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Original article

Effect of restorative massage on regional blood flow in Paralympic athletes

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Abstract: *Objective* — to evaluate an impact of a restorative massage course, integrated into a training session, on the regional blood circulation in Paralympic athletes.
Materials and Methods — Athletes with impaired musculoskeletal system (IMSS), shooters and powerlifters (n=23), were subjected to a course of restorative massage in a special preparatory microcycle of the competitive period. In the main group, massage sessions were included in the training session, whereas in the control group, they were conducted at the end of the training session. The evaluation of peripheral circulation in the upper limbs was performed via vascular blood flow test; and the effectiveness of arterial and venous blood flow, vascular tone and elasticity were assessed.
Results — The obtained results for the first time allowed describing the effect of restorative massage on the peripheral circulation of Paralympic athletes. After a course of restorative massage was integrated into a training session, changes in peripheral hemodynamics were noted. We revealed an improvement in arterial blood flow due to an increase in the time of rapid blood filling, a decrease in the tone of medium and small vessels, and a reduction in peripheral vascular resistance (PVR). Arterial and venous blood flow at the level of postcapillaries improved in all segments. The blood flow was effectively redistributed between the distal and proximal segments of the upper limbs.
Conclusion — The use of massage sessions in the middle of a training session has a positive effect on the state of peripheral circulation in the proximal upper limbs and the tone of large vessels, whereas the use of massage at the end of a workout has a predominant effect on the tone of small vessels and the state of blood circulation in distal segments of the limbs.

Keywords: recovery, Paralympians, massage, circulatory system.

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Introduction

Pursuing adaptive sports by individuals with musculoskeletal system lesions lead to an improvement in the cardiovascular system functioning and an increase in its adaptive capabilities [1-3]. Adaptation of the cardiovascular system to specific motor activity of Paralympic athletes is implemented not only at the level of the entire body, but also at the peripheral level: in the functioning muscles, where local muscular endurance is manifested [4]. The information presented in the published sources on the changes in the peripheral circulation of athletes is often contradictory and is dedicated to the assessment of the blood flow in healthy athletes. According to experts, as a result of long-term strength training (powerlifting), changes in the peripheral circulatory system are noted. Pronounced changes are recognized at the level of distal segments (shin – foot); peculiarities are observed in the arterial and venous links of the vascular bed, the intensity of blood flow decreases, and the outflow of blood through the veins becomes problematic [5].

Zamchiy et al. [6], while evaluating the circulatory system in powerlifters, revealed increased arterial tone, increased tone of veins and venules, low tone of medium and small arteries in legs and feet, and symptoms of blood flow asymmetry. Kudrya et al. [7] pointed out that no adaptive changes in vascular tone were noted in representatives of power sports: an intensity of blood flow was increasing at the level of medium and small arteries and veins, which contributed to subsequent increase in blood pressure at rest [8].

In Paralympic athletes, due to the peculiarities of their musculoskeletal system functioning, the main physical load falls on the upper half of their body and upper limbs [9-11]. This feature of performing physical activity is accompanied by adaptive changes in the circulatory system both in central [9, 10] and peripheral regions [10, 12].

Experts have repeatedly noted the adaptive features of the central blood circulation in Paralympic athletes [9-12], whereas there is virtually no information on the nature of changes in the peripheral circulation under the impact of specific physical activity in Paralympic athletes. The second starting point of our research was the lack of information on exact strategy of restoring blood circulation in Paralympic athletes and on the effect of massage on the state of their peripheral circulation. Hence, these issues served the basis for our study.

Trembach et al. established that the main load during the bench press exercise in powerlifters with impaired musculoskeletal

system (IMSS) affected m. pectoralis major, dexter and sinister, and m. triceps brahii, dexter and sinister [4]. In the course of our own research, we discovered a change in the nature of the peripheral circulation and hemodynamics of athletes with IMSS involved in bullseye shooting and powerlifting [13] during the stage of fast recovery. The revealed changes require the use of special means of recovery and adjustment of the training process [14].

Increasing physical and emotional loads, along with an increasing number of maladaptive reactions, require a revision of methodological approaches and adjustments to organizing the training process of Paralympic athletes, and also the correction of their recovery programs [15, 16]. Particular importance is given to the possibilities of providing fast recovery of disabled athletes in a natural training environment, using modern effective technologies and means [15].

The objective of our study was to evaluate an impact of a restorative massage course, integrated into a training session, on the regional blood circulation in Paralympic athletes.

Material and Methods

The assessment of the effect of massage course was carried out on the basis of the analyzing a set of parameters. Evaluation of peripheral circulation was performed by rheography according to conventionally used method [16]. Registration was carried out simultaneously on two adjacent segments of the upper limbs in the shoulder-forearm leads, located symmetrically, using a six-channel *Reo-Spectrum* rheographic complex (Neurosoft LLC, Ivanovo).

Assessment of the peripheral circulation in the upper limbs was performed via indicators of vascular blood flow test. An interpretation of the obtained data was based on information in available published sources on the relationship of rheographic parameters with the physiological characteristics of peripheral circulation [16]. For instance, the value of the rheographic index (*RI*, conventional units) makes it possible to characterize the volumetric blood filling in the main arteries of the study area: with a reduction in blood filling, the value of this parameter declines. The elasticity of blood vessels is a function of the propagation time of the pulse wave (Q_x, s): with a decrease in elasticity and an increase in resistance, the speed of wave propagation can significantly decline. Assessment of peripheral vascular resistance and tone of the precapillary vessels was estimated via calculating the dicrotic index (*DIC*, %): its higher values implied higher peripheral vascular resistance.

The state of the venous outflow and the tone of the veins at the level of postcapillaries were assessed by calculating the diastolic index (*DIA*, %): an increase in the index indicates a difficulty in blood outflow at the level of postcapillaries. The filling of large arteries under the influence of the heart contraction and the tone of the distributing arteries were identified by the value of the maximum rate of rapid filling (V_{max}, Ohm/s): with a decrease in the rate of over 50% of the norm, vascular hypertonicity is noted, whereas with a decrease of more than 50% of the norm, hypotonicity is observed. The tone of medium and small resistance arteries was assessed on the basis of the average rate of slow filling (V_{av}, Ohm/s): in combination with *DIC* value, this parameter allows estimating the state of venous outflow.

Statistical processing of the study results was carried out using the statistical software package Microsoft Excel 2003 and Statistica, version 6. Checking for the normality of the data distribution was performed via the Kolmogorov–Smirnov test. Due to non-normal distribution of our data, the significance of differences was determined using the nonparametric Wilcoxon and Mann-Whitney tests (critical significance level $p < 0.05$). The results are presented as a median, and lower and upper quartiles: Me (LQ; UQ). The dynamics of parameter values after a massage course was estimated by the magnitude of their growth rates calculated using the Brody formula.

Study participants

The study involved athletes with IMSS, pursuing regular physical activity, typically of a static nature (bullseye shooting and powerlifting) (n = 23). Based on the nature of musculoskeletal system injuries, the study participants were distributed as follows. Athletes with spinal cord injury at the level of Th 5-6 – L 1-2 segments (n = 9), athletes with amputation of one / both lower limbs at the level of the middle third of the thigh (n = 6), and athletes with congenital forms of IMSS (n=8). In terms of their level of sports qualification, all participants were either Candidates for Master of Sports or Masters of Sports. The mean age of the participants was 27.6⍰4.3 years.

All study subjects were provided with comprehensive and reliable information about the ongoing activities. Voluntary informed consent forms were signed by all participants. The study was conducted in accordance with the bioethical standards set out in the 1964 Declaration of Helsinki and was approved by the local research ethics committee.

Research design

At the preliminary stage, on the day of no physical activities, at rest, testing was performed to compare hemodynamic parameters among athletes in groups formed according to nosological criteria. Due to the fact that there were no significant differences in nosology, all athletes were combined for further research.

The second stage of the study included an assessment of hemodynamic parameters 30 minutes after performing some specific physical activity. The study was conducted on the first day of the microcycle, before the onset of the massage course. At the third stage of the study, two groups were formed by random selection: the first (the main group, n=12) and the second (the control group, n=11). In the main group, restorative massage sessions were included directly into training sessions of a special preparatory microcycle during the competitive stage of the annual cycle of sports training. Massage sessions were held during the interval between exercises, replacing the pause in training, which was previously used for passive resting.

In the control group, athletes were receiving a completely identical massage course, but it was carried out after the completion of the training session. A pause in training session was filled in traditional way (passive resting, general developmental exercises and listening to the music). In both groups, the full course included eight massage sessions.

The basis for restoration methodology development was the approach proposed by Kennedy et al. [17, 18] for Paralympic athletes. The massage procedure was gentle, short-term, relaxing, sensu the recommendations of Epsi-Lopez et al. (2020) [19]. Muscles and connective tissue structures were massaged. The main massaged areas involved the cervical collar zone, the

occipital region of the head, the shoulder girdle, and the shoulder region. The duration of a single session was 7-9 minutes.

Results

The peripheral circulation in Paralympic athletes after performing a specific physical activity was characterized by a pronounced directional asymmetry (right-left differences). In the distal-proximal segment at the level of the forearm, there was a pronounced reduction in the level of blood filling in both groups.

The tone of small and medium arteries at the level of the left shoulder was high, as evidenced by the time of fast and slow blood filling and the value of the dicrotic index. There was an increase in peripheral vascular resistance (PVR) and vascular tone at the level of precapillaries. The maximum rate of rapid blood filling was significantly reduced in all segments on both sides, which indicated a high tone of the arteries as well. At the level of the forearm, there we detected an increase in the tone of resistance vessels, due to the predominance of the tone in medium and small arteries, as evidenced by an increase in the rate of slow blood filling at the level of the shoulder and its decline at the level of the forearm. The state of elasticity and tone of large vessels allowed estimating the propagation time of the rheographic wave, which was reduced in all segments. The latter finding implied an increase in the tone of large vessels (*Tables* 1, 2). The process of blood outflow from arteries to veins and the tone of venous vessels at the level of postcapillaries was elevated in the shoulder segment and reduced at the level of the forearm. We observed some difficulty in venous outflow at the level of the forearm with normal venous tone.

Table 1. State of peripheral circulation in athletes with disabilities of the musculoskeletal system before and after a course of massage on the shoulder area, *Me (LQ; UQ)*

Parameters	*Groups*	*Limb segments. Shoulder*					
		left			right		
		before	after	P-level	before	after	P-level
RI, conventional units	1	0.43 (0.23; 0.67)	0.48 (0.26; 0.61)	0.032	0.68 (0.56; 0.72)	0.56 (0.36; 0.62)	0.032
	2	0.41 (0.28; 0.46)	0.43 (0.34; 0.51) #	0.034	0.66 (0.57; 0.72)	0.61 (0.48; 0.72)	0.034
Q_x, s	1	0.14 (0.12; 0.19)	0.19 (0.14; 0.26)	0.034	0.14 (0.11; 0.19)	0.23 (0.17; 0.26)	0.032
	2	0.12 (0.09; 0.17)	0.18 (0.14; 0.23)	0.034	0.13 (0.10; 0.19)	0.19 (0.14; 0.22) #	0.034
DIC, %	1	82.29 (76.14; 91.26)	64.71 (56.17; 85.13)	0.039	91.43 (86.27; 96.26)	58.15 (51.74; 75.22)	0.039
	2	83.31 (79.84; 93.18)	76.27 (71.29; 83.23) #	0.048	91.68 (88.27; 95.26)	79.92 (70.14; 82.48) #	0.048
DIA, %	1	77.06 (73.66; 88.23)	63.91 (53.58; 82.17)	0.034	92.43(86.14; 97.48)	71.82(65.69; 84.27)	0.034
	2	76.17 (70.57; 84.26)	64.22 (60.09; 73.47)	0.034	92.99 (89.14; 97.26)	79.96 (76.14; 91.26) #	0.034
V_{av}, Ohm/s	1	0.71 (0.63; 0.76)	0.63 (0.58; 0.67)	0.079	0.62 (0.55; 0.69)	0.56 (0.50; 0.67)	0.079
	2	0.70 (0.63; 0.74)	0.62 (0.53; 0.65)	0.061	0.62 (0.55; 0.68)	0.58 (0.51; 0.65)	0.061
V_{max}, Ohm/s	1	0.71 (0.65; 0.79)	0.98 (0.91; 1.03)	0.039	0.96 (0.95; 0.99)	1.33 (1.26; 1.37)	0.039
	2	0.72 (0.69; 0.83)	0.84 (0.81; 0.93) #	0.048	0.98 (0.83; 1.06)	1.31 (1.25; 1.39) #	0.048

Group 1 – main (n=12), Group 2 – the control (n=11). The statistical significance of differences was established ($p<0.05$): * – intragroup differences before and after the course, # – intergroup differences before and after the course. RI, conventional units – rheographic index; Q-x, s – pulse wave propagation time; DIC, % – dicrotic index; DIA, % – diastolic index; V_{av}, Ohm/s – average rate of slow filling of blood vessels, V_{max}, Ohm/s – maximum rate of fast vessel filling.

Table 2. State of peripheral circulation in athletes with disabilities of the musculoskeletal system before and after a course of massage on the forearm area, *Me (LQ; UQ)*

Parameters	*Groups*	*Limb segments. Forearm*					
		left			right		
		before	after	P-level	before	after	P-level
RI, conventional units	1	0.18(0.12; 0.21)	0.43 (0.32; 0.47)	0.034	0.32 (0.28; 0.44)	0.48 (0.36; 0.59)	0.032
	2	0.17 (0.12; 0.21)	0.32 (0.25; 0.41)	0.034	0.32 (0.24; 0.39)	0.37 (0.30; 0.41)	0.034
Q_x, s	1	0.19 (0.14; 0.24)	0.22 (0.18; 0.26)	0.034	0.13 (0.11; 0.19)	0.18 (0.14; 0.22)	0.032
	2	0.17 (0.14; 0.25)	0.21 (0.17; 0.25)	0.034	0.12 (0.09; 0.21)	0.17 (0.14; 0.23)	0.034
DIC, %	1	78.84 (71.54; 83.16)	67.23 (59.13; 78.23)	0.039	77.14 (66.21; 85.27)	62.39 (52.12; 71.84)	0.039
	2	79.81 (72.37; 89.12)	69.31 (60.14; 71.33)	0.048	76.14 (69.25; 84.23)	68.77 (61.29; 82.15)	0.048
DIA, %	1	37.43 (32.14; 44.26)	43.16 (39.85; 52.27)	0.034	25.14 (22.13; 32.84)	32.74 (29.17; 41.59)	0.034
	2	36.29 (28.76; 39.33)	45.91 (41.19; 54.26)	0.034	24.15 (21.14; 31.27)	37.29 (33.56; 41.19) #	0.034
V_{av}, Ohm/s	1	0.17 (0.14; 0.24)	0.23 (0.17; 0.26)	0.079	0.24 (0.19; 0.27)	0.29 (0.25; 0.34)	0.079
	2	0.16 (0.13; 0.22)	0.27 (0.23; 0.29)	0.061	0.23 (0.19; 0.26)	0.32 (0.27; 0.40)	0.061
V_{max}, Ohm/s	1	0.24 (0.21; 0.26)	0.85 (0.78; 0.92)	0.039	0.14 (0.10; 0.18)	0.96 (0.91; 0.99)	0.039
	2	0.22 (0.15; 0.26)	0.46 (0.41; 0.50) #	0.048	0.13 (0.09; 0.17)	0.73 (0.67; 0.79) #	0.048

Group 1 – main (n=12), Group 2 – the control (n=11). The statistical significance of differences was established ($p<0.05$): P-level – intragroup differences before and after the course; # – intergroup differences before and after the course. RI, conventional units – rheographic index; Q-x, s – pulse wave propagation time; DIC, % – dicrotic index; DIA, % – diastolic index; V_{av}, Ohm/s – average rate of slow filling of blood vessels, V_{max}, Ohm/s – maximum rate of fast vessel filling.

After a course of massage, changes in peripheral circulation were noted in both groups. The changes were multidirectional. In the main group, the most pronounced effect of the massage course was observed at the shoulder level, while in the control group, it was established at the forearm level. In both groups, there was an improvement in the blood supply to the segment. Moreover, it increased by 48.6% in the main group and by 34.5% in the control group. The asymmetry of blood circulation in the right-left direction declined to a value not exceeding 20%, which was detected by experts as a variant of the norm [7, 20]. In the proximal-distal sections, the asymmetry of the peripheral blood flow still persisted, but was not so much pronounced (*Tables* 1 and 2).

In the main group, after the end of the massage course, we discovered a reduction in the tone of medium and small vessels, along with an improvement in blood supply by 44.5% at the level of precapillaries and by 25.1% at the level of postcapillaries and venous outflow. Besides, there was an improvement in the blood filling of the large vessels in the forearm by 111.9% on the left and 149.1% on the right.

In the control group, the predominant changes after the course of massage were noted at the level of distal sections (at the forearm level). Blood filling of large forearm vessels increased by 61.2%, the tone of large shoulder vessels declined, and blood supply improved by 20.3%. In the forearm, the state of arterial blood supply to tissues improved, the tone of small vessels at the level of postcapillaries decreased, and venous outflow improved by 42.8%. The rate of slow filling of medium vessels of resistive type improved by 51.2% on the left and 32.7% on the right. Blood supply to the large arteries of the forearm improved significantly, by 139.5%, mainly from the working (right) side.

Discussion

In the process of sports training, Paralympic athletes experience significant physical loads to form an optimal level of fitness and achieve high sports results [1, 3, 4, 9]. During the power training of athletes, big static loads are inevitable [4-6]. In this regard, a number of risk factors are identified that provoke the development of maladaptive reactions. Among the latter, we should mention the specific changes in the nature of peripheral circulation, which manifest themselves mainly in changes of blood flow in the arterial bed and in the development of venous stasis symptoms, as well as in the formation of a pronounced asymmetry of blood supply to the body segments [5, 6, 15]. In athletes with IMSS, similar risk factors were revealed supplemented in the competitive period by a high level of psychoemotional stress. An elimination of their negative impact requires specific approaches to building the training process and planning the recovery of this category of athletes [15].

The changes in peripheral circulation parameters revealed in our study in athletes with IMSS at rest implied the formation of adaptive reactions in the bloodstream to a large volume of static work and the formation of an optimal blood flow direction. These findings coincide with some published data [13, 14, 20]. An assessment of the blood circulation state in the Paralympic athletes, carried out in natural training conditions, after a specific physical load, revealed a number of changes, indicating the need for rehabilitation measures during the training session.

The search for an optimal combination of contemporary rehabilitation means for Paralympic athletes and their effective inclusion in the training process is an urgent task for many sports authorities [15, 18]. Particular importance is given to the possibilities of conducting timely recovery of disabled athletes, using modern and effective technologies and means, in a natural training environment [15].

Our results on the effect of restorative massage, integrated into a training session, on blood circulation in athletes with IMSS are aimed at changing the predominantly peripheral component of hemodynamics and improving the tissue tone, and they match the findings of other authors [15, 18-20].

Massage performed in the middle of a training session is capable of significantly restoring blood flow in the area of body segments predominantly affected by physical loads, mainly in the working half of the body (left or right), in the proximal sections. It also improves the tone of medium and small vessels and increases the maximum blood flow velocity in all segments of the upper limb. Massage, carried out at the end of the training session, has a more pronounced effect on distal segments, improving the condition of postcapillaries, mainly at the forearm level. It improves the average rate of blood filling, helps reducing the tone of medium and small vessels at the level of precapillaries, preventing the accumulation of metabolites in the muscles.

The proposed technique has a predominant effect on the arterial section of the peripheral circulation, tone and elasticity of blood vessels. The inclusion of short sessions of restorative massage in the training session of athletes with IMSS in a special preparatory microcycle at the competitive stage of sports training has a positive effect. The use of massage in the middle of a workout leads to an improvement in the condition of the working segments and in the tone of large vessels, and also prevents the accumulation of metabolic products in tissues and optimizes the functioning of the heart muscle. Use of massage at the end of a workout improves blood flow at the level of small vessels, removes metabolic products from tissues, and reduces the processes of local muscle fatigue.

Conclusion

In the course of our study, for the first time, the results on the effect of a restorative massage course, integrated into a training session, on the state of peripheral circulation in Paralympic athletes were obtained. Massage performed in the middle of a training session improves the state of volumetric pulse blood filling of the upper limbs at the level of the shoulder segments; decreases the severity of the left-right asymmetry of blood flow to the baseline values; reduces the tone of the resistance vessels and precapillaries; and improves the state of venous outflow in the working shoulder muscles by 25.1%.

Massage, performed at the end of a training session, has a positive effect on peripheral circulation at the forearm level. In this case, the pulse blood supply of the shoulder segment improves, and the tone of medium-sized vessels declines at the level of postcapillary venules and veinous system.

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Conflict of interest

None declared.

Ethical approval

All procedures performed in human studies were following the ethical standards of the institutional research committee, as well as 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards.

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