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**Original Investigation**

# Hemodynamic response of the circulatory system to static exercise in women of different ages

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***Purpose:*** One of the factors influencing changes in blood pressure is the age of the examined person. Hence, the aim of this study is to determine the hemodynamic response during the isometric handgrip test (HGT) in women of different ages.
***Methods:*** The study involved 116 women over 19 and under 80 years of age, divided into 6 age groups, i.e. up to 30 (23.17±2.90) years, 40 (35.89±2.08) years, 50 (45.31±3.17) years, 60 (56.69±3.20) years, 70 (65.24±1.30) years and over 70 (74.07±3.10) years of age. Under these people, somatic and maximum handgrip strength (MVC) measurements were performed. In resting conditions and in the first, second and third minute of HGT performed with a force of 30% MVC, systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) were measured.
***Results:*** Younger individuals were characterized by lower body mass index (BMI) and higher MVC values than older women. During HGT, higher values of circulatory system variables were observed compared to resting values from the 2nd minute of the test and the effect size of these changes (η2) ranged from medium (.09) to big (.45). In terms of intergroup differences, higher HR and lower SBP were observed in younger women compared to older women, with no significant differences in DBP.
***Conclusions:*** Age and the involutional changes it determines in women are of significant importance for the development of hemodynamic reactions both at rest and during HGT. The age limit of 50 years is significant in this respect.

***Keywords:*** blood pressure, women, age, hand grip test, baroreceptors

## Introduction

A properly functioning human circulatory system is one of the indicators of health. Therefore, monitoring the functioning of this system should be systematic, as pathological changes, including hypertension, often appear in modern civilization. Due to the lack of characteristic symptoms, many people are not aware that they suffer from a primary or secondary form of this disease, which, if left untreated, can lead to serious health consequences, including: left ventricular hypertrophy, retinopathy, kidney failure or an increased risk of coronary artery disease, heart attack and stroke. Risk factors that increase the incidence of hypertension include age, unhealthy diet, smoking, alcohol consumption, overweight, exposure to chronic stress, high cholesterol, diabetes, and lack of physical activity.[1] Even without the above factors, hypertension can occur and proceed asymptomatically for a long time, and its only symptom may be an occasional headache. The origin of hypertension is still unknown, and one of its causes is considered to be imbalances in the autonomic nervous system. Additionally, the age-related stiffness of blood vessels, especially the aorta, reduces the ability of the circulatory system to adapt to pressure changes, which increases the load on the heart and promotes the development of hypertension.[2] Hypertension as a disease is often underestimated and if treated insufficiently aggressively, it causes further negative health effects.[3]

Current international guidelines for the prevention of hypertension recommend that adults engage in physical activity at least two days per week and engage in at least 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity aerobic activity per week.[4–6] Furthermore, resistance training has been suggested as an effective method for reducing resting blood pressure in both normotensive and hypertensive populations.[7]

It is estimated that by 2030, people over 65 years of age will constitute 24% of the population in Europe, which may contribute to an increase in the number of cases of hypertension.[8] Therefore, it is crucial to counteract the negative effects of this aging, which reduces functional efficiency and negatively affects the mental sphere of a person. Therefore, monitoring blood pressure from childhood is of great importance for public health. Studies conducted in Poland in 2017 showed that as many as 35.3% of the population of 5.834 people over 18 years of age had hypertension. It was also shown that among overweight and obese people, both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were significantly higher than in people with normal body weight and underweight.[9] It was also shown that hypertension occurs less often in women than in men, who also have a lower level of awareness of this condition than women. Also, the population of young people in their twenties was already characterized by hypertension of the order of 12% among women and 27% among men. In this population, a low level of awareness of hypertension was also demonstrated, reaching 32% among young women and 25% among men.[10] These data emphasize the need for regular and prompt assessment of blood pressure.

Hypertension can be diagnosed in adults if the average DBP values calculated on the basis of two separate measurements taken during two independent visits to a doctor are equal to or greater than 90 mmHg and for SBP this value is greater than or equal to 140 mmHg. Hypertension can be diagnosed during a single visit when its values are 180/110 mmHg or more and the presence of other factors that could affect it has been excluded. Diagnosis of hypertension according to the above criteria is relatively late and by that time many negative health complications of this disease may have already occurred.

In light of the above data, it is crucial to develop effective research tools that will enable quick and easy monitoring of health status, including assessment of blood pressure. One of them may be the measurement of hand grip strength, the results of which, in addition to the assessment of hand function, are related to many parameters defining health status, such as: the response of the circulatory system to isometric exercise, the risk of premature death, deterioration of physical fitness, estimation of the risk of postoperative complications or prolonged hospitalization.[11-13] The hand grip strength test is a quick and inexpensive way to measure a person's muscle strength, which has been recognized by many clinicians as a satisfactory indicator in the epidemiological study of circulatory system function and is an important element in the assessment of the risk of occurrence and progression of diseases of this system.[14,15] Ewing et al.[16] indicated that the handgrip test (HGT) was most widely used in the study of standard cardiovascular reflexes in the assessment of autonomic neuropathy in patients with diabetes, alongside such simple, non-invasive and safe tests as: heart rate response to deep breathing, heart rate response to standing up, blood pressure response to standing up or circulatory system response during the Valsalva maneuver. The 10-year experience of these authors has shown that using only one of these 5 tests does not differentiate the degree or severity of autonomic system damage in these patients. Despite these doubts, these tests are still called the gold standard for the assessment of cardiovascular autonomic neuropathy.[17] Of the above-mentioned, HGT has been recognized as a research tool, but not a clinical one. It should also be noted that many of these studies assessing the circulatory system response during HGT are based on small and homogeneous groups of people.[18,19] Therefore, the authors of this study took these limitations into account, striving for a more diverse analysis.

Hence, the aim of the presented study is to assess the exercise pressor response of the circulatory system and its modifying factors occurring during HGT in women of different ages.

## Methods

*Participants*

The study involved 116 healthy, randomly selected women divided into 6 groups based on their age. Group I consisted of 40 women aged 18-30 years, group II consisted of 19 women aged 31-40 years, group III consisted of 13 women aged 41-50 years, group IV consisted of 13 women aged 51-60 years, group V consisted of 17 women aged 61-70 years, and group VI consisted of 14 women over 70 years. None of the women had ever engaged in any physical activity, nor were they addicted to stimulants. Detailed somatic characteristics of the examined women and the maximum (MVC) and relative (30% MVC) strength of the dominant hand are presented in Table 1.

**Table 1**. Age, somatic data and hand grip strength.

| **Groups** | **Somatic data** | | | | **Grip strength** | |
|---|---|---|---|---|---|---|
| | **Age [y]** | **BM [kg]** | **BH [cm]** | **BMI [kg/m²]** | **MVC [kg]** | **30%MVC [kg]** |
| I (*n*=40) | 23.17 ± 2.90 | 63.88 ± 13.39 | 167.90 ± 6.71 | 22.55 ± 3.97 | 22.93 ± 3.56 | 6.83 ± 1.07 |
| II (*n*=19) | 35.89 ± 2.08 | 73.17 ± 13.05 | 165.50 ± 6.14 | 26.73 ± 4.58 | 22.56 ± 6.20 | 6.77 ± 1.86 |
| III (*n*=13) | 45.31 ± 3.17 | 69.62 ± 8.56 | 164.23 ± 9.85 | 26.10 ± 4.74 | 21.38 ± 4.17 | 6.42 ± 1.25 |
| IV (*n*=13) | 56.69 ± 3.20 | 66.08 ± 8.17 | 163.00 ± 4.02 | 24.89 ± 3.13 | 17.31 ± 4.61 | 5.19 ± 1.38 |
| V (*n*=17) | 65.24 ± 1.30 | 71.06 ± 11.03 | 161.00 ± 7.12 | 27.44 ± 4.25 | 18.06 ± 4.41 | 5.42 ± 1.32 |
| *P*< | .001 | .05 | .01 | .001 | .001 | .001 |
| *P*< | | I vs II <.05 | I vs V <.05 | I vs II <.01 | I vs IV <.01 | I vs IV <.01 |
| | | | I vs VI <.01 | I vs V <.01 | I vs V <.01 | I vs V <.01 |
| | | | | I vs VI <.01 | I vs VI <.01 | I vs VI <.01 |

Note: For age, all post hoc comparisons were significant (*P*<.001); BM - body mass; BH - body heigth; BMI - body mass index; MVC – maximum handgrip strength; all data are expressed as M±SD (mean ± standard deviation).

*Design*

This study was approved by the Research Ethics Committee of the Jan Długosz University in Częstochowa (Poland) – document KE-U/62/2025 of January 22, 2025. The study protocol respects principles formulated in the World Medical Association Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subject. After familiarizing themselves with the procedures, methods, benefits and potential health risks associated with the study, each participant familiarized themselves with the conditions of the experiment and signed an informed consent to participate voluntarily in accordance with ethical standards. The examinations were performed in the morning, and women with: (1) cardiovascular disease, (2) hypertension, (3) neurological disease and (4) upper limb injuries were excluded from the study. Individuals (5) consuming alcohol, nicotine, and psychoactive substances, and (6) not completing the examination procedures were also excluded. The inclusion criteria were as follows: (1) normal blood pressure (resting diastolic blood pressure below 90 mmHg, resting systolic blood pressure below 140 mmHg, (2) no use of cardiac medication or stimulants, (3) no intense exercise in the last 24 hours, (4) no chronic diseases. The study began with determining the age of the women studied, then their basic somatic data were recorded, i.e. body mass (BM), body high (BH) and body mass index (BMI) was calculated. At the beginning, after 10 minutes of sitting in resting conditions, heart rate (HR) was counted and systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured. The grip strength of the dominant hand MVC was determined in 3 trials using a hand dynamometer. The maximum handgrip strength (MVC) was considered to be the highest value obtained in one of these trials. After a 5-minute break, the volunteers maintained the grip on the hand dynamometer for 3 minutes with an individually selected force at the level of 30% MVC with the elbow resting on the table and SBP and DBP measurements were taken on the opposite arm at the end of each minute. HR was counted using the auscultatory method.

*Methodology*

Somatic measurements were taken using a body composition analyzer Tanita TBF 300A (Amsterdam, the Netherlands), which measures based on electrical bioimpedance. Blood pressure was measured with an electronic sphygmomanometer TMA-6 OMEGA (TECH-MED, TECHNIKA MEDYCZNA B. WÓJCIK, Warsaw, Poland). Heart rate was measured electronically using a chest strap device POLAR H10 (Polar Electro, OY, Kempele, Finland). Handgrip strength was measured with a dynamometer KERN MAP, version 1.2. (KERN & SOHN GmbH, Balingen, Germany).

*Statistical analyses*

The obtained values were expressed as arithmetic mean (M) and standard deviation (±SD). The Shapiro-Wilk test was used to examine the normality of the distribution of the obtained data. Comparisons at individual time points were made using the Friedman's rank test and the Dunn-Bonferroni post hoc formula. Intergroup analyses were performed using the Kruskal-Wallis test. $P < .05$ were considered statistically significant. In addition, eta-squared ($\eta^2$) was calculated to investigate the effect size. All analyses were performed using Statistica, version 13. 3 (TIBCO Software, Palo Alto, CA, USA).

## Results

The volunteers participating in the study differed in age, basic somatic data and absolute and relative MVC values (Table 1).The main effect of statistical significance between groups for all variables was $P < .001$. Post hoc analysis showed significant differences between all groups with respect to age ($P < .001$). Women from group I were lighter than women from group II ($P < .05$). However, women from group I were characterized by greater body height than women from group V ($P < .05$) and women from group VI ($P < .01$). Post hoc analysis showed the following differences in body mass index (BMI): group I vs. group II ($P < .01$), group I vs. group V ($P < .001$), group I vs. group VI ($P < .01$). The groups also differed in maximum handgrip strength (MVC) and 30% MVC: group I vs. group IV, group I vs. group V, and group I vs. group VI ($P < .01$).

It was shown that the hart rate (HR) of the women studied at rest was within the norm for healthy individuals. The exercise test used caused a significant increase in these values, with the most dynamic increase in groups I, II and III, while the HR increased the slowest in groups IV, V and VI in relation to the resting values. In relation to HR measured in the 1' of the test, statistically higher values were obtained for group I in the 2' and 3' of the effort and for groups II, III, IV and VI only in the 3' minute of its duration. Intergroup comparisons showed that HR at rest did not differ statistically, while significant differences occurred at all measurement points of the exercise test ($P < .001$). The highest values during the exercise test were achieved in group II and the lowest in group V. The effect size for this variable in groups II, III, IV and IV was big, while in groups I and V it was medium (Table 2).

In the scope of resting systolic blood pressure (SBP) values, the

**Table 2**. Changes in heart rate in individual groups of women studied.

| Groups | HR [bpm] | | | | ***P*** **(rest vs 1')** | ***P*** **(rest vs 2')** | ***P*** **(rest vs 3')** | ***P*** **(1' vs 2')** | ***P*** **(1' vs 3')** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Rest** | **1' [min]** | **2' [min]** | **3' [min]** | | | | | | |
| I (*n*=40) | 79.46 ± 15.13 | 86.68 ± 15.09 | 91.59 ± 17.27 | 94.85 ± 18.33 | < .01 | < .001 | < .001 | < .05 | < .001 | .11 |
| II (*n*=19) | 80.17 ± 15.25 | 94.72 ± 20.76 | 109.00 ± 25.49 | 123.83 ± 24.95 | .121 | < .001 | < .001 | .085 | < .001 | .37 |
| III (*n*=13) | 67.92 ± 10.60 | 75.54 ± 15.04 | 85.85 ± 22.30 | 90.92 ± 27.79 | .345 | < .001 | < .001 | .111 | < .01 | .18 |
| IV (*n*=13) | 72.15 ± 13.35 | 75.38 ± 14.30 | 77.85 ± 12.38 | 80.77 ± 15.92 | .998 | < .05 | < .001 | .664 | < .05 | .18 |
| V (*n*=17) | 67.82 ± 8.71 | 72.71 ± 9.05 | 73.67 ± 8.09 | 74.73 ± 9.22 | < .05 | < .01 | < .001 | .997 | .944 | .09 |
| VI (*n*=14) | 69.14 ± 12.73 | 74.43 ± 13.53 | 75.79 ± 14.23 | 78.21 ± 16.74 | .243 | < .01 | < .001 | .746 | < .05 | .19 |
| *P*< | .47 | .001 | .001 | .001 | | | | | | |
| | | I vs V < .05 | I vs V < .01 | I vs II < .05 | | | | | | |

| | | | | |
|---|---|---|---|---|
| *P*< | | II vs IV < .05 | I vs VI < .05 | I vs V < .05 |
| | | II vs V < .01 | II vs IV < .01 | II vs III < .05 |
| | | II vs VI < .05 | II vs V < .001 | II vs IV < .001 |
| | | | II vs VI < .001 | II vs V < .001 |
| | | | | II vs VI < .001 |

Note: HR - heart rate; all data are expressed as M±SD (mean ± standard deviation); $\eta^2$ - effect size: ≈ .01 – small effect, ≈ .06 – medium effect, ≈ .14 – big effect.

accepted norms were not exceeded in the individual groups of women. The exercise test caused a significant increase in SBP, and this was already in the 1st minute for groups I, III, IV and V, with the fastest increase in group I and the slowest in group IV of women in relation to resting values. On the other hand, significantly higher SBP values than in the 1st minute of the test were obtained in the 3rd minute in groups: I, II, V, VI. The highest values of this variable were achieved by group VI in the 3rd minute of the test, which exceeded 160 mm Hg. In resting conditions and in individual measurement time points of the exercise test, there were significant intergroup differences. The effect size for SBP in groups II, III, IV, V and VI was big, while in groups I it was medium (Table 3).

**Table 3**. Changes in systolic blood pressure in individual groups of studied women.

| **Groups** | **SBP (mmHg)** | | | | ***P* (rest vs 1')** | ***P* (rest vs 2')** | ***P* (rest vs 3')** | ***P* (1' vs 2')** | ***P* (1' vs 3')** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Rest** | **1' [min]** | **2' [min]** | **3' [min]** | | | | | | |
| I (*n*=40) | 123.71 ± 12.42 | 131.56 ± 13.01 | 134.80 ± 15.37 | 138.24 ± 16.03 | < .001 | < .001 | < .001 | .875 | < .001 | .13 |
| II (*n*=19) | 120.83 ± 8.27 | 129.28 ± 9.22 | 139.33 ± 12.02 | 146.17 ± 13.86 | .121 | < .001 | < .001 | .085 | < .001 | .45 |
| III (*n*=13) | 116.46 ± 12.88 | 125.92 ± 16.48 | 132.92 ± 17.55 | 138.62 ± 23.39 | < .05 | < .001 | < .001 | .664 | .136 | .19 |
| IV (*n*=13) | 127.92 ± 16.93 | 140.62 ± 15.61 | 143.31 ± 16.97 | 156.62 ± 26.62 | < .05 | < .05 | < .001 | .985 | .242 | .23 |
| V (*n*=17) | 126.82 ± 14.92 | 139.76 ± 14.21 | 142.47 ± 15.04 | 151.20 ± 14.25 | < .05 | < .01 | < .001 | .991 | < .05 | .28 |
| VI (*n*=14) | 137.36 ± 13.24 | 153.64 ± 18.91 | 158.50 ± 22.16 | 163.50 ± 22.98 | .094 | < .01 | < .001 | .989 | < .01 | .21 |
| *P*< | .01 | .001 | .01 | .001 | | | | | | |
| | I vs VI < .05 | I vs VI < .01 | I vs VI < .01 | I vs VI < .001 | | | | | | |
| *P*< | II vs VI < .05 | II vs VI < .01 | | | | | | | | |
| | III vs VI < .01 | III vs VI < .01 | | | | | | | | |

Note: SBP - systolic blood pressure; all data are expressed as M±SD (mean ± standard deviation); $\eta^2$ - effect size: ≈ .01 – small effect, ≈ .06 – medium effect, ≈ .14 – big effect.

Resting diastolic blood pressure (DBP) values did not exceed physiological norms. The exercise test led to a significant increase in these values already in 1' for groups I and II, in 2' in groups I, II, V, VI and in 3' in all groups compared to the resting data. The most dynamic increase in DBP during the exercise test occurred in group I and the slowest increase of this variable in groups III and IV in relation to the resting values. In 3' of groups I, II and V, higher DBP values were observed than in 1' of the exercise test. Additionally, in 3' of group I, a significantly higher value of this variable occurred ($P < .05$) than in 2' of the exercise test. No intergroup differences in DBP were observed either in resting conditions or during the exercise test. For this variable, the effect size achieved in groups II, III, IV and V was big, while in groups I and VI it was only medium (Table 4).

**Table 4.** Changes in diastolic blood pressure in individual groups of studied women.

| Groups | DBP (mmHg) | | | | *P* (rest vs 1') | *P* (rest vs 2') | *P* (rest vs 3') | *P* (1' vs 3') | *P* (2' vs 3') | η² |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Rest** | **1' [min]** | **2' [min]** | **3' [min]** | | | | | | |
| I (*n*=40) | 75.00 ± 9.63 | 82.49 ±10.44 | 83.44 ± 11.56 | 86.27 ± 12.42 | < .001 | < .001 | < .001 | < .05 | < .05 | .13 |
| II (*n*=19) | 82.17 ± 9.43 | 87.39 ± 9.55 | 91.22 ± 10.89 | 94.50 ± 10.46 | < .05 | < .001 | < .001 | < .001 | .272 | .18 |
| III (*n*=13) | 75.85 ± 9.71 | 82.08 ± 12.75 | 85.08 ± 15.69 | 90.23 ± 17.87 | .484 | .242 | < .001 | .111 | .242 | .19 |
| IV (*n*=13) | 79.46 ± 10.88 | 86.62 ± 9.54 | 86.85 ± 9.40 | 91.77 ± 12.80 | .136 | .090 | < .001 | .410 | .568 | .23 |
| V (*n*=17) | 77.59 ± 9.47 | 84.00 ± 9.30 | 85.20 ± 9.83 | 88.60 ± 10.59 | .080 | < .01 | < .001 | < .05 | .623 | .28 |
| VI (*n*=14) | 78.93 ± 8.17 | 80.36 ± 22.20 | 87.07 ±7.61 | 89.53 ± 8.38 | .140 | < .05 | < .001 | .342 | .992 | .11 |
| *P*< | .100 | .416 | .118 | .079 | | | | | | |

Note: DBP - diastolic blood pressure; all data are expressed as M±SD (mean ± standard deviation); η² - effect size: ≈ .01 – small effect, ≈ .06 – medium effect, ≈ .14 – big effect.

## Discussion

During handgrip test (HGT), systolic blood pressure (SBP) and diastolic blood pressure (DBP) increased, which was a direct effect of static muscle fiber contraction and exerted tonic mechanical pressure on muscle blood vessels and sympathetic nerve fibers located in them[20] without stimulating metabolic receptors, especially in the initial phase of the test.[21] It should be added that one of the prerogatives of using HGT is the detection of hypertension in the early stages of its development.[22] A normal exercise circulatory response during this test is considered to be an increase in DBP above 15 mmHg, a borderline 11-15 mmHg, and an abnormal one below 10 mmHg.[17] In the groups of women studied by us, the increase in DBP during HGT oscillated around 11 mmHg, which, in accordance with the above data, allows us to assess the response of the circulatory system to the performed isometric effort as borderline, i.e. slightly more efficient than abnormal. The consequence of the classic vegetative cardiovascular reflex to the increase in blood pressure and stimulation of high-pressure baroreceptors is a reduction in blood flow, which is expressed, among others, by a reduction in hart rate (HR). During the HGT test, such a reaction is not observed, because despite the reduced blood flow in the working forearm, no compensatory reduction in HR is observed; on the contrary, this variable is increased as an expression of general sympathetic stimulation occurring during the ongoing exercise test.[23] It has also been suggested that activation of the sympathetic nervous system limits muscle-induced vasodilation regardless of age.[24]

Reports from other authors suggest that this vegetative cardiovascular reflex activated during HGT is modified, among others, by human age. A breakthrough in this respect is the age limit of about 50 years, after which cardiovagal baroreflex sensitivity significantly decreases, both in men and women.[25] Our data also seem to confirm such a division, with the difference that the rate of increase of SBP and DBP in individual age groups during HGT in relation to resting values was greater in older women over 50 years of age, and the rate of increase of HR was greater in younger groups of women up to 50 years of age in relation to people representing another age group. Intergroup comparisons also indicate that in individual minutes of the test there was a difference or a tendency to achieve higher pressures in older groups and in relation to HR in younger groups of women, with the cut-off also being 50 years of age. These data suggest that both high-pressure baroreceptor sensitivity and cardiac sympathetic influences may be different in younger and older women. The calculated effect size for HR, SBP, and DBP clearly indicate that the HGT test had a moderate effect on the hemodynamic responses of the youngest women (group 1), whereas in the other groups, this effect was big. Therefore, it can be assumed that the functional status of the circulatory system in the youngest group of women was the best and should be assessed using a more intense exercise challenge than the HGT test.

It should also be noted that the age limit of 50 suggested above, indicating differences or tendencies to different intensities of hemodynamic reactions during HGT, may coincide with the onset of menopause in these women. During this period, risk factors for circulatory system diseases begin to become more apparent, which may be an important modulator of the response of this system to static load.[26] Another factor related to the age difference of the studied women may be changes in the nervous system consisting in the loss of motor neurons belonging to the fast motor units of skeletal muscles. This unfavourable process begins after the age of 30 years. The resulting changes, called sarcopenia, are also associated with a decrease in skeletal muscle mass and strength, as well as with the intensification of pathological changes in the circulatory system.[27] These changes may modify the extent of the hemodynamic response during HGT, especially since in the volunteers we studied there were significant intergroup differences in maximum handgrip strength (MVC) and relative strength developed at a load of 30% of MVC in this test. It should be noted that the MVC value, apart from expressing handgrip strength, may be an indirect indicator of vitality, physical fitness and a number of risk factors in the aging process,[28] an indicator of upper and lower body strength, or muscle mass, [29]as well as informing about blood pressure and hypoaglesia.[30]

Indirectly, somatic changes expressed, among others, by the body mass index (BMI) are also related to the age of the subjects, which in our studies increased with the age of the subjects and was parallel to the resting and exercise changes in blood pressure. Confirmation of the changes in the increased hypertensive reaction during HGT is also provided by other studies, which showed that healthy people with obesity are characterized by an increased response of systolic and diastolic blood pressure to moderate physical activity.[27,31] The above-described hemodynamic reactions of the circulatory system developed during HGT and the factors determining them may be related to the age of the women studied, despite the fact that in recent years it has been shown that hemodynamic reactions occurring during HGT are not a reliable parameter in the diagnosis of cardiovascular autonomic neuropathy in people with diabetes. Hence, HGT began to be treated not as a clinical tool but only as a screening test detecting the occurrence of hypertension in the early stages of its development.[22,25,32]

Another factor modifying the hemodynamic reactions during HGT, unrelated to the age of the subjects but modifying the cardiovascular reflex, is the respiratory activity, which was not controlled in our studies.[22,33] It is therefore unknown to what extent the possible differentiation of the respiratory activity during HGT among the women studied could modify the hemodynamic response in the test performed.

It is important to recognize that the number of factors that can modify hemodynamic responses during HGT is significant. It should be noted that the number of volunteers in groups III, IV, and VI was small, which could have somewhat compromised the reliability of the hemodynamic response during HGT. To avoid this negative factor, the number of participants should be increased in future studies. Because the studies discussed included women of varying ages, their physical fitness levels, medication intake, and changes in blood hormone levels show significant variation, future studies should consider these variables, which may interfere with achieving correct hemodynamic results during this type of exercise.

To sum up, it should be stated that the amount of force developed during HGT, dependent on the age of the studied women, was the main factor generating the hemodynamic response and had the least impact in the youngest group of women.

## Practical applications

Hypertension is a serious disease that is currently widespread among various social groups and even among the population enjoying excellent health, such as athletes. The HGT described in the presented article makes it possible to detect an abnormal pressor response of the circulatory system to the load of static effort of a small muscle group. Such an abnormal pressor response may occur even before the appearance of increased pressure in resting conditions of the body. This extremely valuable information allows for taking preventive or therapeutic actions at an early stage to reduce or prevent the development of hypertension and its negative effects in the body. Because the described HGT is cheap and easy to perform, even in home conditions it can play an important role in maintaining public health.

## Conclusions

The hemodynamic differences occurring during rest and during the provocation caused by the use of HGT are related to the age of the studied women, and the boundary differentiating the occurrence of these reactions oscillates around the age of 50(y). Derivative factors in relation to the age of the studied women that generate the described hemodynamic differences may be degenerative changes in the nervous system, hormonal changes related to the phenomenon of menopause or sarcopenia progressing with age, causing somatic changes and reduced muscle strength.


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## Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

## Ethical Committee approval

Research Ethics Committee of the Jan Długosz University in Częstochowa (Poland) – document KE-U/62/2025 of January 22, 2025.

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## Topic

Health Sciences

## Conflicts of interest

The authors have no conflicts of interest to declare.


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## Author-s contribution

Conceptualization, B.P. and A.P.; methodology, A.P. and P.D.; software, B.W. and P.D.; validation, K.L.; formal analysis, A.P. and P.D.; investigation, B.P. and A.P.; resources, P.M.; data curation, B.P and K.L.; writing—original draft preparation, A.P. and B.P.; writing—review and editing, A.P.; visualization, B.W.; supervision, P.M; project administration, B.P. All authors have read and agreed to the published version of the manuscript.

## References


1. Brook RD, Appel LJ, Rubenfire M, et al. Beyond medications and diet: alternative approaches to lowering blood pressure: a scientific statement from the American Heart Association. *Hypertension*. 2013;61(6):1360–83. doi: 10.1161/HYP.0b013e318293645f
2. Pettersen KH, Bugenhagen SM, Nauman J, Beard DA, Omholt SW. Arterial stiffening provides sufficient explanation for primary hypertension. *PLoS Comput Biol*. 2014;10(5):e1003634. doi: 10.1371/journal.pcbi.1003634
3. Brili S, Dima I, Ioakeimidis N, et al. Evaluation of aortic stiffness and wave reflections in patients after successful coarctation repair. *Eur Heart J*. 2005;26:1394. doi: 10.1016/S1872-9312(07)70030-3
4. Mancia G, De Backer G, Dominiczak A, et al. ESH-ESC practice guidelines for the management of arterial hypertension: ESH-ESC task force on the management of arterial hypertension. *J Hypertens*. 2007;25(9):1751–62. doi: 10.1097/HJH.0b013e3282f0580f
5. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc*. 2004;36(3):533–53. doi: 10.1249/01.mss.0000115224.88514.3a
6. Chobanian AV, Bakris GL, Black HR, et al. The seventh report of the joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA*. 2003;289(19):2560–71. doi:10.1001/jama.289.19.2560
7. Badrov MB, Freeman SR, Zokvic MA, Millar PJ, McGowan CL. Isometric exercise training lowers resting blood pressure and improves local brachial artery flow-mediated dilation equally in men and women. *Eur J Appl Physiol*. 2016;116(7):1289–96. doi: 10.1007/s00421-016-3366-2
8. Eurostat. *Population structure indicators at national level 2021*. Updated May 8, 2025. https://ec.europa.eu/eurostat/databrowser/view/demo_pjanind/default/table?lang=en
9. Ma³yszko J, Mastej M, Banach M, et al. Do we know more about hypertension in Poland after the May Measurement Month 2017—Europe. *Eur Heart J Suppl*. 2019;21:D97–D100. doi: 10.1093/eurheartj/suz067
10. Everett B, Zajacova A. Gender differences in hypertension and hypertension awareness among young adults. *Biodemogr Soc Biol*. 2015;61(1):1–17. doi: 10.1080/19485565.2014.929488
11. Shaughnessy KA, Hackney KJ, Clark BC, et al. A narrative review of handgrip strength and cognitive functioning: bringing a new characteristic to muscle memory. *J Alzheimers Dis*. 2020;73(4): 1265-1278. doi: 10.3233/JAD-190856
12. Sallinen J, Stenholm S, Rantanen T. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc*. 2010;58(9):1721–6. doi: 10.1111/j.1532-5415.2010.03035.x
13. Bohannon R. Hand-grip dynamometry predicts future outcomes in aging adults. *J Geriatr Phys Ther*. 2008;31(1):3–10. doi: 10.1519/00139143-200831010-00002
14. Hess NC, Carlson DJ, Inder JD, Jesulola E, McFarlane JR, Smart NA. Clinically meaningful blood pressure reductions with low intensity isometric handgrip exercise. A randomized trial. *Physiol Res*. 2016;65(3):461–8. doi: 10.33549/physiolres.933120
15. Carlson DJ, Inder J, Palanisamy SK, McFarlane JR, Dieberg G, Smart NA. The efficacy of isometric resistance training utilizing handgrip exercise for blood pressure management: a randomized trial. *Medicine (Baltimore)*. 2016;95(52):e5791. doi: 10.1097/MD.0000000000005791
16. Ewing DJ, Martyn CN, Young RJ, Clarke BF. The value of cardiovascular autonomic function tests: 10 years experience in diabetes. *Diabetes Care*. 1985;8(5):491-8. doi: 10.2337/diacare.8.5.491
17. Körei AE, Putz Z, Vági OE, et al. The handgrip test – A historical test for diabetic autonomic neuropathy or a marker of something else? *J Diabetes Complications*. 2024;38(2):108668. doi:10.1016/j.jdiacomp.2023.108668
18. Sayer AA, Syddall HE, Dennison EM, et al. Grip strength and the metabolic syndrome: findings from the Hertfordshire cohort study. *QJM*. 2007;100(11):707–13. doi: 10.1093/qjmed/hcm095
19. Kelley GA, Kelley KS. Isometric handgrip exercise and resting blood pressure: a meta-analysis of randomized controlled trials. *J Hypertens*. 2010;28(3):411–8. doi: 10.1097/HJH.0b013e3283357d16
20. Kamiya A, Michikami D, Shiozawa T, et al. Bed rest attenuates sympathetic and pressor responses to isometric exercises in antigravity muscles in humans. *Am J Physiol Integr Comp Physiol*. 2003;286(5):844-50. doi: 10.1152/ajpregu.00497.2003
21. Saito M, Iwase S, Hachiya Y. Resistance exercise training enhances sympathetic nerve activity during fatigue-inducing isometric handgrip trials. *Eur J Appl Physiol*. 2009;105(2):225-34. doi: 10.1007/s00421-008-0893-5
22. Ewing DJ, Irving JB, Kerr F, Wildsmith JA, Clarke BF. Cardiovascular responses to sustained handgrip in normal subjects and in patients with diabetes mellitus: a test of autonomic function. *Clin Sci Mol Med*. 1974;46(3):295–306. doi:10.1042/cs0460295
23. Kishor Keshari K, Kumar T, Lnu S, Kumar C, Kumar M. Evaluation of cardiovascular response to isometric handgrip exercise in obese individuals. *Cureus*. 2023;15(7):e41898. doi:10.7759/cureus.41898
24. Kempler M, Hajdú N, Putz Z, et al. Diabetic cardiovascular autonomic neuropathy, the handgrip test and ambulatory blood pressure monitoring parameters: Are there any diagnostic implications? *J Clin Med*. 2020;9(10):3322. doi:10.3390/jcm9103322
25. Yeh CH, Kuo TBJ, Li JY, et al. Effects of age and sex on vasomotor activity and baroreflex sensitivity during the sleep-wake cycle. *Sci Rep*. 2022;12(1):22424. doi:10.1038/s41598-022-26440-3
26. Burger JPW, Serne EH, Nolte F, Smulders YM. Blood pressure response to moderate physical activity is increased in obesity. *Neth J Med*. 2009;67(8):342-6.
27. Idilbi N, Amun W. Hand grip strength as a predictor for success in weaning from ventilation. *Isr Med Assoc J*. 2022;25(12):797-802
28. Labott BK, Bucht H, Morat M, Morat T, Donath L. Effects of Exercise Training on Handgrip Strength in Older Adults: A Meta-Analytical Review. *Gerontology*. 2019;65(6):686-98. doi: 10.1159/000501203
29. Cronin J, Lawton T, Harris N, Kilding A, McMaster DT. A Brief Review of Handgrip Strength and Sport Performance. *Journal of Strength Cond Res*. 2017;31(11): 3187-217.

doi: 10.1519/JSC.0000000000002149
30. Yamada Y, Spitz RW, Wong V, et al. The impact of isometric handgrip exercise and training on health-related factors: A review. *Clin Physiol Funct Imaging.* 2022 ;42(2):57-87. doi: 10.1111/cpf.12741
31. Marlatt KL, Pitynski-Miller DR, Gavin KM, et al. Body composition and cardiometabolic health across the menopause transition. *Obesity (Silver Spring)*. 2022;30(1):14-27. doi:10.1002/oby.23289
32. Damluji AA, Alfaraidhy M, AlHajri N, et al. Sarcopenia and cardiovascular diseases. *Circulation*. 2023;147(20):1534-53. doi:10.1161/CIRCULATIONAHA.123.064071.
33. Hughes WE, Kruse NT, Casey DP. Sympathetic nervous system activation reduces contraction-induced rapid vasodilation in the leg of humans independent of age. *J Appl* Physiol (1985). 2017;123(1):106-15. doi:10.1152/japplphysiol.00005.2017

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