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REVIEW

Usage of near infrared spectroscopy in physiotherapy

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background Near infrared spectroscopy (NIRS) is increasingly used as a local tissue oxygenation equipment and it fulfills the functions of an efficient local microcirculation and a concussion growth monitor. Using it in surgery, physiotherapy or rescue indicates a high interdisciplinary diagnostic potential, which could lead us to improve the quality of patients' lives. The aim of this study was to review literature related to the physiotherapy aspect of using near infrared spectroscopy and to the consideration given to the development of this method.

Material/Methods A review of literature related to the topic.

Results Research shows that NIRS is a good tool to assess the changing state of microcirculation in the monitored area.

Conclusions As mentioned above, NIRS can be used in a number of methods available in traditional medicine and physiotherapy. This work is only a set of selected methods, but the development of technology can help to minimize the dimensions of such devices, and to maximize the effects and use of this method, which will certainly make the healing process easier.

Key words NIRS, therapeutic effect, circulation, blood oxygenation/oxygen dynamics

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INTRODUCTION

Near infrared spectroscopy (NIRS) is interesting because of its monitoring potential. In the era of a constantly evolving civilization we can see a common desire to improve the known earlier methods and techniques that could help to improve our quality of life and ensure the best possible medical care both in hospital and at home. Application of this method could affect all people: those who use civilization progress in medicine to improve their quality of life and also those who use them commonly, like doctors, nurses, physiotherapists, therapists etc. Due to a lack of research regarding big populations with unified circumstances, NIRS is not widely used in this field.

NIRS was first used as a method to monitor regional oxygenation of living human tissue in 1997. Franz Jöbsis measured the regional index of oxygenated hemoglobin in the microcirculation of the cerebral cortex in babies [1]. NIRS is a research technique that uses electromagnetic wave of about 800–2500 nm which is based on interpretation of the spectra oscillating-rotating substance [2] and is safe for human tissue. It uses three characteristics of the substance: emission (transmission), absorption (absorbance) and reflectiveness (reflection).

A NIR photon, after entering a tissue, may undergo many reactions, including: reflection (on the border between the two centers), remission of the tissue absorption, a Doppler phenomenon, elastic collisions or Raman dispersion. Dispersion events during the flexible collisions are one of the major forms of NIR influences on a tissue, which penetrates, since the dispersion occurs much more frequently than absorption (10–50 times more often), and this phenomenon is desirable in terms of biological safety, because of no phototoxic effect on a tissue [3, 4].

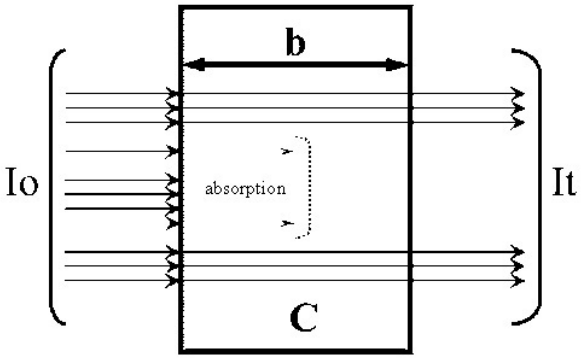
The human tissue is partially permeable to light and NIR. Photons, after entering the tissue, undergo typical laws of quantum mechanics and the laws of optics. When it comes to penetration, NIR photons are captured by the respective photosensors. Measurements are typically made on the basis of the phenomenon of dispersion, described by the rules of Rayleigh and Stokes [5].

For practical purposes the NIR technology can be divided into two groups: non-absorbent and absorbent one. Both are widely used in medicine, the latter allowing, among others:

- monitoring of microcirculatory blood speed [6];
- analyzing the composition of the mixture of respiratory gases;
- monitoring of changes of the chest volume in respiratory deficiency [7];
- measuring tissue temperature in hard-to-reach places, such as the eardrum [8];
- determining the level of ischemic changes within the living tissues of the heart and intestines [9, 10];
- helping to identify the zones of necrosis and limb injuries after injuries, burns, frostbite, thrombosis and Raynaud's disease [4, 11].

These examples have application in medicine, but some of them directly affect patients with whom physiotherapists work.

In turn, an absorption type of NIRS with the oscillating spectrum is based on an oscillating spectrum analysis and the optical Beer–Lambert law (Fig. 1).



$$I_t = I_o e^{-kbc}$$

$$C = 1/bk \ln Io/It$$

Fig. 1. Lambert–Beer law

Tissues absorb NIR photons largely on elements called chromophores. The main chromophores are hemoglobin, myoglobin and cytochrome c oxidase. NIRS monitors utilize absorption of differential NIR waves between oxygenated hemoglobin (HbO_2) and reduced (Hb). These data illustrate the degree of oxygenation of the tissue in the area of microcirculation. Changes in local tissue oxygenation measured with NIRS monitor show the imbalance between oxygen supply and its extraction by the tissue, which can serve as a monitor for beginning ischemic lesions.

A NIRS monitor is equipped with an IR light source system and a photodetection signal analyzer. After passing through a tissue light is received by the detection fiber optic bundle (Fig. 2). Both beams end with optodes which fulfill function of an emitter and detector and are placed on the patient's skin over the examined area of the body.

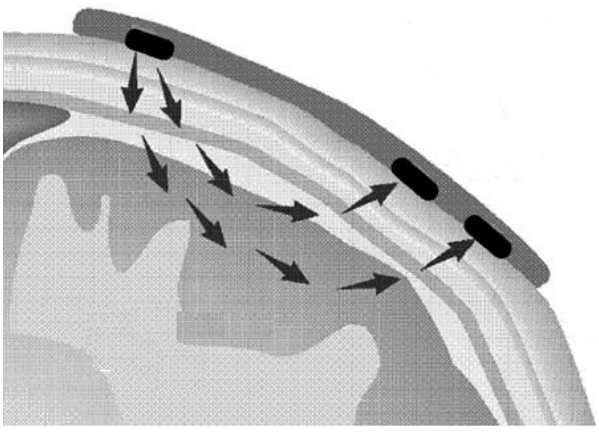


Fig. 2. NIRS flowchart

Near-infrared spectroscope NIRO200 Hamamatsu, Japan is an example of a device for measuring the level of oxygenation using a non-invasive method (Fig. 3). Sources of emission and NIR detectors are placed in a rubber holder so that the relative position of optodes to each other is constant and unchanging [12].

Because of function of local microcirculation and the development of a shock monitor, NIRS ensues a large interdisciplinary diagnostic potential of this method (surgery, emergency, physiotherapy or sports medicine).

Fig. 3. Near Infrared Spectroscope NIRO200 Hamamatsu, Japan

The objective of the present literature review was to analyze bibliography related to physiotherapy using near-infrared spectroscopy and the consideration given to the development of this method.

The fact that working with patients with certain type of physiotherapy equipment brings function improvement and with some other types it does not prompted us to focus this article on collecting information that using NIRS in selected methods of physiotherapy has a greater scientific justification in treatment processes. Therefore, the aim of this study was to answer the following questions:

- do the commonly used by physiotherapists treatments have scientific justification?
- can the use of near infrared spectroscopy make tissue oxygenation changes easier to detect?
- can the NIRS development lead to improving patients' quality of life?

MATERIAL AND METHODS

To prepare this paper we used articles posted on PubMed database. We searched publications related to NIRS and physiotherapy. We tried to find articles that describe methods commonly used by physiotherapists and those which describe healthy patients to visualize the proper tissue changes (but with some of the methods it was impossible due to lack of articles).

USAGE OF NIRS

USAGE OF NIRS IN ULTRASOUND THERAPY

One form of physical therapy is ultrasounds. They are often used as a component of physiotherapy in clinical practice. We can use them to work on a number of ailments including musculoskeletal disorders such as pain, muscle spasms, joint stiffness and all kinds of tissue damage (muscles, tendons and ligaments). In addition, ultrasounds are currently considered as one of the main physical methods in physiotherapy. The basic parameters that must be determined before the therapy session is the frequency, intensity, method/cycle time, and the surface of both the head and the treatment area, where in the frequency ranges from 1 MHz (used in the treatment of deeper tissues) to 3 MHz (used in superficial tissues). In addition, a combination of the intensity and the work cycle allows for thermal and non-thermal (e.g. mechanical) effects of the application of ultrasounds. Physiological effects of ultrasound include: increased temperature, increased tissue metabolism, improved extensibility of collagen fibers and reduced viscosity of the liquid component in the tissue. But does ultrasound therapy increase local blood circulation? Researchers have tried to answer this question for some time, as research papers available so far are quite contradictory [13, 14]. The first one to clarify the issue was Morishita et al. [15], who with the help of near infrared spectroscopy (NIRS) demonstrated the validity of its assumptions.

Until now, to measure the effects of cardiovascular changes we used plethysmography (which measures the vasodilator strength, Doppler laser (measuring blood flow on the surface of the skin) and ultrasounds (measuring blood flow in the deep blood vessels). However, no studies have shown changes in the level of hemoglobin (Hb) concentration, and these changes reflect circulation of blood and oxygen dynamics. It follows that the therapeutic effect of ultrasounds on the local dynamics of blood circulation and the oxygen within muscle tissue remained unknown. The hypothesis assumed that the ultrasound therapy reduces pain, stiffness and muscle fatigue, tissue injuries and helps the healing process by improving blood circulation, which improves nutrition and oxygen supply of the tissue.

In the abovementioned study, 3 groups were tested: the first underwent therapy, the second without turning on an ultrasound device (placebo) and the third one – the control group. Studies have shown an increase in total hemoglobin (total-Hb) and oxygenated hemoglobin (oxy-Hb) without an increase in deoxygenated hemoglobin (deoxy-Hb) in the group that used the therapy session using the ultrasound device (Fig. 4). These results indicate that ultrasound therapy effectively affects the dynamics of oxygen, which translates to the expected therapeutic effects. Reading these data would not be possible without the use of near-infrared spectroscopy (NIRS).

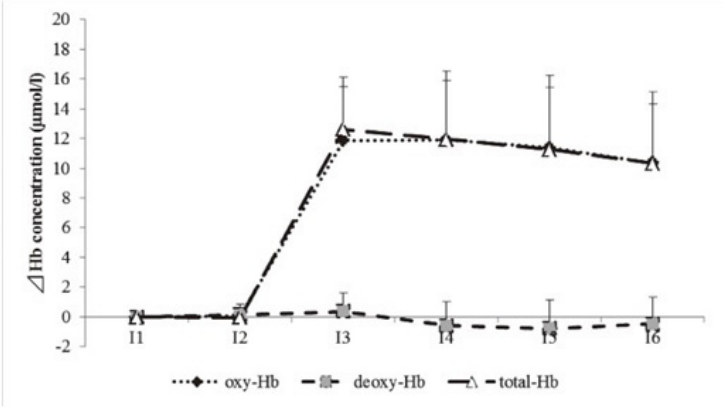


Fig. 4. Changes in the hemoglobin concentration in the group that used ultrasound therapy [15]

USAGE OF NIRS IN MASSAGE

The increasing dependence of our society on cars and an increase in time in which it is necessary to move or work in a sitting position has been associated with a higher risk of pain in the lower spine, and hence, the increasing number of work dismissals. Durkin et al [16] decided to test the impact of the lumbar massage on sitting comfort, muscle fatigue, muscle oxygenation, blood circulation in the muscle and simulated hour control ride. The subjects were divided into two groups: massaged and controlled ones. On the right and left side of the thoracic and lumbar erector spinae electromyography and frequency of average power generated by the muscles was measured. Near infrared spectroscopy, and the temperature measured on the right side of the thoracic and lumbar spine have been used to determine the oxygenation and blood circulation in muscles at the time of performing the test. The results showed a significantly higher skin temperature in the massaged group after a test drive. NIRS results also reflect this trend. Recording the frequency of the average muscle power showed that the power is increased with time in the control group, and showed a prolonged period of rest and a lower threshold of muscle activity, which could result in engaging secondary structures. Studies have shown beneficial effects of massage on the lumbar spine area in blood circulation and oxygenation in the muscle tissue [16, 17].

HIGH INTENSITY LASER THERAPY (HILT) AND THE USE OF NIRS

Today, high intensity laser therapy (HILT) is intended, inter alia, to treat muscular disorders, but its efficiency has not been successfully confirmed due to the lack of quantitative evaluation and feedback in real time. To cope with this challenge, Lee et al. [18] in their study combined high intensity laser and a noninvasive optical monitoring system to assess the level of spasticity in a patient. To avoid interaction of the two light sources, the laser wavelength was set at 808 nm. A NIRS Monitor was used to measure the hemoglobin concentration according to the modified Beer-Lambert law. The HILT transitory effect was evaluated based on the results of patients with spasticity after a stroke. This study showed a proportional relationship between a manual evaluation of the muscle HILT effect obtained in patients with hemiplegia. This system proven to be helpful in the simultaneous assessment and treatment of spasticity, and also shows hope that it will be possible to monitor the concentration of hemoglobin in real time during laser therapy.

USAGE OF NIRS IN ACCUPRESSURE

Asian countries use acupuncture and acupressure as one of the complementary or alternative methods to normal therapy. In acupressure people typically use fingertips for therapy in contrast to acupuncture where needles are used. Both methods produce satisfying results in many disorders of a medical nature. Although the mechanism of action of acupuncture has not been confirmed in scientific studies, its impact on the amount of blood circulating in the peripheral arteries has already been confirmed [19].

We also know that with the help of acupuncture and acupressure we can modulate blood circulation in skin tissues [20, 21]. Little has been known about microcirculation in deeper peripheral tissues (in this case – the knee), Litscher et al. [22] decided to investigate the effects of acupuncture on the local circulation changes in the mentioned area. The aim was to investigate the effect of local acupressure on one of the gallbladder meridian points, named Xiyangguan on the oxygenation of deeper knee tissues (2–4 cm) using near infrared spectroscopy.

Gallbladder meridian runs along the side of the thighs and knees, which descends down along the anterior border of the tibia [23]. The above described point is in the hollow of the upper relative to the lateral epicondyle of the femur, above the lower edge of the patella, and the process was performed by an experienced Chinese physician practicing traditional Chinese Medicine (Fig. 5).

Fig. 5. Measurement of blood flow using NIRS at the stimulation point [22]

The test results show a significant increase in oxygenation of the tissue near the area where acupressure was performed in all participants during and after treatment as compared to the opposite side of the knee, which was not treated (Fig. 6).

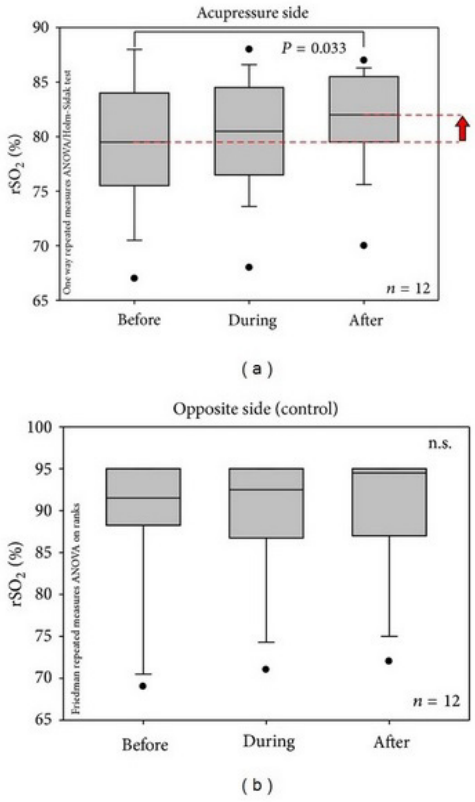


Fig. 6. Changes in the regional tissue oxygenation before, during and after performing acupressure on both sides of the knee, a) the side subject to acupressure, b) the control side not subject to acupressure [22]

These results are consistent with the theory of meridians, which argues that by stimulating points, first by putting an impact on the whole area along the meridian, and then the function of surrounding tissues can be enhanced by stimulation [24].

The above information is a confirmation that acupressure can provide a method for pain relief, reduction and elimination of knee edema caused by inflammatory processes, and many other medical problems.

USAGE OF NIRS IN LOCAL CRYOTHERAPY

In recent years, physiotherapists use local cryotherapy in form of ice sprays especially in team sports but also in their own practice. Shadgan et al. [25] tried to prove application of ice spray on subcutaneous and intramuscular blood flow and oxygenation on the thigh muscle. This experiment involved 13 healthy participants. The protocol consisted of cold spray applications, then a thirty-second break followed by another cold spray application. The authors observed a decrease in O_2Hb and tHb only in the superficial layer. Conclusions from this study are that cold spray induced a transient change in the blood flow and oxygenation of the superficial tissues with no change in deeper tissues over the healthy vastus medialis muscle. The effect on the superficial hemodynamics and oxygenation of limb muscles may limit the therapeutic benefit of this cryotherapy.

CONCLUSIONS

A NIR beam penetrates human tissues regardless of the presence of pulsating blood, skin warming, hypothermia, frostbite or edema. Traditional methods of hemodynamic assessment: pulse oximetry, peripheral heart rate, or blood pressure reflect the system parameters and their assessment can be difficult, e.g. in the case of shock/concussion, hypothermia, frostbite and swelling.

A NIRS monitor detects changes in concentration of oxygenated hemoglobin in the tissues and, therefore, NIRS measurements change even during shock and fluid resuscitation. NIRS values are immediately reduced in the case of impaired perfusion (e.g. concussion) and rising rapidly in case of perfusion improvement (e.g. fluid therapy). With these features NIRS is a good tool to assess the changing state of the microcirculation in the monitored area.

Due to this valuation analysis we think that the selected physiotherapeutic methods have bigger scientific justification. We also think that using NIRS in the kind of procedures mentioned above can make tissue oxygenation changes a lot easier to detect.

Near infrared spectroscopy is constantly evolving and now we have wireless models, in which big apparatus and wiring is not needed. With the development of this method and the same technology, it might be possible to construct NIRS devices on a microscopic scale (i.e. microchip), through which we will be able to control the oxygenation of tissues throughout the body. That would lead to improvement in the quality of all patients' lives.

NIRS can be used in a number of methods available in traditional medicine and physiotherapy, and this work is only a collection of selected methods. We hope that the development of this method will contribute to the effective work of both, medical staff and physiotherapists themselves.

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