurs independently of the patient's weight loss [19].

Clinical data analysis confirms that physical activity induces a drop in blood pressure in all patient groups - from individuals with normotension, through prehypertension, to established hypertension. Hypertensive groups: Experience the most significant therapeutic response, with a drop of 5 - 8 mmHg (representing 4 - 6% of resting BP). These reductions are approximately twice as large as in prehypertension and four to five times larger than in individuals with normotension. Prehypertensive groups: Exhibit a drop within the range of 2 - 4 mmHg (2 - 4% of resting BP). Normotensive groups: Experience the lowest reduction, oscillating between 1 - 2 mmHg (1 - 2% of resting BP) [21]. In the context of dynamic resistance training, the highest reactivity in lowering SBP and DBP was recorded in patients diagnosed with prehypertension [16].

5. 6. Summation of Physical Exercise and Pharmacotherapy

Although current scientific evidence is not fully established in this regard, implementing exercise intervention alone may induce deeper drops in blood pressure than relying on pharmacotherapy alone. Conversely, the use of combined treatment, including physical activity and hypotensive drugs, does not exhibit additive or synergistic effects. Despite the lack of this synergy, therapy combining both elements is characterised by higher efficacy in lowering blood pressure compared to the use of exclusive pharmacotherapy [17]. In clinical terms, the phenomenon of PEH in patients diagnosed with hypertension is significant, as it ultimately allows a reduction in the requirement for antihypertensive medication [14]. Therefore, patients should be actively encouraged to participate in sports, as numerous studies have shown that such interventions have a highly beneficial impact on the overall treatment of hypertension [22].

6. Conclusion

Physical exercise shows positive impact on blood pressure control. The blood pressure-lowering efficacy of exercise therapy stems from its multidirectional impact on the cardiovascular system. It primarily affects the vascular endothelium, increasing the bioavailability of NO, which induces vasodilation and, consequently, a decrease in blood pressure. Physical exertion also reduces oxidative stress and chronic inflammation. The hypotensive effect of exercise is most pronounced in patients with hypertension compared to patients with pre-hypertension or normal blood pressure. All exercise modalities - aerobic, isometric, resistance, combined training - help to maintain blood pressure control. Isometric exercise demonstrates the most favourable outcomes in hypertension management. The newest guidelines recommend isometric exercise alongside aerobic exercise. This means it should be taken into account when formulating recommendations for hypertensive patients in clinical practice. For desired results, aerobic exercise should be at least 150 minutes per week. Isometric training should supplement aerobic training 2 - 3 times a week. Non-pharmacological interventions, such as exercise, should be an integral part of the treatment for hypertension - a major modifiable cardiovascular risk factor - as well as a key element in the prophylaxis of cardiovascular diseases.

Disclosure

Author Contribution

Conceptualization, A.W.; methodology, M.O. and A.W.; data interpretation and synthesis, A.W. and M.S.; manuscript preparation - original draft, A.W., A.Ka., A.P., A.Kw., A.Ż., J.K., J.F., K.T., and K.C.; writing—critical revision, All authors. All authors have read and agreed to the published version of the manuscript.

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Funding Statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data sharing is not applicable to this article.

Acknowledgments

None.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Declaration of the Use of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Artificial Intelligence (AI) Large Language Models for the purpose of linguistic refinement, text formatting, and verification of bibliographic styles. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the substantive content of the publication.

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