Assessment of the impact of occlusion training on upper limb muscle strength and endurance – preliminary study

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Abstract

Background: Occlusion training, also known as Blood Flow Restriction (BFR) training, involves partially restricting arterial blood flow and completely restricting venous blood flow in working muscles. It has been shown that BFR training, when combined with resistance, enhances the effectiveness of exercises compared to strength training without occlusion.

Aims: The aim of this study was to evaluate the impact of occlusion training on upper limb muscle strength and endurance.

Material and methods: Thirty-seven men aged 19 to 26 participated in the study. Two experimental groups (one with occlusion and one without) and one control group were formed. The experimental groups trained three times a week for one month, totaling 12 training sessions. The training protocol involved performing repetitions of pull-ups. The occlusion group used floss bands on the proximal part of their arms. Before and after the training period, participants underwent tests to measure the maximum number of pull-ups, handgrip strength, and endurance.

Results: Occlusion training improved the maximum number of pull-ups significantly ($p<0.001$). However, no statistically significant improvement in endurance was observed ($p=0.294$).

Conclusions: Occlusion training of the upper limbs increases muscle strength but does not significantly affect muscle endurance.

Key words

training, strength, occlusion, hypertrophy.

Introduction

Occlusion training, also known as Blood Flow Restriction (BFR) training, involves partially restricting arterial blood flow and completely restricting venous blood flow in working muscles [1]. This is typically achieved using elastic or pneumatic cuffs applied to the proximal parts of the limbs [1, 2]. This procedure increases pressure under the cuff and creates a hypoxic environment, which researchers suggest positively affects muscle hypertrophy [1, 3].

It has been demonstrated that BFR training is highly effective when combined with resistance. This combination enhances exercise efficiency more than strength training alone [4]. Such training increases muscle strength and hypertrophy, making it popular not only among athletes but also in rehabilitation settings [5, 6].

Although the use of occlusion might seem controversial and raise concerns, studies combining it with low-resistance training have not shown adverse effects in healthy individuals or older adults with cardiovascular diseases. Additionally, it has been found that this form of therapy can minimize the risk of deep vein thrombosis [7]. Occlusion training avoids the overload and excessive metabolic cost typical of high-load training [8].

The primary goals of occlusion training are to increase muscle strength and endurance. Strength is essential for overcoming resistance [9], while muscle endurance allows the maintenance of force production over time [10]. Maintaining these abilities at a high level is crucial for both sports performance and daily activities. This study aims to evaluate whether individually tailored strength training combined with restricted blood flow significantly affects these abilities and to what extent occlusion influences upper limb exercises.

Aims

The aim of this study was to assess the impact of occlusion training on the strength and endurance of upper limb muscles.

Material and methods

Ethical considerations

The project received positive approval from the Thematic Team for Ethics in Scientific Research of Physiotherapists at the KIF (National Chamber of Physiotherapists) – opinion no. 2/2022.

Study participants

Thirty-seven men aged 19 to 26 were included in this classical experimental study. Participants were randomly divided into three groups: two experimental groups and one control group. Detailed data are presented in **Table 1**.

Qualification criteria

Inclusion criteria were: age between 18-30 years, male gender, and no contraindications for occlusion training. Exclusion criteria included cardiovascular diseases, history of deep vein thrombosis, cancer, lymphatic edema, asthma, skin diseases, inflammation in the upper limbs, recent injuries (within six months), high-intensity physical activity or professional sports, and withdrawal from the study at any stage.

Measurements

Before starting the study, all participants were informed about the procedures and filled out questionnaires to provide necessary data such as age, body weight, height, physical activity, and dominant hand. They also consented to participate in the study.

Measurements consisted of three tests preceded by a 3-minute warm-up in the form of boxing running. The first test involved performing the maximum number of pull-ups with an overhand grip. The second test measured handgrip strength using a SH5001 hydraulic dynamometer from SAEHAN Corporation. Participants performed three maximum grip trials with each hand, with the highest measurement recorded. The third test was an isometric test where participants aimed to hang on a bar in an overhand grip for as long as possible. After completing all tests, partici-

Table 1. Detailed characteristics of the study groups.

Characteristics	Group							
	Control		Training without occlusion		Training with occlusion		Overall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	22.2	2	21.6	2	21.4	1.5	21.8	1.9
Mean Body Weight (kg)	75.3	11.4	79.7	9.6	77.5	10.2	77	10.5
Mean Height (cm)	180.2	5.5	180.1	5.2	179.1	4.9	179.9	5.2
BMI	23.1	2.6	24.5	2.3	24.1	2.8	23.8	2.6

Abbreviations: *SD – standard deviation; BMI – Body Mass Index.*

pants were randomly assigned to one of the three groups. All tests were repeated one month later.

Interventions

The control group maintained their usual lifestyle without additional physical activities or training.

The experimental group without occlusion participated in training sessions three times a week for one month, totaling 12 sessions. Each session started with a 5-minute warm-up in the form of boxing running, followed by four sets of pull-ups. The number of repetitions in each set was based on 1RM (One Repetition Maximum) determined during initial measurements. The sets were as follows: 1st set – 30% RM, 2nd set – 20% RM, 3rd set – 20% RM, 4th set – 30% RM. One additional repetition was added to each set every week. The occlusion training group followed the same protocol but used floss bands applied to the proximal part of the arms. The bands were stretched to 60% of their maximum tension. Medium-hardness bands from Health&Roll (203cm x 5cm x 2mm) were used.

Statistical analysis

IBM SPSS Statistics was used for statistical analysis. The normality of the distribution of the analyzed variables was checked using the Shapiro-Wilk test. The Kruskal-Wallis test and one-way ANOVA were used to determine statistically significant differences among more than two groups. Tukey's multiple comparison test was used to identify specific group differences. The student t-test was used for dependent groups with statistically significant changes. The significance level was set at $p<0.05$ for all tests.

Results

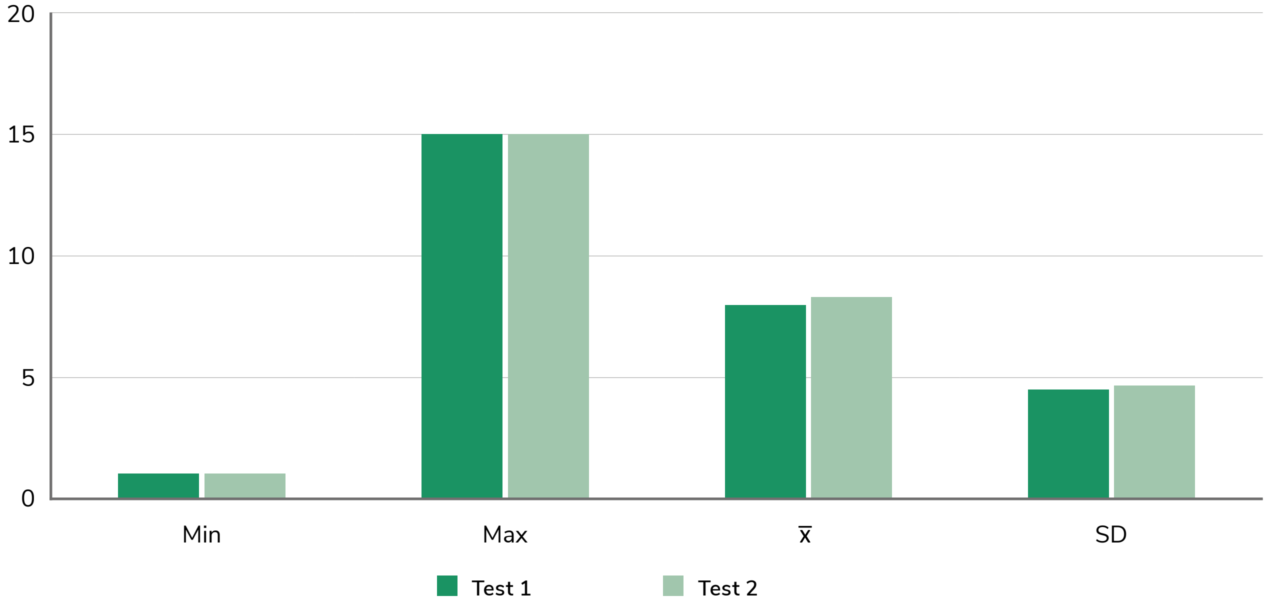
The following tables compare the results of the first and second tests in the control group, the training group without occlusion, and the training group with occlusion (**Figures 1-12**). In the control group, a statistically significant difference was observed in the right handgrip strength ($p=0.025$), which showed a decrease (**Figure 2**).

In the training group without occlusion, statistically significant differences were observed in the maximum number of pull-ups ($p=0.037$) and the isometric test ($p=0.015$), both showing significant improvement (**Figures 5** and **8**).

In the occlusion training group, a significant difference was observed in the maximum number of pull-ups ($p<0.001$), showing significant improvement (**Figure 9**).

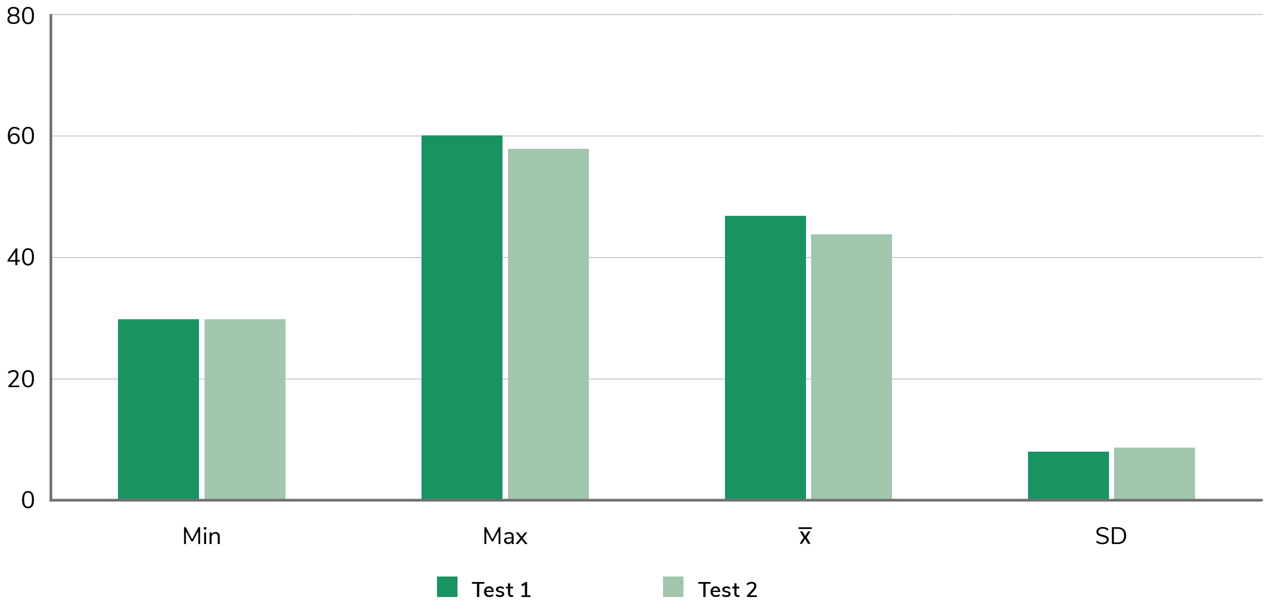
Significant differences were observed between the occlusion training group and the control group in all tested parameters except the isometric test. However, no significant advantage of occlusion training over conventional training was found (**Table 2**).

Figure 1. Comparison of the Test 1 and Test 2 results for maximum number of pull-ups in the control group.



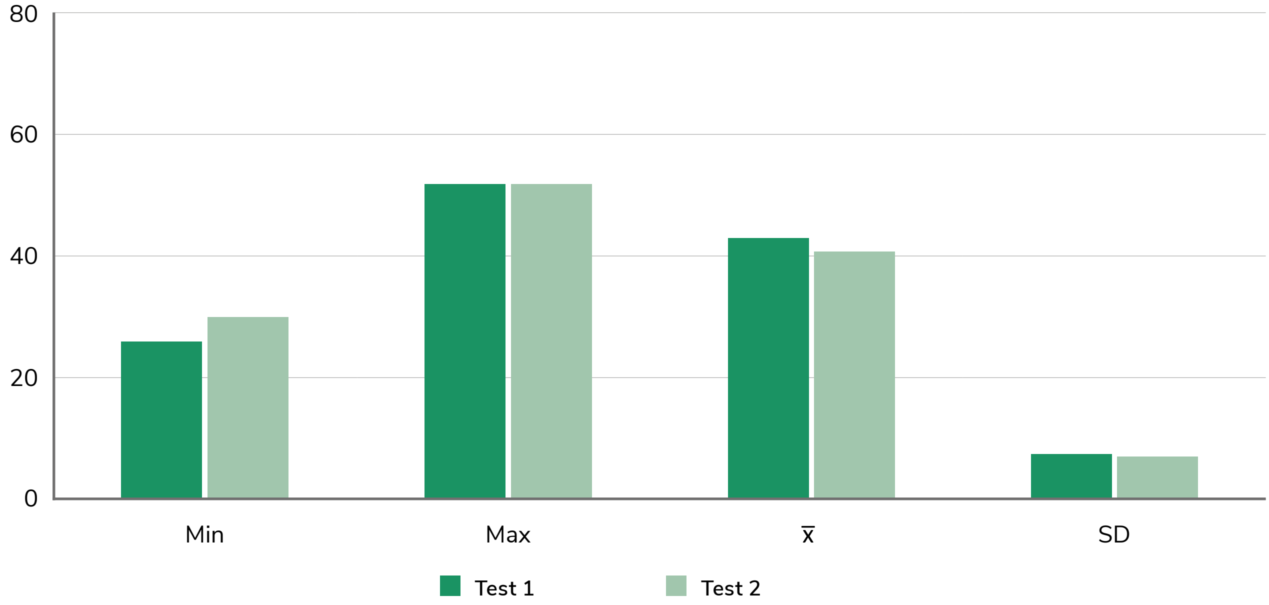
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 2. Comparison of the Test 1 and Test 2 results for right handgrip strength in the control group.



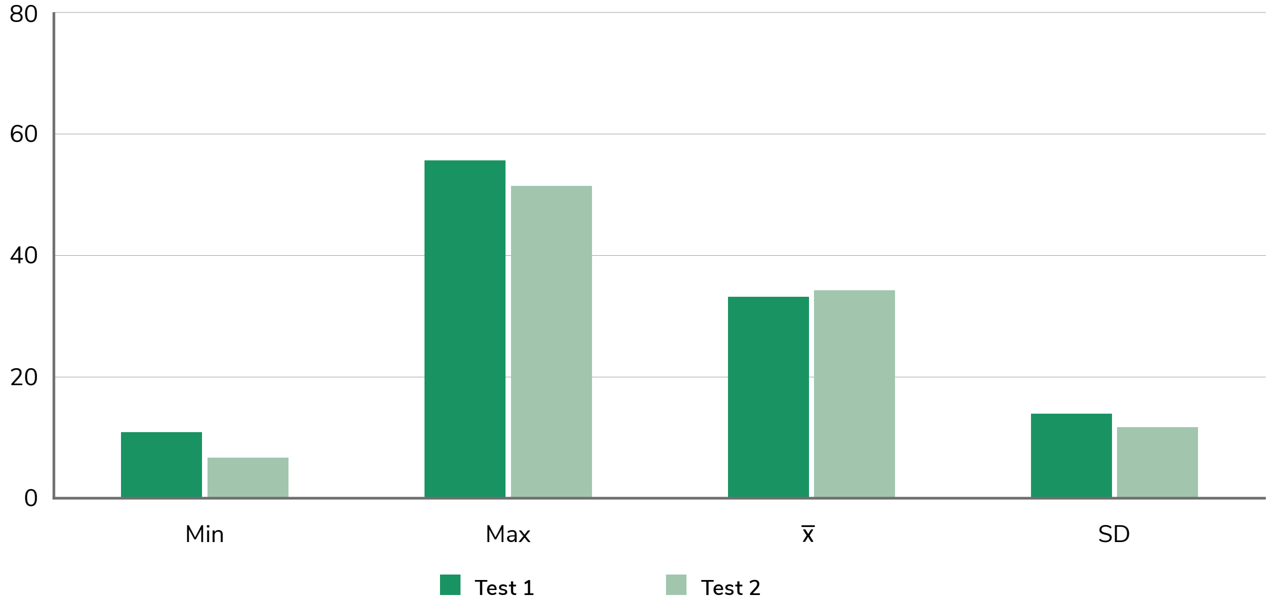
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 3. Comparison of the Test 1 and Test 2 results for left handgrip strength in the control group.



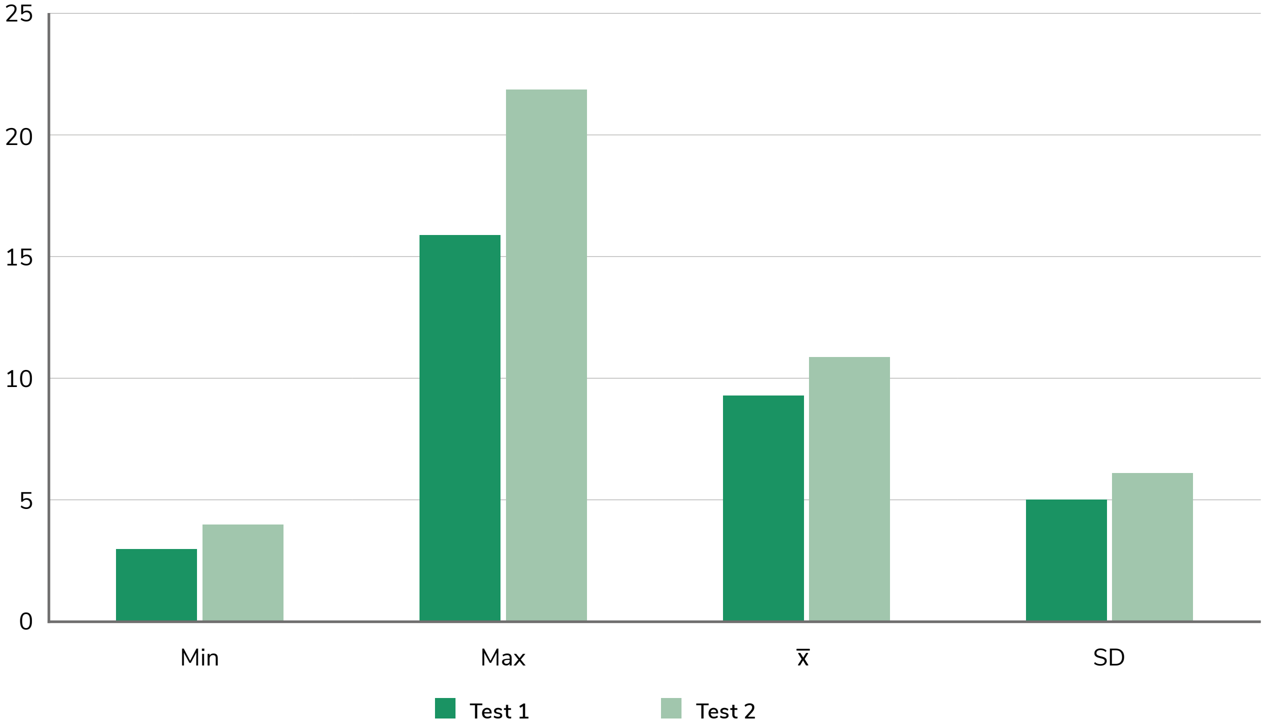
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 4. Comparison of the Test 1 and Test 2 results in the isometric test in the control group.



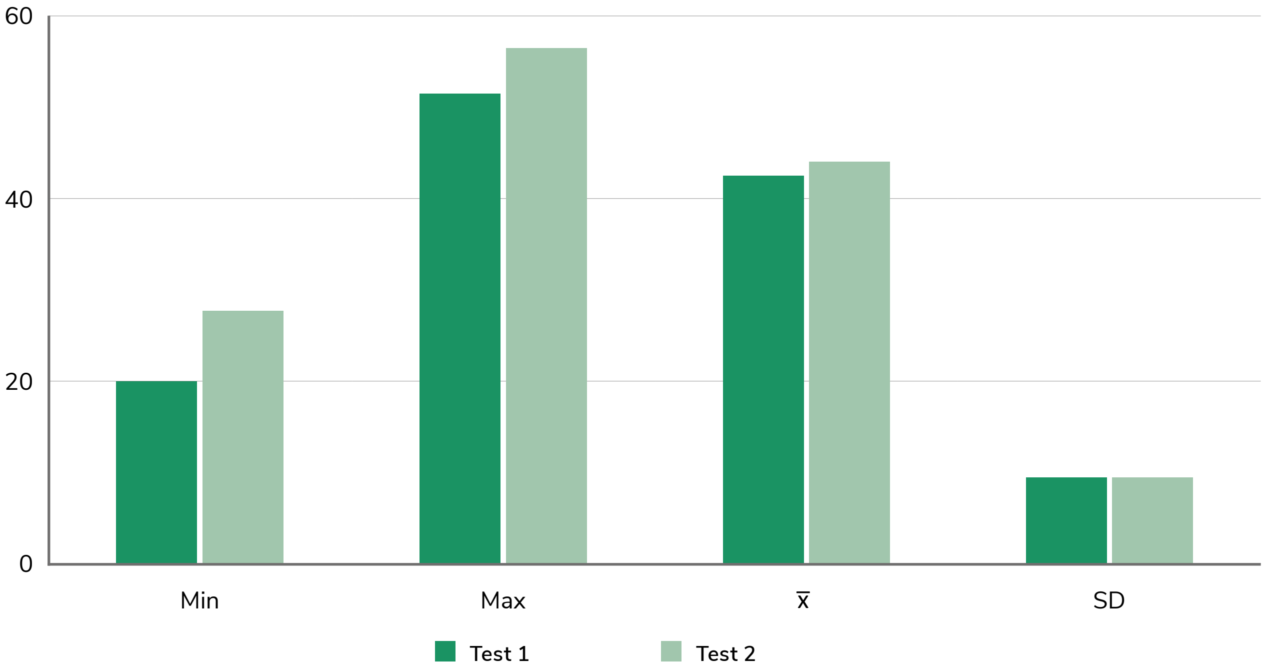
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 5. Comparison of the Test 1 and Test 2 results for maximum number of pull-ups in the training group without occlusion.



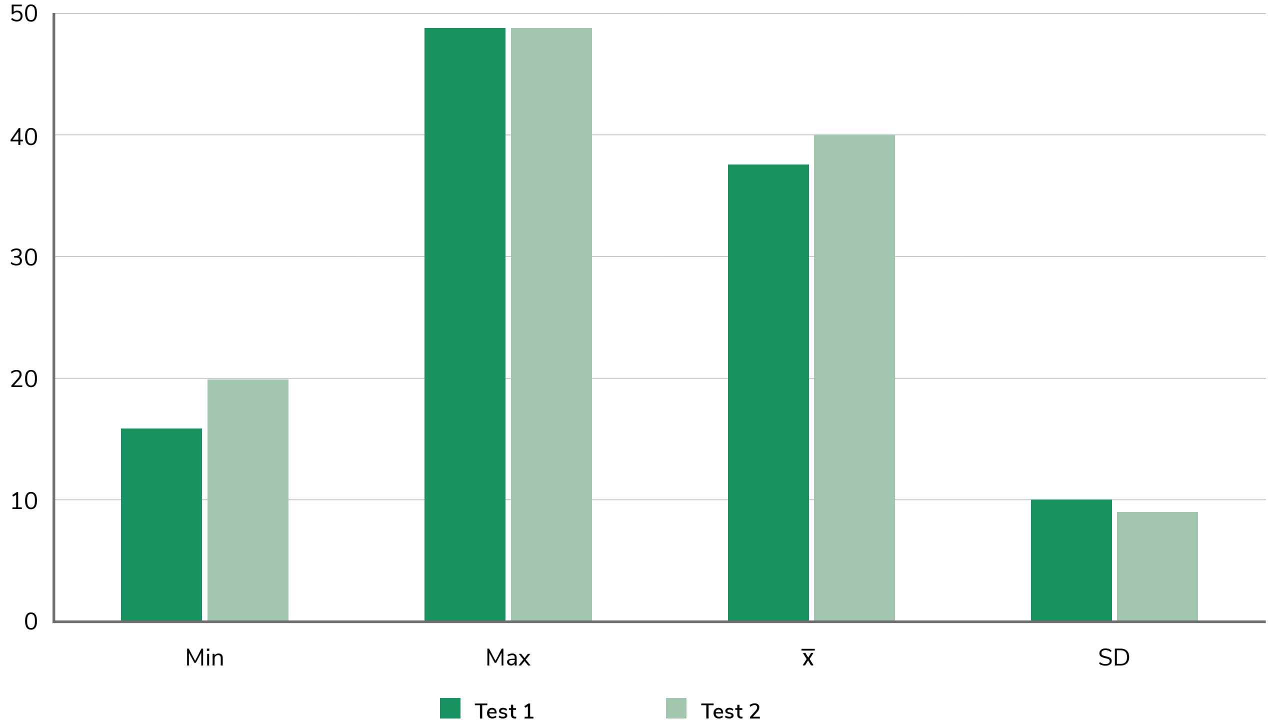
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group; $\bar{x}$ – arithmetic mean; SD – standard deviation.*

Figure 6. Comparison of the Test 1 and Test 2 results for right handgrip strength in the training group without occlusion.



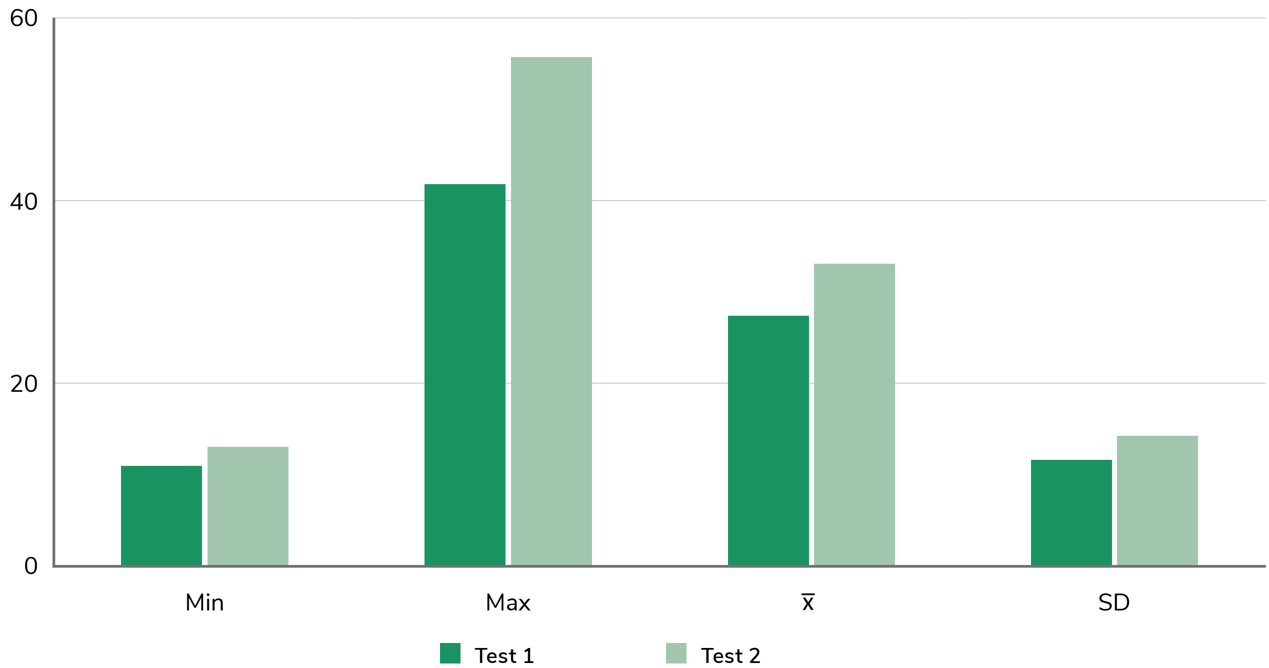
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group; $\bar{x}$ – arithmetic mean; SD – standard deviation.*

Figure 7. Comparison of the Test 1 and Test 2 results for left handgrip strength in the training group without occlusion.



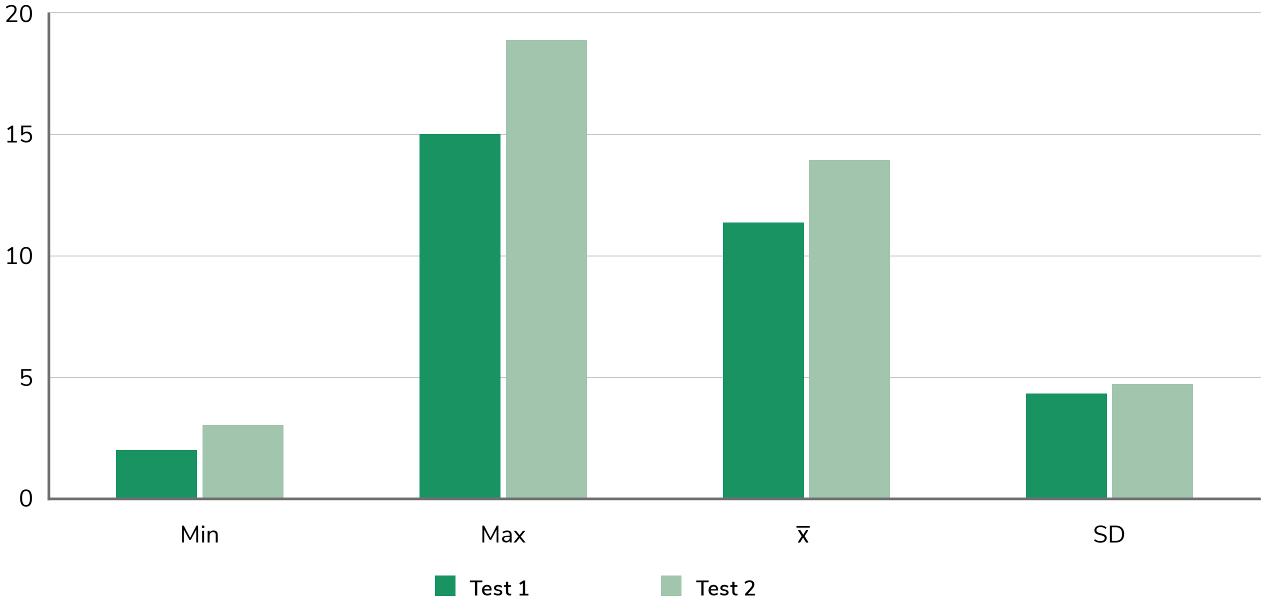
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 8. Comparison of the Test 1 and Test 2 results in the isometric test in the training group without occlusion.



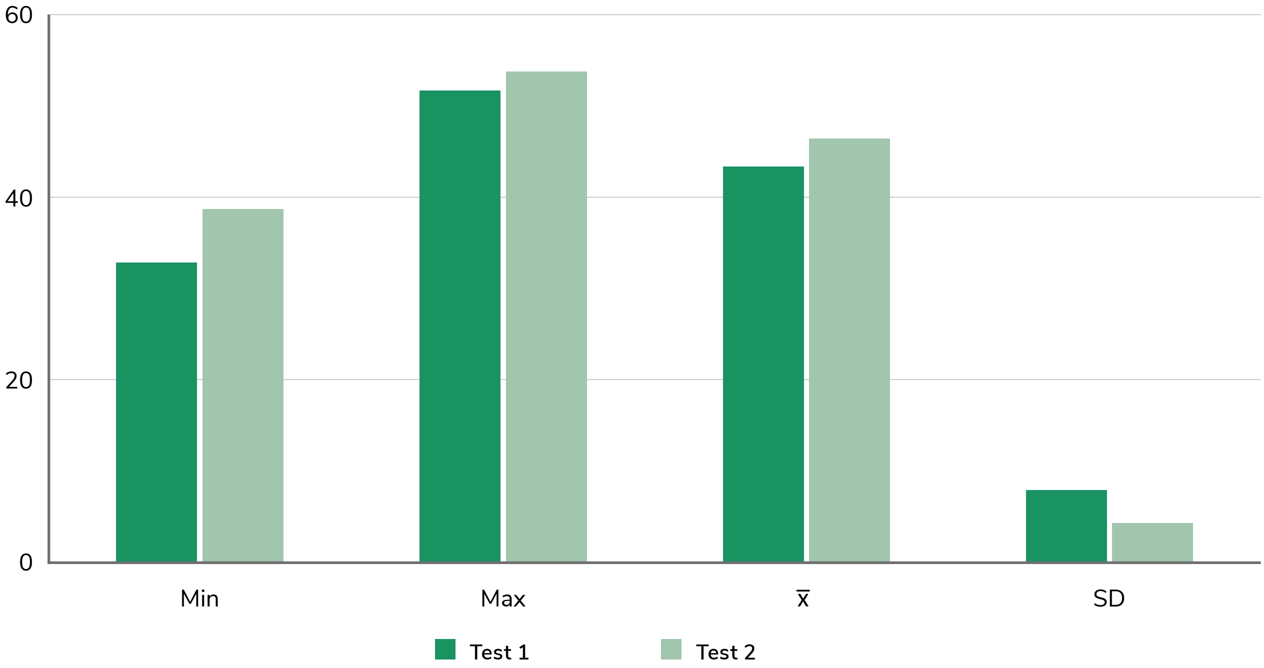
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 9. Comparison of the Test 1 and Test 2 results for maximum number of pull-ups in the occlusion training group.



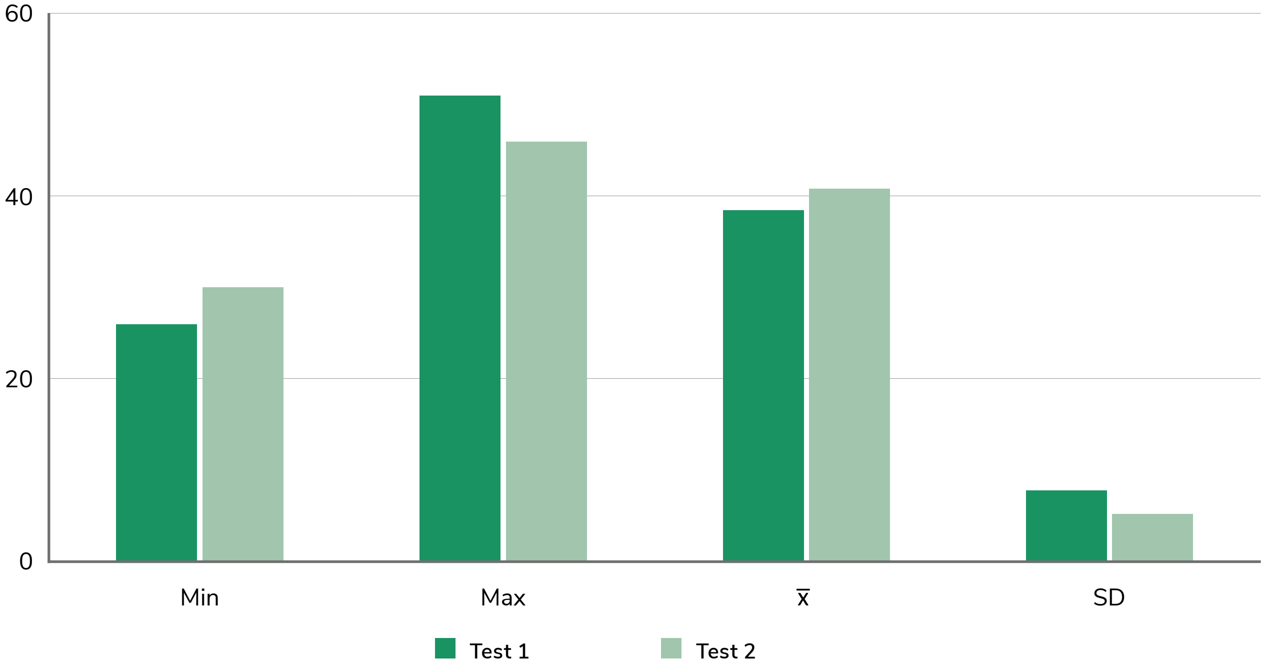
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group; $\bar{x}$ – arithmetic mean; SD – standard deviation.*

Figure 10. Comparison of the Test 1 and Test 2 results for right handgrip strength in the occlusion training group.



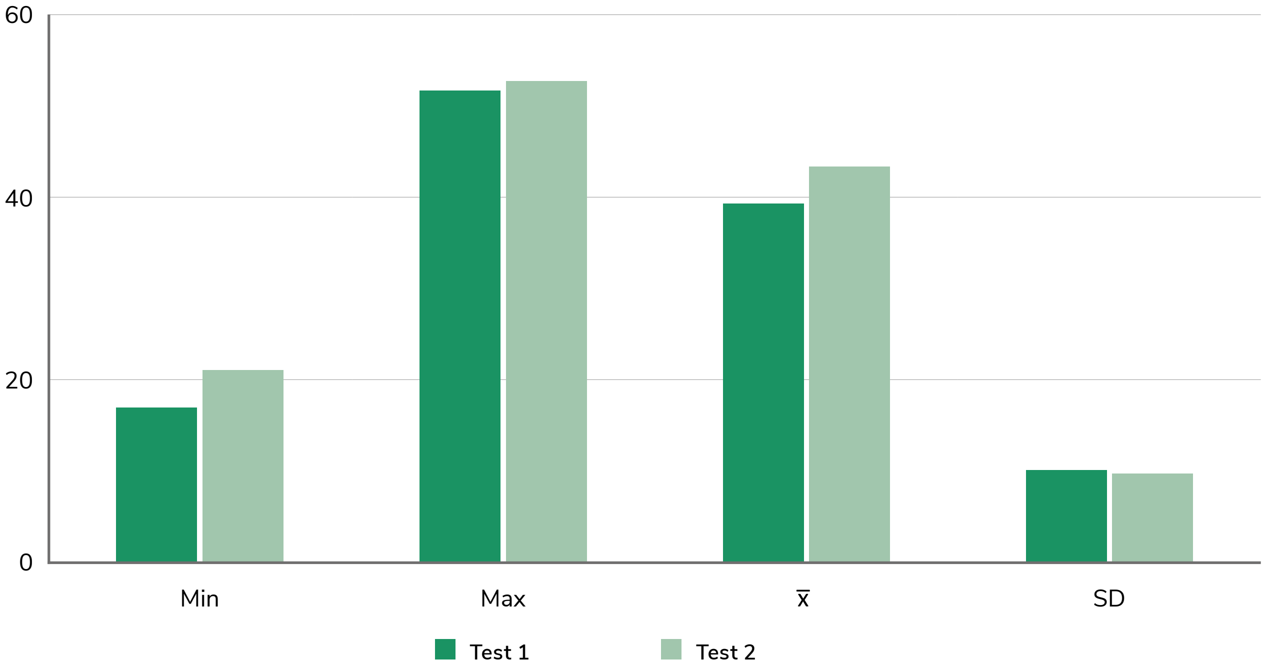
Abbreviations: *Min – minimum result in the group; Max – maximum result in the group; $\bar{x}$ – arithmetic mean; SD – standard deviation.*

Figure 11. Comparison of the Test 1 and Test 2 results for left handgrip strength in the occlusion training group.



Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Figure 12. Comparison of the Test 1 and Test 2 results in the isometric test in the occlusion training group.



Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation.*

Table 2. Comparison of intergroup changes.

Variables	Group	Min	Max	$\bar{x}$	SD	ANOVA / K-W Test
Maximum Number of Pull-Ups	C (1)	-1	2	0.35	0.79	p=0.002 S.D.: 3>1
	noOT (2)	0	6	1.6	2.07	
	OT (3)	0	5	2.6	1.51	
Right Handgrip Strength	C (1)	-12	4	-3	5	p=0.014 S.D.: 3>1
	noOT (2)	-8	8	1.4	5.89	
	OT (3)	-3	12	3	4.81	
Left Handgrip Strength	C (1)	-10	5	-2.41	4.96	p=0.016 S.D.: 3>2>1
	noOT (2)	-2	10	2.7	4.4	
	OT (3)	-6	10	2.4	5.32	
Isometric Test	C (1)	-10	18	1.41	7.69	p=0.294
	noOT (2)	-1	19	5.6	5.91	
	OT (3)	-6	13	3.9	5.8	

Abbreviations: *Min – minimum result in the group; Max – maximum result in the group;* $\bar{x}$ *– arithmetic mean; SD – standard deviation; S.D. – significant differences; "p" – significance of the test; C – control group; OT – training group with occlusion; noOT – training group without occlusion.*

Discussion

Occlusion training is gaining popularity not only in the world of sports but also in physiotherapy and medicine. New studies continuously emerge focusing on its impact on the human body. To date, few studies have explored its effectiveness in combination with pull-up exercises. Cook et al. [11] conducted a similar study on semi-professional rugby players with training sessions held three times a week for three weeks. Each session consisted of squats, bench presses, and pull-ups. Unlike our study, no significant improvement in pull-up strength was observed [11].

Yasuda et al. [12] examined how bench press training with occlusion affected upper body muscle strength. Their two-week training program showed positive effects on upper limb muscle strength, consistent with our findings, where resistance training with occlusion improved upper limb strength. Interestingly, despite similar conclusions, the training protocols did not engage exactly the same muscle groups in both cases [12].

Fitschen et al. [13] studied the relationship between continuous and intermittent resistance training with blood flow restriction and their effects on muscle strength. Both groups showed similar strength gains. Furthermore, it was demonstrated that taking breaks from BFR between sets reduced pain during training. Our study did not include such breaks. It can be inferred that this form of rest between sets could have influenced the training efficiency and reduced fatigue in our participants [13].

Early et al. [14] and Ladlow et al. [15] investigated whether conventional low-load strength training could be as effective as high-load BFR strength training. Both studies showed comparable effects on muscle strength and hypertrophy. It should be noted that the participants in Ladlow et al.'s study were adults with lower limb injuries. It can be inferred that BFR training offers additional benefits in terms of improving functional capacity, as observed in this group. Our study observed an increase in upper limb strength, but muscle endurance did not improve. However, to make a valid comparison, it would be necessary to conduct the study on the same muscle groups.

Gepfert et al. [16] demonstrated that resistance training combined with blood flow restriction does not decrease strength-endurance capacity. They compared a BFR training group with a control group and found that muscle tension time increased in the BFR group, indicating improved muscle endurance. In our study, a significant change in the isometric test was observed only in the non-occlusion training group. No differences were found between the groups. Gepfert et al. [16] used a different methodology, with participants performing different exercises and using higher training loads than in our study. Modifying the methodology might reduce the discrepancies observed in the study results described above.

Both our study and the majority of referenced studies indicate that exercise-based occlusion training can be an effective technique for building muscle strength. BFR training may prove to be a viable alternative for older adults dealing with osteoporosis, degenerative diseases, or those unable to engage in high-load strength exercises. Further research on the impact of occlusion on the human body may develop this topic further, and BFR training could become a leading method in sports rehabilitation and safe return to physical fitness.

Study limitations

The initial testing and training took place in a professional gym at AWF Katowice. Participants unfamiliar with such environments may have experienced elevated stress levels, potentially affecting the number of pull-ups performed during the preliminary series. Given that the participants were generally not very active, the initial number of pull-ups was relatively unimpressive, resulting in a significant training effect from regular sessions. It is possible that more trained individuals might show different results from occlusion training. Ensuring consistent tension in occlusion bands across training cycles was also challenging. This issue is a typical problem in occlusion training, bringing our results closer to real-world training scenarios where precise tension is less emphasized. For future studies, we recommend using pneumatic cuffs for greater repeatability.

Conclusions

Occlusion training increases upper limb muscle strength but does not significantly affect endurance. The methodology of the adopted training protocol may be crucial in changing muscle strength and endurance in the upper limbs.

Declarations

Ethical Considerations: The project received positive approval from the Thematic Team for Ethics in Scientific Research of Physiotherapists at the National Chamber of Physiotherapists (KIF) with opinion no. 2/2022. Informed consent was obtained from each participant after providing comprehensive information on the study's aim and protocol. The study was designed and conducted in accordance with the Declaration of Helsinki (1964) and Good Clinical Practice (GCP) guidelines.

Clinical Trials: This study was not registered as a clinical trial as it did not involve investigational products or interventions that would classify it under clinical trial regulations.

Conflict of Interest: The authors declare no conflict of interest. The study was conducted independently and without any influence from external organizations or entities.

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