Comparative evaluation of the effects of high-intensity and low-intensity laser radiation on microcirculation among patients with knee arthritis

D B Kulchitskaya¹, T V Konchugova¹, ², N E Fedorova¹

¹ Federal State Institution “Russian Scientific Center of Medical Rehabilitation and Balneology” of Ministry of Health of the Russian Federation, Moscow, Russia
² I M Sechenov First Moscow State Medical University, Moscow, Russia

n.fedorova@mail.ru

Abstract. Sixty patients with knee arthritis aged from 40 to 75 years old were examined. The patients were randomly divided into two groups: 1st group (30 patients) received high intensity laser radiation; 2nd group (20 patients) received low intensity laser radiation. As a result of the conducted research it was found that high intensity laser radiation is more efficient and leads to more vivid positive changes in the microcirculation of patients with knee arthritis. The changes in microcirculation were based on the normalization of the myogenic and neurogenic tonus of the arterioles, strengthening oscillation of the endothelial range. As a result of local mechanisms activation of tissue blood flow there occurs adequate modulation of the microcirculatory bloodstream, which is aimed at the elimination of congestive phenomena in the capillary and venular level of the microcirculatory bloodstream. We should note that in the long-term more significant were the positive changes in the state of the venular level of the microcirculation bloodstream. in constructing both.

1. Introduction Arthritis of the knee joint is one of the most common causes of knee pain. There are different types of arthritis that can affect the knee joint. Osteoarthritis is the most common type of knee arthritis. Also called degenerative joint disease, osteoarthritis is characterized by progressive wearing away of the cartilage in the joint. The knee becomes swollen, and activities become increasingly painful. The most common symptoms of knee arthritis include: 1-pain with activities, 2-limited range of motion, 3-stiffness of the joint, 4-swelling of the joint, 5-deformity of the joint. Osteoarthritis is often the result of increased strain on the joint due to weight, or repeated injury or damage. Knee arthritis is definitely more common among middle aged or elderly persons. It is treated to provide pain relief and to increase mobility and strength in the knee. Treatment options include exercises, medications, physical therapy, surgery [1,2,3]. Usually all other methods of knee arthritis treatments are exhausted before surgery is considered. Physical therapy is one of them. Clinical and basic research studies have demonstrated the physiological effects and medical applicability of low-level laser therapy (LLL T) [4, 5]. Ohshirow also demonstrated a positive effect on microcirculation and verified changes by thermography in parallel with the reduction of pain [1, 6]. In addition to cartilage damage and bone metabolism, pathological alterations are also known to exhibit reduced circulation in the vessels of the joint parallel to the degenerative changes. Numerous authors have reported increased micro-vascularization as a histological effect of the laser beam [7, 8].
LLLT reduces pain in knee arthritis and improves microcirculation in the irradiated area. In summary, low-level laser represents an effective treatment tool for short-term improvement in patients suffering from painful knee arthritis [9]. In recent years, new physiotherapy methods, particularly the usage of high intensity laser radiation (HIL-therapy), have been applied in medical practice [10, 11]. However, to date there is little research on the scientific justification of the use of this factor. The goal of this research is in a comparative study of the effect of low intensity and high intensity laser radiation on the microcirculation among patients with knee arthritis.

2. Methods of studying
The study involved 60 patients with knee arthritis aged between 40 and 75 years. Patients were divided randomly into two groups:
- Group 1 (30 patients) received high-intensity laser pulses delivered by a BTL-6000 HIL device, wavelength of 1064 nm, pulse mode, frequency of 25 Hz, a dose of 10 J/cm², onto the projection area of joint spaces and popliteal region, 4 minutes per field, alternate days, a course of 10 treatment sessions;
- Group 2 (30 patients) received low intensity laser impact using a “Mustang 2000” device, wavelength of 890 nm, pulse mode, frequency of 80 Hz, pulse power of 40W, onto the projection area of joint spaces and popliteal region, 4 minutes per field, alternate days, a course of 10 treatment sessions.

In this study, the state of the capillary blood flow was evaluated by laser Doppler flowmetry (LDF), which was carried out using a “LAKK-M” laser capillary blood flow analyzer. The skin of the anterior surface of the knee joint in supine position was studied, at room temperature not less than 20°C.
In the course of the study, the following indicators of LDF-signal were recorded and calculated: mean value of microcirculation index (MI) and its standard deviation (σ).
Analysis of the amplitude and frequency of the rhythmic components of flux motions (fluctuations in the flow of red blood cells measured by LDF) was conducted based on the use of the mathematical apparatus technique of the wavelet transform.
Using wavelet analysis, we calculated and analyzed the amplitude and frequency of rhythmic components, such as:
I-rhythms caused by the secretory activity of the endothelium (E);
II-neurogenic fluctuations arising from the sympathetic adrenergic effects on the smooth muscle in the arterioles and meta-arterioles (N);
III-myogenic rhythms caused by the own internal activity of myocytes by pacemaker mechanism (M);
IV-respiratory rhythms (D);
V-cardiac rhythms (C).
Evaluation of the amplitude (A) indices of each rhythm depended on the strength of LDF-signal (M):
A rhythm/M ×100%, and against the value of its maximum spread (σ): A rhythm/3σ ×100%.

3. Results and Discussion
Before the treatment, most patients had distinct clinical manifestations of knee arthritis, the most important of which were pain during movement and pain after getting up or a period of inactivity. Increase in the affected joint circumference compared with the symmetric healthy one, sensitivity to palpation, rough crepitus during movement, restrain of movements of various degrees, changes in gait were objectively found.
According to the LDF, disorders of microcirculation (MC) were revealed, which allowed dividing all patients into two groups according to the classification proposed by V I Makolkin:
Group A (91%) - Patients with congestive-stagnant type;
Group B (9%) - Patients with normocirculatory type of microcirculation.
Group A patients had an increase in the amplitude of myogenic and neurogenic oscillations by 18% (p <0.05) and 16% (p <0.05), respectively. These data were confirmed by the low myogenic and neurogenic tone of arterioles. A decrease in the amplitude of endothelial oscillations by 12% (p <0.05) and presence of congestive phenomena in the capillary and venular links of the microvasculature were found. The mentioned changes were confirmed by an increase in the index characterizing the
Table 1. Dynamics of LDF-factors under the influence of prolonged treatment effects of high intensity and low intensity laser radiation; statistical significance of P before and after treatment: * — < 0.05, ** — < 0.01, *** — < 0.001.

| Amax / 3σ x 100% | E     | N     | M     | D     | C     |
|-------------------|-------|-------|-------|-------|-------|
| Normal range      | 14.1±0.9% | 17.1±0.8% | 15.0±0.9% | 7.9±0.8% | 5.7±0.7% |
| Group 1 before treatment | 12.39±0.21% | 19.74±0.7% | 17.74±0.5% | 12.3±0.8% | 8.1±0.3% |
| Group 1 after treatment | 13.87±0.1% | 17.5±0.4% | 15.2±0.3% | 9.1±0.4% | 7.0±0.2% |
| Group 2 before treatment | 13.72±0.22% | 19.76±0.7% | 17.91±0.6% | 12.7±0.8% | 8.0±0.3% |
| Group 2 after treatment | 13.0±0.11% | 18.1±0.4% | 16.03±0.4% | 9.9±0.5% | 7.3±0.4% |

The patients in Group B had LDF indicators within the normal range. Following the laser therapy, the examined patients had positive dynamics in LDF indicators. However, more significant changes were observed in patients treated with high-intensity laser radiation. Thus, this category of patients showed improvement in the endothelial function - Ae/3σ 100% indicator changed by 10% (p<0.001) in comparison to the initial one, whereas the second group of patients had an increase in this indicator that was 2 times less – by 5% (p <0.01) to the initial one. A significant decrease in Am/3σ x 100% indicator by 18% (p <0.001) and by 12% (p <0.05) against the initial values was discovered in groups, respectively, which implies normalization of the myogenic tone of arterioles.

As a result of applying sessions of high intensity laser radiation and low intensity laser radiation among patients with knee arthritis, positive dynamics of An/3σ × 100% indicator, the state of the neurogenic tone of arterioles, was observed. It decreased by 14% (p <0.01) and by 9% (p <0.05) against the initial values in the groups, respectively. The above changes were accompanied by improvement in blood filling in the capillary and venular parts of the microcirculation bloodstream. The data obtained by using LDF correlated with the regression of clinical symptoms and signs. Thus, the majority of patients experienced a significant reduction in the severity of pain during activity. It was manifested in a significant decrease in VAS among patients of Group 1 during the second and third treatment sessions by 39.4% and at the end of treatment - by 46.7%. In Group 2, the value decreased by 17.6% in the middle of the treatment, and by 25.1% at the end of the treatment. The intensity of pain at rest changed similarly. The patients of Group 1 experienced a significant decrease in pain intensity by 46.45% against the initial data after the second and third sessions, and by 78.78% by the end of treatment. In Group 2, pain intensity decreased by 19.97% in the middle of treatment and by 34.68% at the end of treatment.
Table 2. Dynamics of LDF-factors 12 months after prolonged treatment with high intensity laser radiation; statistical significance of P—in comparison with values before treatment:

* — < 0.05, ** — < 0.01, *** — < 0.001.

| Amax / 3σ x 100% | E     | N     | M     | D     | C     |
|------------------|-------|-------|-------|-------|-------|
| Normal range     | 14.1±0.9% | 17.1±0.8% | 15.0±0.9% | 7.9±0.8% | 5.7±0.7% |
| Group 1 before treatment | 12.39±0.21% | 19.7±0.7 | 17.74±0.5% | 12.3±0.8% | 8.1±0.3% |
| Group 1 after treatment | 13.87±0.1% | 17.5±0.4% | 15.2±0.3% | 9.1±0.4% | 7.0±0.2% |
| Group 1 12 months after treatment | 12.97±0.2% | 18.7±0.3% | 16.1±0.6% | 8.2±0.8% | 6.1±0.3% |

4. Conclusion

Summarizing the results of the studies relating to the effect of high intensity laser radiation and low intensity laser radiation on the state of microcirculation among patients with knee arthritis, it may be noted that positive changes in the microcirculatory hemodynamics were more significant when using high-intensity laser therapy. The changes in microcirculation were due to normalization of the myogenic and neurogenic tonus of arterioles, and increased oscillations of the endothelial range. Activation of the local mechanisms of tissue blood flow resulted in an adequate modulation of blood flow aimed at the elimination of congestion in the capillary and venular levels of the microcirculation bloodstream.

Analysis of afterhistory, according to LDF, confirmed that 12 months after the treatment with high intensity laser radiation the myogenic and neurogenic tonus decreased, but remained above the initial values (Table 2). Conspicuous is the fact that in the long-term period positive changes in the state of the venular level of the microcirculation bloodstream were more significant. Ad/3σ x 100% indicator improved by 26% by treatment sessions of high intensity laser radiation, whereas 12 months after the treatment it improved by 34%.

5. References

[1] Konchugova T V, Orekhova E M, Kulchitskaya D B 2013 *Issues of Balneology, Physiotherapy and Exercise Therapy* 90 26-31
[2] Dashina T A, Grigorieva V D, Sidorov V D 2011 *Issues of Balneology, Physiotherapy and Exercise Therapy* № 1 16-20
[3] Titkaya E V, Levitsky E F, Zariyova T N, Reshetova G G, Kozlov S V, Barabash L V, Alaytseva S V, Dostoynova O V, Shakhova S S 2014 *Physiotherapy, Balneology and Rehabilitation* № 6 31-38
[4] Alfredo P P, Bjordal J M, Dreyer S H et al 2012 *Clinical Rehabilitation* 26 523-533
[5] Alghadir A, Omar M T, Al-Askar A B, Al-Muteri N K 2014 *Lasers in Medical Science* 29 749-755
[6] Ohshiro T 1988 *Low-Level Laser Therapy: A Practical Introduction* (New York: John Willey and Son) pp. 56–62
[7] Tumilty S, Munn J, McDonough S, Hurley D A; Basford J R; Baxter G D 2010 *Photomedicine and Laser Surgery* 28 3-16
[8] Kulchitskaya D B, Konchugova T V, Kolbaya L I 2012 *Issues of Balneology, Physiotherapy and Exercise Therapy* №1 16-20
[9] Hegedüs B, Viharos L, Germain M, and Gálfi M 2009 *Laser Surgery* 27 577–584
[10] Thabet A A M M, Mohamed M E S, Ali M M I, Helal O F 2013 *Energy for Health* 10 16-21
[11] Viliani T, Carabba C, Mangone G, Pasquetti P 2012 *Energy for Health* 9 18-22