Effect of blood flow restriction cuffs on joint proprioception with the example of the wrist

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Abstract

Background: Occlusion training, also known as blood-flow restriction training (BFR), is an exercise method in which the arterial inflow is partially restricted and the venous outflow is fully restricted in working muscles during exercise. Training performed under occlusion conditions is as effective as weight training with heavy loads. Joint proprioception plays a crucial role in maintaining stability and coordination during movement and protects against injury-causing movements. There is still a lack of studies on the effects of occlusion on joint position sense (JPS).

Aims: This study aimed to evaluate the effect of occlusion training by application of inflating tourniquets on joint proprioception using the example of the wrist.

Material and methods: The study group consisted of 40 volunteers, randomly divided into two groups: BFR and Placebo. The joint position sense test was performed twice in both groups using the Biodex isokinetic dynamometer. Measurement 1 was taken without an occlusion cuff. During measurement 2, in the BFR Group, an occlusion cuff was placed and inflated on the arm of the tested limb. In the Placebo Group, the cuff was applied but not inflated. The test was performed bilaterally for two target positions: 45° dorsiflexion and 30° palmar flexion. The subjects had their eyes covered with a blindfold. The analyzed parameter was the difference between the targeted position and the achieved position (°).

Results: The results obtained in measurements 1 and 2 were compared in both groups using the t-student test for the dependent groups. In both groups, the results of measurements 1 and 2 obtained for the target position of 45° were comparable (p=0.094-0.863). For 30°, in the BRF Group, the angular error was greater in measurement 2 than in measurement 1 (p=0.005-0.035). In the Placebo Group, there was no difference between measurements 1 and 2 (p=0.086-0.379).

Conclusions: This pilot study showed that the occlusion training cuffs placed on the upper arm may negatively affect wrist proprioception.

Key words

proprioception, occlusion training, occlusion cuffs, blood-flow restriction training, isokinetic assessment.

Introduction

Occlusion training, or blood-flow restriction training (BFR), is a training method in which the arterial inflow is partially restricted and the venous outflow is fully restricted in working muscles during exercise [1]. BFR training uses tourniquets, usually in the form of a pneumatic cuff but can also be manually tightened. Such a band is placed in the most proximal region of the exercised upper or lower limb. All muscles below and at the site of cuff compression become under occlusion. Low-load strength training, that is, about 20-30% of 1RM (one-repetition maximum or one-rep max, i.e., the maximum weight per repetition in strength training), performed under occlusion, has been shown to be as effective as high-load strength training [2]. Therefore, this method finds application in physiotherapy due to its ability to prevent atrophy and increase muscle strength after injuries and surgery, among other things, without risking damage to recovering tissues [2].

Proprioception, otherwise known as deep sensation, is defined as awareness of movement and body position in space [3]. It provides information from the musculoskeletal system regarding, among other things, the body's position in space and its parts in relation to each other, but is also responsible for stabilization, body protection, and locomotion [4]. Proprioception comprises kinesthesia, joint position sense (JPS), and neuromuscular control. Kinesthesia and joint position sense are controlled consciously through cortical interactions, while neuromuscular control is primarily subconscious control of joint reflexes from the spinal cord and cerebellum [5]. Proprioception of the joint plays a key role in maintaining stability and coordination during movement and protects against injurious movements [6]. Since the JPS is crucial for proper dynamic control and function of the wrist [7-9], it seems reasonable to gain new knowledge about the effects of muscle occlusion effect on sensation of joint position. This knowledge is important in terms of the safety of using occlusion training, especially for therapeutic purposes.

Aims

This study aimed to evaluate the effect of occlusion training by application of inflating tourniquets on joint proprioception using the example of the wrist.

Material and methods

Ethical considerations

The study was conducted in accordance with the guidelines and principles of the Declaration of Helsinki. Each subject was informed about the purpose and method of the study and signed an informed consent to participate in the study. Before the study, approval was obtained from the Bioethics Committee at the Wroclaw Medical University (Poland) to conduct the study (no. KB–117/2021).

Study participants

The study took place in 2021-2022 in the Independent Laboratory of Ergonomics and Biomedical Monitoring in the Department of Physiotherapy at the Faculty of Health Sciences of the Wroclaw Medical University and in the Department of Trauma Surgery at the Faculty of Medicine of the Wroclaw Medical University. The study group consisted of 40 volunteers from among the students of Wroclaw Medical University.

Qualification criteria

Study participants met all inclusion criteria for the study: body mass index (BMI) in the range of 18.50-24.99 kg/m^2; age in the range of 20-30 years; no current or past upper extremity injuries and/or conditions; no current upper extremity pain; no swelling in both upper extremities; full range of motion of the wrist of both upper extremities with respect to current standards [10]; normal muscle strength acting on the wrist of both upper extremities that is 5 grade according to the Lovett scale [10]; no diagnosed venous insufficiency; no systemic diseases of any kind; right dominant hand). The dominant upper limb was determined to be the one the respondent writes.

Randomization

Subsequently, the 40 study participants were divided into two equal groups using simple randomization: BFR Group and Placebo Group. Detailed characteristics of the study sample are shown in **Table 1**. The two study groups were comparable in terms of age (p=0.893), body weight (p=0.556), body height (p=0.202), and BMI (p=0.991).

Measurements

In both study groups, active repetition of wrist position was measured twice at a 90-minute interval using a Biodex System 4 Pro isokinetic dynamometer. During the study, the subjects wore black, impermeable blindfolds over their eyes.

The starting position for the examination was sitting. The examination was performed bilaterally from the dominant upper limb. Beginning with the dominant hand, the subject's wrist from the neutral position (**Fig. 1**) was placed in 45° dorsiflexion (**Fig. 2**), then the subject's task was to memorize this position for 10s. Subsequently, the hand was returned to the neutral position, and the subject had to reproduce the memorized position. The subject then had a one-minute break, after which a second position was inflicted. The second position was 30° of palmar flexion of the wrist (**Fig. 3**). The testing sequence was the same as for the first position. The entire sequence was then repeated for the opposite hand.

Table 1. Comparative analysis of the characteristics of the studied sample.

Characteristic	BFR Group	Placebo Group	p
n	20	20	
% ratio W/M	55/45	50/50	N/A
Age (years)	22.6 ± 0.75	22.65 ± 1.46	0.893
Body weight (kg)	72.75 ± 14.74	70 ± 14.51	0.556
Body height (m)	1.76 ± 0.08	1.73 ± 0.09	0.202
BMI	23.31 ± 3.48	23.30 ± 3.20	0.991

Notes: *Values are expressed as arithmetic mean and standard deviation (±).*

Abbreviations: *BMI – body mass index; W – women; M – men; n – number of subjects in the study group; p – level of statistical significance; N/A – not applicable.*

Placebo group

The tested subject assumed a specified position on the dynamometer as above, after which an AirBand occlusion training band was placed on his arm (**Fig. 4**). The armband for this group was only placed on the arm, adhered to the arm but did not tighten, and was in this form the entire study. Then, the proprioception test proceeded with the same sequence as the measurement 1 without the armband. When there was a change of arm, the armband was removed from the arm that had already been tested and placed in the same way on the opposite arm.

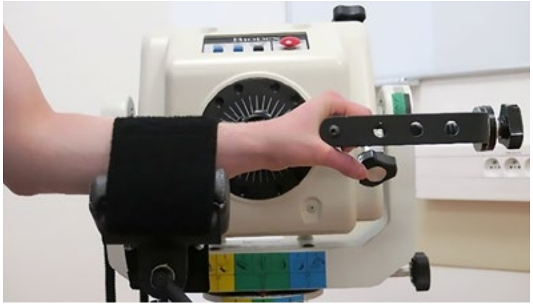

Figure 1. Positioning the subject's wrist in a neutral position.

Figure 2. Positioning the subject's wrist in a 45° dorsiflexion position.

Figure 3. Positioning the subject's wrist in a 30° palmar flexion position.

Figure 4. AirBands used in the study.

BRF group

The measurement 1 was performed without tourniquets. Just before measurement 2, subjects from both groups were fitted with a tourniquet on the arm of the test limb. Wireless BFR AirBands (VALD Health, VALD Pty Ltd; United States: United Kingdom), designed for upper limbs, were used for the study. The bands were managed using the AirBand app installed on a tablet (Galaxy Tab S7 SM-T870, Samsung Electronics Co., Ltd. 129, Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Republic of Korea). The armband was worn at the level of the shoulder nodule. Initially, the tourniquet was calibrated, which consisted of measuring the maximum (100%) limb compression, after which the tourniquet was deflated. In the BRF Group, it was sequentially inflated to 50% of the maximum compression, and in the Placebo Group, the tourniquet remained uninflated. The parameter studied was the difference between the targeted position and the achieved position, expressed in degrees (°).

Statistical analysis

The statistical analysis was performed using SPSS Statistics Version 28.0.1.0 (142) (IBM SPSS Statistics, Armonk, NY, USA) and Microsoft Office Excel 365 Personal (Microsoft Corporation, Redmond, WA USA). The arithmetic mean and standard deviation (±) were calculated. The results were obtained separately in the two study groups in two measurements, separately for the right and left limbs. The normality of distribution was checked using the Shapiro-Wilk test. The parametric Student's t-test for dependent groups was used to compare the results obtained in measurement 1 to those obtained in measurement 2, separately for the BFR Group and the Placebo Group. The level of statistical significance was set as $p<0.05$.

Results

As shown in **Table 2**, in both the BFR Group ($p=0.222-0.863$) and the Placebo Group ($p=0.094-0.841$), in both upper limbs studied, the difference obtained in the measurements 1 and 2 between the angular position aimed at 45° of dorsiflexion of the hand and the angular position achieved was not statistically significant.

Table 3 presents a comparative analysis of the results of the difference between the targeted position and the best repetition achieved for 30° of palmar flexion obtained during measurements 1 and 2 of active joint position recovery. In the BFR Group, the difference obtained was statistically more significant in measurement 2 than in measurement 1 (p=0.005-0.035). No statistically significant differences were noted in the Placebo Group (p=0.086-0.379).

Table 2. Comparative analysis of the results of the difference between the targeted position and the achieved best repetition for 45° of dorsiflexion obtained during measurements 1 and 2 of active joint position restoration.

The difference between the targeted position (45° of dorsiflexion) and the achieved position (°) – best repetition.				
Study Group	**Tested Limb**	**Measurement 1**	**Measurement 2**	**p-Value**
BFR Group	Right limb	6.78 ± 8.38	4.31 ± 3.65	0.222
	Left limb	5.18 ± 5.46	4.94 ± 4.17	0.863
Placebo Group	Right limb	4.25 ± 2.88	4.02 ± 3.39	0.841
	Left limb	4.01 ± 2.90	5.92 ± 4.13	0.094

Notes: *Values are expressed as arithmetic mean and standard deviation (±).*

Abbreviations: *BFR group – group with tightened AirBands; Placebo group – group without tightened AirBands; p – level of statistical significance.*

Table 3. Comparative analysis of the results of the difference between the targeted position and the achieved best repetition for 30° of palmar flexion obtained during measurements 1 and 2 of active joint position restoration.

The difference between the targeted position (30° of palmar flexion) and the achieved position (°) – best repetition.				
Study Group	**Tested Limb**	**Measurement 1**	**Measurement 2**	**p-Value**
BFR Group	Right limb	7.92 ± 7.38	11.87 ± 7.32	0.005
	Left limb	4.75 ± 5.03	8.18 ± 6.44	0.035
Placebo Group	Right limb	7.60 ± 5.56	9.11 ± 6.54	0.379
	Left limb	8.60 ± 6.42	11.72 ± 6.40	0.086

Notes: *Values are expressed as arithmetic mean and standard deviation (±).*

Abbreviations: *BFR group – group with tightened AirBands; Placebo group – group without tightened AirBands; p – level of statistical significance.*

Discussion

This original research study aimed to evaluate the effect of wearing occlusion training bands on joint proprioception using the example of the wrist. Based on the study, disturbances of hand position sensation were observed in one of the two positions tested. Therefore, it can be assumed that the arm occlusion may interfere with wrist proprioception, although the study should be considered only a pilot study.

Currently, there needs to be more research in the literature on joint proprioception during BFR training, although it is necessary to consider the safety of using BFR. To date, it has been assumed that the risk factors of BFR training are comparable to those of traditional training and take into account, among other things, muscle damage [11,12]. Regarding proprioception, in the literature, the study by Yamada et al. [13] can be found on the effect of low-intensity aerobic exercise, more explicitly walking, along with applied BFR using elastic bands, on knee proprioception. From a safety point of view, it is much more important to evaluate possible impairment of joint position sensation during training with occlusion. Our results are opposite to those of Yamada et al. [13], whereas we measured JPS during occlusion, not after occlusion. In the study by Yamada et al. [13], the BFR bands were removed after exercise before measurements were taken. Since BFR training has been used mainly in sports, the target group in this study was healthy recreational athletes. Given that the current literature is paying more and more attention to the use of BFR in rehabilitation, similar studies should be conducted on trauma patients in the future, as we know they already show deficits in JPS [9]. In these patients, BFR may further affect proprioception; however, until this is studied, it remains a matter of debate.

The most significant limitation of the presented study was that the JPS assessment of the wrist was always performed in the same order; that is, the first targeted position was 45° of dorsiflexion, followed by a targeted position of 30° of palmar flexion. Therefore, it is not possible to conclude whether a more significant difference in JPS was recorded for the 30° of palmar flexion target position due to the particular position or the longer occlusion time.

Conclusions

Occlusion training bands worn on the arm negatively affected the sensation of one of the two tested hand positions. This means occlusion training bands worn on the upper limbs may interfere with wrist proprioception. The study should be considered a pilot study, and future research needs to be expanded to evaluate the safety of BRF training.

References

1. Pearson SJ, Hussain SR. A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. Sports Med. 2015; 45 (2): 187–200.
2. Lorenz DS, Bailey L, Wilk KE, Mangine RE, Head P, Grindstaff TL, et al. Blood Flow Restriction Training. J Athl Train. 2021; 56 (9): 937–944.
3. Silverthorn DU. Fizjologia człowieka. Wydawnictwo Lekarskie PZWL: Warszawa 2018.
4. Stryła W, Pogorzała AM. Ćwiczenia propriocepcji w rehabilitacji. Wydawnictwo Lekarskie PZWL: Warszawa 2015.
5. Hagert E. Proprioception of the wrist joint: a review of current concepts and possible implications on the rehabilitation of the wrist. J Hand Ther. 2010; 23 (1): 2–17.
6. Riemann BL, Lephart SM. The sensorimotor system, part I: the physiologic basis of functional joint stability. J Athl Train. 2002; 37 (1): 71–79.
7. Karagiannopoulos C, Sitler M, Michlovitz S, Tierney R. A descriptive study on wrist and hand sensori-motor impairment and function following distal radius fracture intervention. J Hand Ther. 2013; 26 (3): 204–214.
8. Valdes K, Naughton N, Algar L. Sensorimotor interventions and assessments for the hand and wrist: a scoping review. J Hand Ther. 2014; 27 (4): 272–285.
9. Hincapie OL, Elkins JS, Vasquez-Welsh L. Proprioception retraining for a patient with chronic wrist pain secondary to ligament injury with no structural instability. J Hand Ther. 2016; 29 (2): 183–190.
10. Józefowski P. Diagnostyka czynnościowa narządu ruchu z elementami pionizacji i reedukacji chodu. Wydawnictwo Medyczne MedPharm: Wrocław 2013.
11. Patterson SD, Hughes L, Warmington S, Burr J, Scott BR, Owens J, et al. Blood Flow Restriction Exercise: Considerations of Methodology, Application, and Safety. Front Physiol. 2019; 10: 533.
12. Loenneke JP, Wilson JM, Wilson GJ, Pujol TJ, Bemben MG. Potential safety issues with blood flow restriction training. Scand J Med Sci Sports. 2011; 21 (4): 510–518.
13. Yamada Y, Kasprzak R, Shotten S, Miller-Brown A, Mathew AMG, Loenneke JP, et al. Walking with practical blood flow restriction did not induce impairment of knee proprioception and fatigue. J Trainology 2021; 10: 16–19.