Biomedical Engineering
Whole Body Cryotherapy

Acta

Twenty years ago cryotherapy was introduced in Poland as one of the effective therapeutic methods. Cryotherapy refers to the application of extreme cold to treat the pathologic lesions. It includes cryosurgery or cryoablation applied to destroy diseased tissue, directly and cryostimulation. Cryotherapy in terms of cryostimulation belongs to the physiotherapeutic methods and posses many specific and unique features. It rely on use of cold for partial or whole body chilling to treat many disorders.

This book presents the results of scientific research and clinical applications of cryotherapy. Some of the chapters were presented in Polish as research papers in regular journal Acta Bio - Optica et Informatica Medica. This publication should help to disseminate these results to wider audience.

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Biomedical Engineering, Whole Body Cryotherapy, 1/1/2006

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Biomedical Engineering

Series Editors: H. Podbielska, W. Stręk, G.J. Müller

Whole Body Cryotherapy

Guest Editors: H. Podbielska, W. Stręk, D. Biały

Inżynieria Biomedyczna

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Preface

Biomedical engineering is growing field of science, technology and clinical applications, bringing together the intra- and interdisciplinary knowledge and experiences. This growth is demonstrated by numerous new applications for benefit of human being.

In 1995 two Polish scientists, namely Prof. Halina Podbielska and Prof. Wiesław Stręk launched a new Polish journal Acta Bio-Optica et Informatica Medica, devoted to the applications of lasers and informatics in medicine. Very soon they have realized that these two fields belong to the large family of biomedical engineering technologies. So, nowadays this journal is published under the auspices of the Polish Society of Biomedical Engineering and became a communication forum and place for exchange of many ideas between medical doctors, scientists and engineers.

In many fields, from time to time, the books appear being a collection of reprints of the most interesting papers in particular area. Our idea is to present such papers published previously in Polish in Acta Bio-Optica et Informatica Medica, together with submitted new publications in the new series of book volumes Acta Biomedical Engineering. The aim of the book series is to disseminate valuable contributions to the specific fields of biomedical engineering. This volume is devoted to the cryotherapy and the selection of papers has been made with care by guests editors: Prof. Halina Podbielska, Prof. Wiesław Stręk and Dr. Dariusz Biały.

Family of biomedical engineering specialists is from nature not only multidisciplinary, but also multinational. The specialists from many countries have a strong cooperation in various fields of contemporary biomedical engineering, like e.g. Prof. Podbielska who has joint projects in Biooptics with German group of Prof. Gerhard Müller Prof. h.c Dr.h.c. mult., an internationally well-renowned scientist, Director of the Institute of Medical Physics and Laser Medicine Charité-Universitätsmedizin Berlin. Prof. Müller agreed to be one of the editors of Acta Biomedical Engineering books series.

Editors

Scientific Editors of this issue

Prof. Dr. Halina Podbielska D.Sc. Ph.D. Eng. M.D.

Prof. Halina Podbielska received her M.Sc. and Engineering Degree in Applied Physics/Optics from Faculty of Science of Wroclaw University of Technology in 1978, and her Ph.D. degree in Physics from Institute of Physics in 1982. Her M.Sc. and Ph.D. theses were awarded by special Award for Excellence. In 1987 she received her M.D. degree from Faculty of Medicine of Medical University of Wrocław. In 1992 she received her Habilitation degree in Physics and became the professor of biooptics and head of the Bio-Optics Group at the Institute of Physics. In 2002 she received The Professor title and since then she is a full professor. Her professional experiences include medical application of optics and medical lasers. Recent activities include sol-gel biomaterials and their applications, photodynamic therapy and biometrics. She is an author or co-author of over 200 publications. She holds 5 registered patents and 6 pending patents. Prof. Podbielska was visiting scientist in several scientific institutions worldwide: as an A.v.Humboldt fellow at the University of Frankfurt/Main, University of Muenster, Charite Medizin University of Berlin, Germany, and at the Weizman Institute of Science, Israel. In years 2002-2005 she was a visiting professor at Institute of Optics of Technical University in Berlin. She was giving seminars or short courses at several Universities and scientific Institutions in Poland, Russia, Israel, Germany, Italy, Mexico, Brasilia and in the USA. She was an organizer and chair of the series of international SPIE Conferences on Biomedical Optics and an editor of number of Proceedings books. In 1995, she launched a new Polish Journal Acta Bio-Optica et Informatica Medica and she is there the Editor-in Chief. She is a Board Member of Polish Society of Biomedical Engineering and many internationally recognized bodies. H. Podbielska is also a supervisor of many Ph.D. and M.Sc. theses in biomedical engineering, many of them awarded for excellence.

Prof. Dr. Wiesław Stręk Ph. D.

Prof. Stręk graduated from Adam Mickiewicz University in Poznań in Physics. After completing his study, he joined the Institute of Low Temperature and Structure Research of Polish Academy of Sciences in Wrocław. Currently, he holds the position of a head of Department of Spectroscopy of Excited States. He received his Ph. D. degree in Molecular Physics in 1979. In 1983 he received Habilitation degree in Chemical Physics. In 1991 he received the Professor title. Hi was visiting scientist in various institutions in Denmark, Russia, France, Finland, Israel, Germany, Brazil and Belarus. His research interests include non-linear optics, spectroscopy of laser materials, interaction between light and biological systems, as well as medical techniques: of lasers and cryotherapeutical devices. He designed the first Polish cryogenic chamber. Prof. Stręk is a member of editorial committees of many journals, e.g. Material Sciences, Journal of Alloys and Compounds, Acta Bio-Optica et Informatica Medica, Sozologia. He is an author and co-author of over 300 research papers and many patents.

Dr. Dariusz Biały Ph.D. M.D.

Dr. Biały graduated from Silesian Medical University in Katowice in 1996. After completing his study, he joined department of Cardiosurgery of Medical University in Wrocław. Simultanously, he started to work at the Cryotherapy Laboratory of the University School of Physical Education in Wrocław. Currently, he works in interventional cardiology. His main interest in cryotherapy deals with applications of systemic cryotherapy in various fields of medicine and sport. He was one of the initiators of cooperation with sport clubs and national athletics team, judo and other sportsmen. His study allowed to include this method in training cycle of professionals. He is an author or co-author of over 70 publications in national and international journals. His main scientifc interests include new diagnostic and therapeutic methods based on advanced technologies. He works in projects on photodynamic diagnosis and therapy in atherosclerosis treatment, as well as on application of nanostructures and biodegradable materials in cardiology.

Laudation on Prof. Dr.-Ing. Gerhard J. Müller, Prof.h.c Dr.h.c. mult., of Charité-Universitätsmedizin Berlin, Director of the Institute of Medical Physics and Laser Medicine

Prof. Gerhard Müller is an internationally well-renowned scientist who has been honoured many times for his outstanding scientific achievements and his service to the international science community. He started his scientific career in basic and applied spectroscopy with the thesis on optical hyperfine structure in 1974 and he completed his habilitation in 1975, both at Technische Universität, Berlin. He received his first tenure at Friedrich-Alexander University (Erlangen) in 1976.

In 1979 he interrupted his university career by accepting a position with Carl Zeiss, Oberkochen, Germany, as the managing director of the newly founded central-research laboratories. He filed numerous patents (more than 240 in total), e.g. on the laser scanning microscope. By 1981 Prof. Müller became the Managing Director R&D of the Microscopy Division of Carl Zeiss and by 1983 he was appointed Chief Executive Officer for Technology Coordination of the entire Zeiss group.

In 1985 Prof. Müller became the Managing Director of the newly founded Laser-Medizin-Zentrum (now the Laser- and Medizin- Technologie GmbH, Berlin, LMTB), which had been established as a non-profit research agency supported by leading German industries, e.g. Carl Zeiss, Siemens, Aeskulap, Dornier-Med.Techn. - just to name a few. At the same time he was appointed to full professorship for biomedical engineering and laser medicine at Freie Universität Berlin.

Examples for his international scientific recognition are the awards he received from the American Society of Laser Medicine, the American Association of University Radiologists, the Carl Scheel award of the German Physical Society and numerous other national and international societies, as well as the multiple honorary academic degrees for example Dr.h.c. from the Chernyshevsky State University Saratov, Russia in 1995, from Russian Academy of Science in 2000 and the National and Kapodistrian University of Athens in 2005, and Prof. h.c. from Lomonossov State University Moscow in 1997. He also was awarded the Service Medal of the Federal Republic of Germany (Bundesverdienst-kreuz) by the German Federal President. In 1997 Prof. Müller was appointed a member of the Board of Directors of SPIE, the International Society of Photo-Optical Instrumentation Engineers and together with Prof. M. Kujawinska from Warsaw he represented the scientific community of Europe.

Already since 1991, he has been maintaining close relationships to the Institute of Physics of the Wroclaw University of Technology. The cooperation with Prof. Halina Podbielska and Faculty of Fundamental Problems of Technology, besides the scientific content, was beneficial for the Polish students of Biomedical Engineering. The personal engagement of Prof. Müller and his co-workers, made it possible that Polish students several times were able to take part in biomedical engineering and medical lasers courses, seminars and laboratories, prepared specially for them in Berlin. The joint activities include also scientific exchange program enabling Polish scientists to do research work in Berlin. Prof. Müller was a host of young A.v. Humboldt research fellow Dr. Agnieszka Ulatowska-Jarża from Prof. Podbielsk'a Group, who conducted her biooptical and biomedical engineering research under his guidance. Prof. Podbielska also visited Institute. In 1995 the new Polish journal devoted to biomedical engineering and optics, Acta Bio-Optica et Informatica Medica, was created in Wrocław by initiative of Prof. Podbielska and of Prof. Wiesław

Stręk from Polish Academy of Science. From the beginning Prof. Müller is the member of Scientific Editorial Board of this journal.

In 2001 Prof. Müller visited Wrocław as a honorary guest and invited lecturer of the 5. Symposium of Societas Humboldtiana Polonorum (SHP). SHP is a society founded by former Polish A.v.Humboldt Foundation research fellows. Since that time Prof. Müller started also cooperation with other former A.v. Humboldt research fellows, namely Prof. Tadeusz Trziszka and Prof. Józef Nicpoń from the Agricultural University in Wroclaw. Together with the Polish partners, the team of Prof. Müller succeeded in procuring a number of joint internationally funded projects and conferences and in publishing many scientific papers. The cooperation with the Agricultural University, namely the Faculties of Professors Trziszka and Nicpoń, were highlighted by a joint international workshop and seminar, the results of which were published in an internationally available reference book entitled "Optoelectronics Applications in Medicine, Food Technology and Environmental Protection", First Polish-German Seminar, Wroclaw, December, 2001; Trziszka, Nicpon, Podbielska, Müller, et al.(eds.) ecomed Verlagsgesellschaft, 2002.

During numerous visits to Wroclaw, Prof. Müller and his team could stimulate the application of new technologies, including laser techniques and computer-based electrocardiogram measurements in animal therapy and diagnostics. Thanks his support, the special workshop on lasers for veterinary medicine was organized in 2004, together with Prof. Podbielska from the Wrocław University of Technology and the Institutes of Professors Trziszka and Nicpon of Agricultural University.

Prof. Müller's extraordinary commitment for the scientific community of Poland, and especially of Wroclaw, had already been recognised by awarding him, both the Gold Medal of the Faculties of Food Science and of Veterinary Medicine of the Wroclaw Agricultural University.

Prof. Prof. Müller is a big friend of Poland. Being a German citizen, he always underlines that his roots are in Poland through his Polish grandma (Selma Duda) and his father who was born and raised in Silesia. Therefore, he maintenances cooperation contacts with Polish scientists and he did it in the past, as well.

Already during his graduation in the seventies, he had several contacts with Polish colleagues from Gdańsk, Toruń, and Kraków. Based on this cooperation, he and representatives of his team were invited not only to the Summer School of Quantum Optics in Toruń 1976 and to the EGAS Conference at Jagiellonian University in Cracow, July 1977, but he also received a special invitation to the historical and remarkable Summer School of Quantum Optics in Wieżyca in 1979, organised by the University of Gdańsk.

Contents

Contents

Systemic cryotherapy. Indications and contraindications, process of treatment and its physiological and clinical results

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Abstract: The response of human organism to cryogenic temperatures exposure was presented. Indications and contraindications against procedures were analysed. The possibilities of clinical application of cryogenic chamber usage were demonstrated.

Key words: systemic cryotherapy, indications, contraindications, cryogenic chamber

The story of therapeutic application of cold is probably as old as mankind and medicine. Such treatment was performed by ancient Egyptians ca. 2500 years B.C. Hippocrates advised hypothermia as the remedy against swelling, bleeding or pain and also observed that cold shows analgesic properties. These facts were later confirmed by surgeons. Among others, Napoleonic surgeon baron D.J. Lorrey during Russian campaign observed that limbs of wounded soldiers could be amputated with minimum pain and bleeding as long as they were earlier covered with ice or snow.

Superficial analgesic properties of chloroethane, which had been known since XVII century, were discovered in France in 1847 by P. Flourens. However first clinical application of chloroethane in the form of aerosol took place only in 1866 in Switzerland and was carried by P. Redard. Redard was also the first to incorporate chloroethane in systemic analgesia. Until today, analgesic properties of chloroethane are utilized by sport medicine mainly in treatment of injuries. Chloroethane evaporation from the area of application causes local temperature change even by -20^{o}C.

Modern cryogenics was introduced when physicists learned how to condense gases, ie. since the end of XIX century. Contemporary physicists, also with Polish researchers among them, achieved more than condensation of oxygen, carbon dioxide, air or hydrogen. They also enabled production of these cooling agents in industrial volumes and invented methods of storing them in special tanks that are used up to now.

In the first half of XX century cryobiology was developed. Cryobiology investigates changes in cells and tissues under the operation of subzero temperatures. Liquid cooling agents were applied in therapy of dermatological illnesses and superficial benign or malignant tumors.

In 1907 Whitehouse constructed a device releasing vapors of liquid nitrogen which was employed to remove superficial tumors and therapy of some dermatological changes. On the base of construction of Whitehouse's device all modern cryoapplicators were built. Cryoapplicator is a common name for all portable sources of liquid nitrogen or other cooling agents. Therefore Whitehouse's device was a milestone in the development of therapy based on destruction of diseased tissues - it was called "cryosurgery" or "cryodestruction". In various diseases and in many clinical disciplines cryosurgery became the treatment of choice.

In the 1970's of our century a new conception of cryotherapy was invented. It included stimulating, superficial operation of cryogenic temperatures (below -100°C) during very short periods of time (2-3 minutes) in order to induce and utilize physiological, systemic reactions against cold, assist basic treatment and ease motion therapy.

Cryogenic temperatures can be applied endemically in the case of skin and joint diseases or systemically in the case of many other diseases - in cryochambers or cryocabins.

Cryotherapy was introduced into clinical practice by Toshiro Yamauchi and his team working in Reiken Rheumatis Village Institute in Oita (Japan). It was there where world-first portable cryoapplicators and cryochamber were built (1978). In 1981 during European Congress on Rheumatology Yamauchi presented systemic therapy and its influences on both diseased tissues and the whole body.

The Japanese results inspired Reinhardt Fricke, head of St. Joseph Clinic of Rheumatology in Senenhorst (Germany), who established cooperation with the Oita center and also started to investigate all kinds of cryotherapy. Initially Fricke followed Japanese methods but after some time introduced new procedures, eased the therapeutic regime and shortened duration of therapy to 6-8 weeks.

In Poland, cryotherapy was introduced in 1983 in Wrocław in the Department of Physiotherapy headed by professor Zdzisław Zagrobelny. It was here, where the first cryoapplicator was installed and used to apply cryotherapeytic treatment assisted by kinesitherapy to volunteers with rheumatism and posttraumatic diseases. Before that, Dr Szeffer-Marcinkowska incorporated vapors of liquid nitrogen to dry-cooling of scalding wounds of test-animals which significantly accelerated healing of those. This method has already been incorporated into clinical practice and showed similar therapeutic results.

In 1989 Poland's first cryochamber was built (2nd in Europe and 3rd in the world).

The first Polish cryochamber was tested on healthy volunteers, students of the Academy of Physical Education in Wrocław, and it was installed in Rheumatological Ward in the hospital in Kamienna Góra where it has been successfully operating since 8 Oct 1990. The chamber utilizes air cooled to -110°C : -160°C as cooling agent.

The human body maintains constant internal temperature with daily fluctuation of 0,5°C - 0,7°C and is more sensitive to external cold than to heat. Apart from physiological regulation the human body features also behavioral regulation.

Physiological defensive mechanisms against cold include: conservation of cold (contraction of superficial blood vessels) and production of heat (muscular trembling, visible or invisible thrills - the latter inducing only increased plasmatic concentration of K+ ions). Such thermogenesis is activated by thermoregulation centers at the body temperature of 36°C. The heat produced in that way 2-3 times exceeds the volume of heat produced during basic metabolism.

In adults only long lasting exposure to cold or short but very intensive operation of extremely low temperatures launches additional, hormonal reaction accelerating tissue metabolism and increasing the temperature of tissues. There are also other reactions aimed to maintaining the heat homeostasis.

The very well known analgesic effect of low temperatures is caused by cold induced shutdown of receptors and their connections with proprioceptors and braked conduction in sensory neurons. Pain alleviation is also reasoned by the Melzack-Wall theory of "control gates" (1965) on pain conduction in central nervous system. Moreover, there are biochemical bases of low-temperature analgesia which include increased secretion of beta-endomorphin - a highly analgesic neuropeptide - and its increased concentration in blood serum. Such effect - apart from cold - is also due to other factors such as stress.

The impact of low temperature on loosening of skeletal muscles can be explained by decreased number of pain stimuli reaching the spinal cord and segmental inhibition of gamma-motoneurons stimulation. Moreover, an additional mechanism of loosening muscular tension was found - it is caused by inhibition of conduction in motion nerves.

The changes in circumferential blood circulation are crucial for patients subjected to low temperature therapy. Within the limbs, their blood supply regulation depends

entirely on sympathetic system and as a consequence under operation of low temperatures the loss of heat in limbs is higher than withinthe thorax (Levis' reaction) which results in narrowing of blood vessels and decreased perfusion. On the other side, cold reduces sensitivity of organic muscles against sympathetic stimuli and operation of catecholamine which enables better blood supply in limbs, however, this mechanism is not very efficient.

Extended application of cold is, similarly as stroke (shock), followed by centralization of circulation which enables possibly easiest flow of warm blood to life supporting organs. Systemic results of cooling of areas of skin or whole body depend on: patient's age and their record of diseases, state of nutrition, efficiency of blood vessels, period of cold application and its intensity, action of prescribed pharmaceuticals, alcohol consumption, individual tolerance against cold.

Systemic cryotherapy applied to healthy persons or suffering from rheumatic or degenerative diseases for 2-3 minutes in the temperature of -140^{o}C (+/- 10^{o}C) induces numerous clinical, hormonal and biochemical effects. These effects are extraordinary both from scientific or therapeutic point of view. The operation is a specific opposition of Finnish sauna. Clinical consequences of systemic cryotherapy include(after endemic therapy not each of them is observed):

- outstanding, positive impact on psyche - betterment of mood
- subjective analgesia against articular, superficial and also internal pain, overcoming of weariness
- loosening of muscles tightened around diseases joints, significant increase of muscular strength despite excessive, disease-characteristic decay of muscles, braked sensory and motoric conduction in nerves
- massive blood flow through body diaphragm and organs which causes pinkening and sensation of hot

All these facts which can be observed at least 3 hours after treatment contribute to improved rehabilitation enabling 3-times greater intensification and extension in time. Also it is possible to increase the number of applications up to 3 per day. Heat conservation in thorax is fully maintained, its superficial temperature can be lowered by 0,5 to 3,2^{o}C, and at the kneecap level by 9,5 - 11,5^{o}C with unchanged temperature of body cavities which is proved by normal temperature of oral cavity.

All patients who were qualified for treatment in cryogenic chamber were subjected to regular, thorough medical examination. Actual and past physical state of each patient was surveyed to eliminate possible contraindications against cryotherapy (recent and past diseases, prescribed medicines). Patients were also questioned about individual tolerance towards cold. All patients were subjected to auscultation of lungs and heart, palpation of abdomen cavity, measurement of blood pressure and pulse frequency, electrocardiographic examination and neurological examination. The 5-year experience of Polish and Western researchers in systemic cryotherapy helped to indicate contraindications against this kind of treatment.

The absolute contraindications are as follows:

- sensitivity against cold,
- cryoglobulinemia,
- cryofibrinogemia,
- Raynaud disease,
- Cold urticaria
- Purulent or gangrenous skin diseases,
- Agammaglobulinemia,
- Diseases of central nervous system,
- Neuropathy of sympathetic system,
- Hypofunction of thyroid,
- Endemic disturbance of blood supply,
- Significant deficiency of blood,
- Action of some medicines especially neuroleptics and alcohol,
- General cachexia and hypothermia,

- Claustrophobia,
- Little experience of persons applying the treatment,
- Any technical defect of the device

After thorough examination, marking hemodynamic indicators and spirometric examination of patients before and after therapy in cryochamber it was possible to indicate absolute contraindications concerning cardiovascular and respiratory system. These are as follows:

- defects of aortic valves,
- diseases of cardiac muscles or valves during cardiac failure
- acute effort angina pectoris or spontaneous angina pectoris,
- disturbance of heart operation at the pulse rate higher than 100/min
- arteriovenous leakage in lungs
- acute diseases of respiratory tract of various origin

It is assumed that patients who are qualified for cryogenic treatment show normal gas exchange, regular breathing and can show inefficient ventilation of lungs.

Relative contraindications:

- age over 65 years,
- overcome venous blood clots, embolism of circumferential arteries
- excessive emotional liability resulting in eg. excessive perspiration

Each patient before entering the chamber was instructed to wipe the body with a towel in order to remove sweat. This is important because of possibility of formation of ice crystals on the surface of the body which could induce momentary sensation of prickling cold.

Each patient was also asked to avoid deep breaths while breathing through surgical mask and follow the rule: inspiration must be 2 times shorter than expiration. If lungs are rapidly filled with extremely cooled air which after warming doubles its volume it may induce respiratory oppression. Staying in operating chamber without aforementioned safety mask is inadmissible.

Additional safety clothes for patients include: woolen socks, wooden boots, woolen gloves, special ear cover, not to mention shorts or swimsuits. Eyeballs do not require any safety equipment.

In this way secured patients are asked by chamber servicemen to enter the antechamber where they accommodate to low temperature. Then patients in groups of 5 enter the chamber and walk round and round during 120 seconds. Often they are accompanied by serviceman wearing special suit.

Patient while staying in the chamber retains visual and vocal contact with servicemen outside the chamber and the doctor who qualified them for the treatment. The doctor is also on stand-by in case any incidental reaction occurs. Breathed steam is immediately turned into ice dust similar to mist. Actually, this dust slowly descends on the bottom of the chamber which brings the necessity to ventilate it from time to time to avoid difficulties in watching the patients. Breathed carbon dioxide also may be frozen into tiny crystals.

After treatment patients stay in room temperature. In general, everyone while staying in the chamber didn't feel cold in the common sense but rather burning of bare parts of the body similar to piercing with blunt needle. It may be described as "chilly burning".

It is worth mentioning that patients were in terrific mood after treatment. They informed about feeling totally calmed down and being full of vigor and physically relaxed. All pain and exhaustion were taken away even if before the treatment they were quite intensive. Described good mood was maintained for several hours and even longer. Next important thing was sensation of heat common for all patients after leaving the chamber. It seems natural because patients were rapidly moved to the room where temperature was 150^{o}C higher that inside the chamber. This sensation might also originate from rapid widening of blood vessels which was indicated by pinkening of skin. No blueing of protruding parts of the body was observed. The sensation of heat was maintained until 4-5 hours after the treatment and with patients who were immediately subjected to intense rehabilitation it lasted even longer.

Systemic cooling did not cause any undesirable effects in the cardiovascular system. Neither in measurements of arterial blood pressure and pulse rate nor in electrocardiographic records were noticed any changes in hemodynamic indicators measured by UCG - ultrasonograph. Therefore it may be stated that systemic cryotherapy does not affect the operation of healthy heart as well as heart showing some minor disturbances of its functions.

Preventing extremely cold air from being inspired into respiratory tract helps to avoid, apart from minor individual cases, respiratory oppression. Occasionally, among those entering the chamber, there were also people who suffered form bronchial asthma. They claimed that breathing inside the chamber is exceptionally easy and natural. It may be due to normal or even increased values of oxygen concentration inside the chamber indicated by oxygen concentration sensor or the fact that in such conditions muscular lining of the bronchi is flaccid.

Taking into consideration all contraindications against cryotherapy it should be underlined that all patients subjected to that treatment were volunteers who signed agreement to participate in the experiment.

"Cold shows soothing properties as it affects brain and nervous system" - this was written in XIX century by Napoleonic surgeon D. Lorrey. However, he observed soldiers during russian campaign when it was extremely cold and his descriptions rather refer to hypothermia. In the chamber, 2-3 minute treatment cannot induce hypothermia which is proved by recorded superficial heat values right after the therapy, temperature of oral cavity and lack of laboratorial signs of hyperactivity of hormonal axis TSH-T4-T3. It may result from accumulated pharmacological action of increased plasmatic concentrations of beta-endorphines, catecholamines and cortisol against central nervous system as it was observed after the treatment.

Despite no research being carried out to investigate that issue, it may be assumed that similar action towards psyche may be induced by ionization of air cooled to -160^{o}C in the cryochamber.

Probably similar observations inspired experiments with cryogenic treatment of patients suffering from various types of depression. Such experiments are carried in Japan but their results have not been finally released. The described psychosomatic effect of extremely low temperatures makes them useful for the purposes of biological restoration - also in sport. Unfortunately application of cryogenic temperatures to organism of an athlete may increase concentration of testosterone to such a level that it would be qualified as doping.

It should be underlined that people who sweat because of emotional reasons show very low tolerance towards low temperatures. As well as inside or outside the chamber they feel severe cold however without trembling and increased body heat. Therefore excessive sweating must be considered as absolute contraindication against cryotherapy.

Just after leaving the chamber patients felt very hot. It is very interesting how production and loss of heat remain balanced despite changing temperatures of environment. The average normal temperature of oral cavity of a healthy, young adult is 36,0 - 37,2^{o}C

This isothermal property of an organism is controlled by following factors:

- skin - normally the loss of heat is due to perspiration but in low temperatures of environment speed of blood flowing through skin becomes a dominant factor.
- Subthalamus is a set of neural structures placed at the bottom of cranium. These structures work as a thermostat. When the body is cooled, especially using extremely low temperatures, skin blood vessels contract and skin becomes blue or pale which is not observed during cryotherapeutic treatment. Also muscular tension increases, sometimes inducing shivers, however, it was not observed after systemic or endemic cryotherapy either.
- Inhalation: if the inhaled air is colder than internal body the heat loss occurs as a result of heating that air in lungs and respiratory tract. In cryogenic conditions this factor is essential.
- Outerwear - during cryotherapeutic treatment outerwear is very specific and enables the loss of heat.

- Low-calorie diet with reduced fat does not activate exogenous biochemical reactions in intestinal metabolism. Excessive consumption of cold drinks dissolves blood and urine which is also connected with loss of heat. All these facilitate cryotherapeutic treatment making it more effective.

Therefore, from theoretic point of view, the systemic cryotherapy including few-second stay in adaptational antechamber (-50°C) and 2-minute exposure in the chamber (from -110°C to -160°C, average -140°C) when extensive areas of the body and respiratory tract are subjected to operation of extremely low temperatures cannot induce any superficial damages. Such treatment may only cause decrease of skin temperature within thorax area by 0,5-3,2°C and legs by 9,5-11,5°C. Internal body heat remains the same which is proved by unchanged temperature of oral cavity. The impact of the treatment on ventilation of lungs is a separate problem.

Cryotherapy cannot induce hypothermia because its syndromes have never been observed. Also, no increased concentration of thyroid hormones was observed which may imply their redundancy in the process of preserving internal temperature.

It is essential that systemic cryotherapy immediately launches thermo-regulation which is aimed on heat preservation to maintain the body temperature. Apart from activated thermo-regulation, some of the hormonal axes intensify their operation, thus, increased concentrations of catecholic amines, endorphins and other substances are observed. In other words, thermo-regulatory effects induced by cryotherapy are symptomatically and therapeutically advantageous for complex treatment of certain diseases.

Heat conservation is better within thorax than limbs. Thus, specific centralization of warm blood circulation occurs which improves the safety of treatment. It is so because normal temperature of blood in main circulatory system is maintained. Within limbs, their blood supply is entirely regulated by sympathetic nervous system. Cold restrains reaction of smooth muscles of blood vessels against sympathetic stimuli which enables transport of warm blood to limbs. However, that mechanism is not very effective. It does not cause any negative results during short-period application of cryogenic temperatures.

The phenomenon of more extensive cooling of limbs than thorax seems to be enhanced by certain technical detail. The cooled air flows into the chamber from the bottom and ascends gradually absorbing the heat from patients staying in the chamber (4 or 5 at a time).

The temperature of skin and thorax restores very quickly after the treatment. In some individual cases the temperature of breastbone skin was higher right after the treatment which proves of early activation of very intense skin perfusion. It may be also due to lack of reaction of microcirculatory system against sympathetic stimulus or increased concentrations of endogenous catecholamines. Thus, most of patients felt cold at first and later only burning and prickling.

It was observed that all patients subjected to 120-second systemic therapy in the temperature of -130°C after 30 minutes from the treatment showed considerable increase of serumal concentration of adrenaline, noradrenaline, ACTH (adrenocorticotropic hormone), beta-endorphin and in case of men - also testosterone. Observed lack of significant increase of plasmatic cortisol concentration despite increased ACTH is hardly believable and may be due to slow secretion of that hormone. Instead, no increased concentration of growth hormone, thyroxine, triiodothyronine, luteinizing hormone, follicle stimulating hormone and 6-keto-PGF1 alfa.

Analgesic effect is very strong and is common for all patients suffering from pain. Such effect lasts 3-4 hours after treatment. However it is not superficial anaesthesia which could enable any surgical operation within cooled area. Thus, this is only subjective analgesia.

Patients suffering from superficial pain receive alleviation, however, even those suffering from severe and intense pain report considerable relief. Therefore the results of cryotherapy are so interesting and contributed to widespread acceptation of the treatment - not only among doctors but, above all, patients.

The mechanism of analgesic operation of extremely low temperatures is complex and is based upon biochemical and functional features. All patients after 2-minute exposure in the chamber showed considerable increase of beta-endorphins and during the therapy these concentrations were systematically higher. It was also observed that serumal increase of endorphins in patients or healthy persons is associated with extreme cold and does not depend on performed exercises. This occurs despite the fact that physical exercise is believed to release secretion of beta-endorphins. Therefore it is clear that cryogenic analgesia has its biochemical basis. Pain is such a feeling that can be sensed by various receptors spread over whole body. There are opinions that there are no specific pain sensitive receptors. Severe and chronic pain, called pathological pain, originates from damage of tissues and leads to physical and mental exhaustion of patient who cannot live normally. The phenomenon of pain has never been properly defined nor understood. It used to be described as a negative feeling which could only be characterized by the person suffering from it. Therefore pain and reaction against it will be different for each person. Concerning individual reaction against pain - it will be also different depending on situation and timing.

The mechanism of releasing beta-endorphins can be described as follows: cold stimulates various receptors (perhaps before their cold-induced functional shutdown through unknown reflex arcs) which activates subthalamus to secrete factor releasing precursor of beta-endorphin i.e.: propiomelanocortin and beta-endorphins and also ACTH. Increased secretion of beta-endorphin from subthalamus and its higher concentration in serum was observed after operation of various stressful factors and as a consequence of physical effort. In this application of cryotherapy it is a matter of great importance.

Also, beta-endorphins are probably secreted by adrenal glands. It is assumed that endogenous catecholamines, concentration of which is high after cryogenic treatment, contribute in some part to releasing beta-endorphins. It is very important in case of rheumatic or degenerative diseases or injuries when rehabilitation plays a key role in preserving and restoring physical performance of patients.

Cryotherapy induces release of beta-endorphins, however, such release may be also due to physical exercises during intense rehabilitation - but this has not been confirmed yet. The analgesic effect of cryotherapy due to operation of endogenous beta-endorphins lasts about 3 hours. Therefore it would be advisable to repeat the treatment 2-3 times a day and follow it with intense rehabilitation which is also favored by physical comfort and painlessness. Such treatment lasting during a long period may preserve the analgesic effect for some time.

The analgesic effect is also caused by cold induced functional shutdown of various cold-receptors and their connections with propioreceptors. This may be the second mechanism, apart from beta-endorpnis operation, that provides deep analgesia and enables rehabilitation. Obviously, inhibition of conduction in sensory neurons has an analgesic effect too.

The next functional phenomenon which causes analgesia is due to existence of so called "control gates" in the central nervous system (according to Mellzack-Wall theory). Pain-stimulated receptor conducts impulses to higher levels of central nervous system by means of two types of neurons:

- quickly conducing, thick, showing low excitability threshold
- slowly conducing, thin and naked, showing high excitability threshold

This theory assumes the existence of cells, situated in spinal cord, which control and select pain impulses conducted by those neurons.

But only those impulses that reach "control gate" as first, which means those conducted by thick neurons, are quickly passed through and stimulate transmitting cells. Those cells transmit the impulse to cerebral cortex where it is received as sense of moderate pain. After that the gate is "closed" for slowly conducted impulses because thin neurons require more intense stimulation. If the slowly moving impulse was passed through the control gate and reached the cerebral cortex it would be received as sense of severe pain.

The second control gate is placed within thalamus and controls pain-induced impulses conducted by cranial nerves and their fibres. Probably the same mechanism applies to impulses conducted by "non-pain" and other specific fibres. Therefore rapid application of extremely low temperatures, initially causing minor pain or burning, seems to disable both control gates to conduct intensive pain impulses, for example pathological pain.

The "control gate theory" itself would clearly explain the analgesic properties of cryotherapeutic treatment even if the fact of increased secretion of beta-endorphins in low temperatures was not known. Such property of systemic cryotherapy, when it is incorporated in complex treatment, enables reduction of doses of common analgesic or non-steroid anti-inflammatory medicines.

Jonderko (1987) explained that reduced flow of pain impulses to spinal cord could account for segmental inhibition of stimulation of gamma-motoneurons, and at the same time, relaxation of muscles which facilitates the motion therapy.

Brzecki et all. (1990) observed another mechanism causing inhibition of conduction of motor impulses under operation of endemic cryotherapy. Before cooling (2-minute treatment using air cooled to -180^{o}C), immediately after and also 1 hour after the maximum muscular effort of left-wrist cubital flexor was measured using two pin electrodes and electromyograph. The electrodes were placed on two nerves: … and left cubital.

The analysis of the record revealed that strength of the muscle (represented by frequency of the record) considerably increased after one hour from the treatment.

It implies that cryotherapy not only features analgesic action through disabling receptors and slowing down conduction in sensory neurons, not to mention increased secretion of beta-endorphins, but also shows an advantageous effect on motor discharge which may lead to strengthening of muscles. Reduction of speed of conduction of motor impulses in the nerves has no impact on muscular strength after cryotherapy. If such change applied to one cooled muscle and two nerves it may BE assumed that in systemic cryotherapy A similar effect will be observed in all dynamic parts of the body. The analgesic effect and inhibition of neural conduction (especially of motor impulses) induce, and to some extent, toning of muscles. Increased muscular strength can be explained by larger number of activated motor units.

Therefore, toning of muscles along with their strengthening are the next, apart from analgesia, results of cryotherapy which considerably contribute to improved rehabilitation of patients by means of motion therapy. As it was observed the cryotherapy itself does not improve fitness of patients. Application of only cryotherapy even deteriorates the ability to perform exercises. Patients themselves pointed out that they felt worse after only cryogenic treatment, however, the objective evaluation of their state was rather impossible. As a conclusion, it may be stated that to achieve improvement or restoration of fitness it is necessary to perform intensive exercises taking advantages of comfortable condition of patients after systemic cryotherapy. Therefore the definition of cryorehabilitation was introduced to underline the absolute necessity to support rehabilitation with cryotherapy and achieve the best possible therapeutic effect.

The circulatory effect of systemic application of low temperatures impacts both micro- and macrocirculation of blood. Changes in microcirculation confirm the therapeutic effects of cryotherapy, however changes in macrocirculation may play a key role in general safety of cryogenic treatment. The primary effect induced by application of extremely low temperatures in microcirculation is, at least in skin, deep contraction of blood vessels causing paleness but without blueing of covered parts of the body, lips and nails. As it seems, capillary constrictors are contracted or tightened which causes limiting and inhibition, in some areas of skin even complete standstill, of capillary blood flow. This results in stimulation of sympathetic system and increasing of concentration of catecholamine. Blood with oxygen that was not transported to tissues flows back, by means of open arteriovenous fistulae, to large veins and right part of heart being only minimally or not at all cooled.

Such a situation takes place for several seconds. Vasodilatation of microcirculation and increased capillary blood flow quickly reinstate the temperature or even increase its value immediately after treatment. Intensified perfusion of skin lasts for many hours and that can be displayed by means of thermographic or isotopic methods. Perfusion of skin and tissues may be escalated when right after the treatment patients are subjected to exercises. The increased plasmatic concentration of prostacyclin, which is responsible for vasodilatation of blood vessels, was not observed.

In general, disturbances of local blood supply may contraindicate local or systemic cryotherapeutic treatment. This is logical, however, and must be clinically verified. Cryotherapeuitc treatment is always connected with extended and intensive rehabilitation of patients. So, if cryogenic temperatures disturb the microcirculation only for a short period and after the treatment it is enhanced even for a long time, thus, for example atherosclerosis of vessels of hindlimbs is a doubtful contraindication. An obvious contraindication may be Buerger disease or diabetes. Therefore that problem remains open.

When it comes to venous microcirculation, especially in hindlimbs, several effects induced by deep cooling of skin veins may cause evolution of inflammations and clots. These effects are: increased number of thrombocytes - highly above standard values, contraction of veins stimulated by hormonal or neural impulses, increased concentration of cortisol. As a result patients who overcame blood clots or congestion of circumferential arteries must be excluded from cryogenic treatment.

Cryosurgery, which utilizes subzero temperatures to destroy diseased tissues, also shows that one of the first effects of freezing temperatures is contraction of veins in microcirculatory system and subsequent formation of clots.

One of the underestimated effects of cryotherapy is anti-swelling action. Swelling and effusion around diseased joint have various causes Anti-swelling action of cryotherapy seems to be induced by: a few hours' extensive blood supply of arteries around swelling, increased capillary filtration, improved potency of lymphatic vessels in surrounding intercellular space and finally rehabilitation of joints.

In macro-circulation under the operation of systemic cooling several effects are observed. These effects concern changes in values of diastolic and systolic pressure of arterial blood and also minimal, maximal and average values of heartbeat rate. In examined groups of healthy, as well as ill persons with rheumatic diseases no particular changes of these parameters were observed - but the practice shows something different.

The daily observations of hundreds of patients and thousands of single treatments proved that cryogenic treatment may significant increase lood pressure, however momentary and imperceptible. This concerns patients with labile arterial hypertension or fixed hypertension either cured or not. There are also less frequent cases of sinusal tachy- and bradycardia, however these cases retreat very quickly.

The above facts may remain unnoticed because normally there are 4-5 persons in the chamber at the same time and after the treatment they are examined only one after another. So patients who were last in the queue may show no signs of sinusal tachy- or bradycardia. It should be underlined that such circulatory effects of cryotherapy are observed very rarely. They should however be taken into consideration. It is likely because systemic cryotherapy stimulates secretion of catechole amines and cortisol hydrocortisone enhancing sensitivity of vascular muscles toward these hormones - with observed normal or slightly more alkalic pH of arterial blood.

Therefore patients with hypotonia and tachycardia or bradycardia should be qualified for cryogenic treatment only after careful examination or pharmacological preparation due to the fact that increased blood pressure could severely endanger their health.

Following all aforementioned absolute and relative contraindications it may be concluded that systemic cryotherapy:

- does not affect heartbeat rate and the value of arterial blood pressure,
- does not launch untimely stimulation of heart,
- does not induce or worsen blood supply of heart, so that there are no signs of stenocardia
- does not reduce contractibility of left ventricle

Thus, excluding all possible contraindications originating from circulatory disturbances induced by cryotherapy, the cryogenic treatment is a safe therapy and does not affect the functionality of circulatory system.

It conditions widespread incorporation of the method which assisted by rehabilitation facilitates long term remissions, brings longterm analgesic effects and improves muscular strength to such extent that has not yet been observed after conventional treatment.

The lack of severe disturbances in the functioning of circulatory system as a whole implies that during low temperature application there are no negative changes in gas exchange and ventilation of lungs.

It is common sense that respiration includes gas exchange between lungs and blood and blood and tissues as well as ventilation of lungs. In that way, suitable volumes of oxygen are evenly transported to all alveoli showing partial oxygen pressure lower than that of deoxidized blood. Thus, the gradient between partial oxygen pressure of alveoli and blood enables oxygen diffusion from alveoli toward blood. The same mechanism applies to oxygen transfer from hemoglobin and its diffusion into tissues.

Therefore respiration is a process that is based on passive diffusion of oxygen through respiratory membrane to capillary vessels entwining the alveoli. After that efficient mechanisms are necessary to transport oxidized blood to tissues where oxygen is released from hemoglobin. The effectiveness of respiration in the sense of tissue oxidation and elimination of CO_2 can be evaluated by means of gasometers or by measuring acido-alkalic equilibrium. It is reported that these indicators remain proper as long as patient showed no contraindications against cryotherapy.

From first-aid practice it is known that respiration is possible even without ventilation. In case of crushing or blocking the chest or any other accident when ventilation is simply impossible the victim can be kept alive by application of pure oxygen straightly into mouth or trachea even for 45 minutes. Such type of respiration is called diffusive respiration.

Another function of ventilation is elimination of CO_2 from tissues and organism. CO_2 by means of diffusion is transferred from tissues into blood and then in THE lungs from capillary vessels into alveolar air. The lack of CO_2 ventilation even during direct application of oxygen (as in the example above) causes quick accumulation of that gas in the organism to a level that threatens functionality of respiratory centers, cephalic arteries and vasomotor centers as well. The quickly increasing hypoxia and hypercapnia occur in every case of suffocation - this is called asphyxiation.

Even most effective ventilation will not maintain proper gas exchange in case of major deficiency of blood or CO induced hemoglobin blockage as it happens in nicotinism, intoxication, oxygen transport disturbances or impaired oxygen release from hemoglobin to tissues. The same applies to severe pathological changes in respiratory membrane, presence of arteriovenous leakage in lungs or other changes in perfusion of some areas of lungs.

The optimal conditions for releasing the oxygen from blood into tissues are achieved when values of hematocrit indicator are lowered to 30^{o} (blood acidosis). In these conditions hemodilution is observed. Hemodilution is employed in cases of severe and extended operations in order to maintain optimal oxidation of tissues and improve rheology of blood. Reducing pH of arterial blood shifts the hemoglobin dissociation curve to the left, thus, larger volumes of oxygen are supplied to tissues. Normally, such defensive mechanisms are not launched because gas exchange is adequate with demands of ill or healthy persons. This is why severe deficiency of blood, arteriovenous leakage in lungs and various severe disease of respiratory tract are included among contraindications against cryotherapy. In other words it is assumed and confirmed by gasometric measurement that patient shows normal gas exchange and respiration. Inefficient ventilation of lungs is not a contraindication.

The statistical analysis of records of spirometric measurements proves that systemic cryotherapy does not affect values of the most important indicators of proper ventilation: VC, MVV, FVC, FEV-1. However clinical analysis of individual cases indicates that

considering the quality of ventilation patients can be divided into 4 groups. One of these groups consisted of 50% of patients who showed the same, normal values of indicators before and after the treatment.

There is also a group in which patients showed various disturbances in ventilation and various diseases of respiratory system. The disturbances are maintained after the treatment and may be even more severe vs. initial state. In particular types of diseases the disturbances after the treatment may deteriorate. Mostly, mixed abnormalities in ventilation were observed. That group consisted of 20% of patients.

About 10% of patients showed normal values of indicators of ventilation before the treatment and after the cryogenic operation they showed various disorders. In most cases disorders were of psychogenic or iatrogenic origin (however individual hypersensitivity of respiratory system against extremely cooled air must be also taken into consideration). It seems that at least disturbances of iatrogenic origin can be overcome and thus number of complications during the treatment can be limited.

About 20% of patients showed various, mixed types of respiratory disorders before the treatment and after the therapy showed normal values of ventilation indicators. In these patients the initial malfunctions of ventilation were undoubtedly of psychogenic origin. Systemic therapy induces outstandingly advantageous results in psychical sphere of a patient: perfect mood, feeling of soothing and deep psychosomatic relaxation. The majority of patients were addicted to nicotine and that might be a root cause of psychogenic disorder in ventilation.

This state may be due to hormonal and metabolic changes which are caused by systemic cryotherapy. It was observed that in both healthy and ill patients suffering from rheumatic inflammation of joints extremely cooled air operating on the whole body and respiratory tract induces secretion of endogenous catecholamines, ACTH, cortisol and beta-endorphins. These hormones and biological substances in higher concentrations cause considerable improvement of cerebral performance. They have also positive impact on respiratory system preventing major complications of ventilation and respiration or soothing any possible diseases.

The cryochamber in Wroclaw consists of two rooms. One is adaptational antechamber where the air is cooled to -50^{o}C and the main chamber where the temperature can reach -140^{o}C or even -160^{o}C. In the first room patients stay only for few seconds and then 2 minutes in the chamber maintaining verbal and visual contact with servicemen. Patients are often accompanied by one of the servicemen inside the chamber. The oxygen indicator installed inside the chamber always shows 21-22% of oxygen content. Such oxygen volume prevents hypoxemic hypoxia also in patients with psychogenic disturbances of ventilation before or after the treatment.

Patients wearing swimsuits, socks, boots and with covered parts of the body enter the chamber through the antechamber. Oral cavity and nose are covered with surgical mask cushioned with several layers of gauze. At this stage it is important to avoid mistakes such as leakiness of the mask or putting too small pieces of gauze. These shortcomings could enable entering of cold air directly from the chamber into respiratory tract. Next factor that may induce changes in ventilation before or after treatment is abandoning the rule of slow and shallow inspiration. The inspiration versus expiration ratio must be like 1:2.

Cold air entering nose and respiratory tract becomes warmer and increases its initial volume which may cause suffocation or respiratory oppression. Such mistakes may be called "iatrogenic reasons of ventilation disorders", however, this definition could be expanded also on cases of disorders originating from hypersensitivity of respiratory system against antigen, allergen or cold air. The feeling of suffocation may also induce psychogenic disorder of ventilation of lungs.

In the cryogenic chamber steam and CO_2 from expiratory air immediately turn into icy dust. It is filtered by the surgical mask and gauze covering mouth and nose so that it does not irritate respiratory tract - of course the mask and gauze are properly applied and the rule of slow inspiration is followed. Therefore cooled air in the chamber consists solely of oxygen and nitrogen. Such a mixture, having passed the surgical mask, becomes

heated very quickly in nasal passages, throat and respiratory tract. It seems that the temperature of that air is considerably higher than the temperature of the air filling the chamber. The safety of application of cryogenic treatment to patients with disorders of ventilation is evidenced by lack of vestigial symptoms of hipoxia and hypercapnia, deterioration of cardiac blood supply or heartbeat disturbances.

Systemic cooling of the whole body in the cryochamber applied in cases of articular inflammatory diseases or metabolism-based diseases is intended to: induce comfortable psychical conditions of patients during rehabilitation, achieve complete analgesia, cause extensive blood supply of cooled areas, loosen the muscles around diseased joints (inhibition of motoneural conduction and increasing muscular strength at the same time).

Aforementioned effects of cryotherapy are maintained even 3 hours after the treatment so rehabilitation exercises can be extended in time and also more general and intensive versus conventional treatment. Cryotherapy also enables also reduction of doses of non-steroid, anti-inflammatory and analgesic medicines or even resignation total withdrawal of those drugs.

Systemic cryotherapy itself proved to be a therapeutic treatment - not only symptomatic one. The excitation of hormonal axis, especially, Ccortisol (CRF-ACTH), and increased plasmatic and endogenous concentrations of those hormones showed anti-inflammatory and healing properties similar to increased GH concentration observed in some clinical cases. Increased concentration of testosterone in man (sometimes in women) showed anabolic properties contributing to improved healing of diseased joints.

After cryogenic therapy some of fixed disorders of ventilation connected with, above all, chronic diseases of respiratory system were cured rather than intensified. This effect concerns also psychogenic disorders of ventilation which become normalized after the treatment. During application of several-week therapy to patients with fixed disorders of ventilation it seems advisable to incorporate also physiotherapy of chest. Especially, it applies to cases of coexisting syndromes of bronchitis-emphysema and asthma-bronchitis-emphysema and may contribute to healing of these disorders during or after therapy.

Continuously developing research on aspects of operation of systemic cryotherapy, in particular, its safety and positive impact on numerous preventive and defensive mechanisms of the organism prove that the treatment assisted by kinetic therapy is strongly recommended in following cases:

- inflammatory diseases of kinetic system: rheumatic inflammation of joints, spastic inflammation of spinal joints, rheumatic fever and other,
- metabolism-based inflammatory changes in nerves - uratic gout
- some of the skin diseases affecting joints - psoriatic skin inflammation
- degenerative diseases and secondary degenerative changes in joints and spine
- rheumatic diseases of soft tissues (myosistis and fibromyositis) or connective tissue
- autoimmune diseases
- chronic inflammation of cervical vertebreae
- biological restoration of exhausted muscles.

This method does not only feature symptomatic operation on mentioned cases but it shows true therapeutic effect in these diseases and moreover facilitates rehabilitation.

Physiological principles of cryotherapy

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Abstract: The adaptative abilities of human organism to low temperatures are known quite well. The thermoregulation as well as cryaesthesia mechanisms were presented. The physiological basics of low temperatures response were demonstrated.

Key words: thermoregulation, cryotherapy

Introduction

Stimulation of organism with various impulses, and thus generation of systemic and organic responses or reflexes that activate natural defensive forces of the body are the most important features of physical therapeutic treatment, including application of cold and other methods. The operation of these impulses can be easily explained on the example of the phenomenon of thermo-regulation which is common in warmblooded creatures. The main purpose of this mechanism is to balance thermoregulatory functions of human body - in other words: to maintain thermal homeostasis. In humans and other warmblooded creatures, in normal conditions, constant temperature is maintained only in body cavities and cranium. Skin and limbs show coldblooded properties. In practice, the coldbloodedness of skin and limbs plays a key role, because it determines the warmbloodedness of body cavities mainly through changes in operation of circulatory system (especially microcirculatory system) and intensity of metabolism which is controlled by thermoregulatory centers [33].

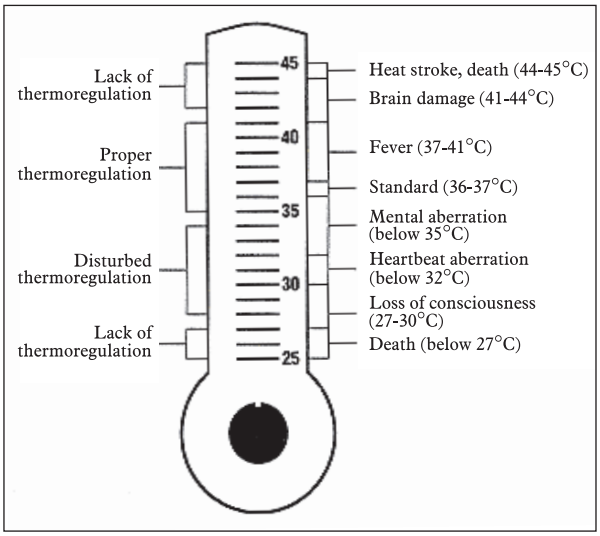

Fig. 1. The tolerance of fluctuations of temperature by human body versus the ability of thermo-regulation.

In normal conditions the temperature of the human body fluctuates by an average of 0,5-0,7°C during the day regardless of surrounding temperature [14]. (It concerns internal organs, the temperature of skin may show greater fluctuations). These changes are completely harmless and even are the symptoms of proper thermoregulation. However, any greater change, especially exceeding maximum or minimum threshold values, can be very dangerous. The range of tolerance of the changes by human body and limits of properly operating thermoregulatory mechanisms are shown in the Fig. 1.

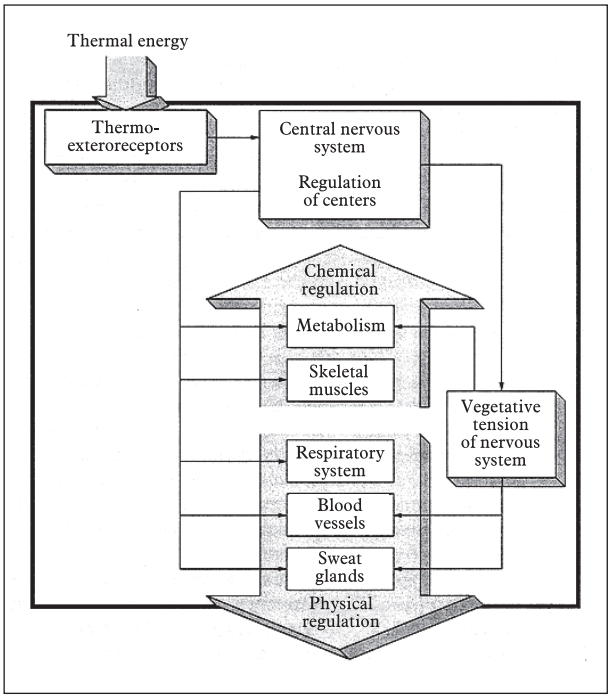

Fig. 2. The schematic of thermal regulation in the body.

The activation of thermo-regulatory reactions in human body takes place by means of thermoreceptors - neural structures which record changes of temperature in time. These receptors can be divided into two groups: thermoexteroreceptors and thermoenteroreceptors. The first ones, as external receptors are located at the circumference of the body ie. in skin and receive thermal stimuli from the environment. The latter control the temperature inside the body [28].

Among thermoexteroreceptors located in skin some of them sense cold, some warmth and the other heat. These receptors are located unevenly and the largest groups are placed in facial skin, abdominal skin and also front side of forearms, arms and fingertips [17, 20]. There are more cold receptors than warmth receptors. There are about 250,000 of cold receptors while warmth receptors consist a group of only 30,000. They are the foundation of thermal sense that enables humans to feel the thermal comfort (or discomfort) which may be related with different value of temperature depending on environmental conditions [25].

Main function of thermo-exteroreceptors is to transfer neural impulses via afferent paths to subthalamus which is one of the most important parts of brain controlling all vegetative and majority of hormonal functions of human body. In subthalamus these impulses are integrated with impulses conducted by thermo-enteroreceptors sensing the actual temperature of blood. As a result specific mechanisms are activated which causes production or loss of heat from the body.

Production or loss are launched by two centers located in subthalamus. First of them protects the organism against overheating and control the loss of heat - its stimulation causes widening of network of skin blood vessels and perspiration. The latter prevents the body from excessive loss of heat by means of narrowing the blood vessels and activating thermogenesis [25, 33]. Operation of this specific biological thermostat in a way depends on concentration ratio of calcium versus natrium ions. Increased concentration of natrium ion induces feverish reaction, on the other hand, increased calcium ion concentration shifts the body temperature to slightly lower value [33].

As an effect of operation of subthalamus several thermo-regulatory mechanisms are activated. These mechanisms can be conventionally divided into two groups: chemical and physical. The reciprocal influence between chemical and physical thermo-regulation is shown in Fig. 2.

Chemical thermo-regulation is based on production of exogenous heat which mainly comes from motor activity of muscles or their visible or invisible trembling, however, only the production of heat exceeding the demands of basic metabolism is considered here. Physical thermo-regulation boils down to gathering or dissipating exogenous heat from the body. It takes place by means of heat transfer accordingly with the gradient of temperature of the body and environment (eg. atmosphere,

objects, items). In this sense the source of heat can be located within or outside the body [33].

Therapeutic application of cold utilizes the effect of intensification of natural, permanent physical mechanisms of heat transfer by means of increased gradient of temperature of tissue. In this case the tissue is the source of heat and environment is the heatsink. The loss of heat from human body through tissues can occur in four different ways depending on object or material absorbing the heat. Until recently, the most widely applied therapeutic method was cooling through conduction based on heat exchange between adjoining objects. It was utilized mainly for the purposes of local cryotherapy and cooling was achieved by means of application of icy cold water, ice chunks or cold compressions.

Cooling through convection of heat from skin into surroundings is right now rarely utilized in medicine and mostly in high fever, heat stroke, some of infectious diseases or defected thermo-regulation. In that method, fans and blowers are used which direct the current of cooled air across or along naked body.

Cooling through evaporation is based on the principle that evaporation of volatile liquids from the surface of a body requires thermal energy which results in lowering of skin temperature. To achieve this, normally chloroethane or considerably safer fluoromethane are used.

Cooling through radiation is growing more and more popular nowadays. It utilizes the fact that human body can loss even up to 55% of heat by means of radiation. In general, radiation proceeds very slowly, with various intensity, in different periods of the day and depending on outerwear. It is more feasible the more is the difference between body temperature and environment. To force the differences in temperature mostly vapors of liquid nitrogen are used as well as cooled air which being blown over surface of the body stimulate the activation of thermo-regulatory mechanisms. Every loss of heat resulting form application of cold can be precisely calculated from specific formulas or equations as long as elements of these are known. Obviously it is more complicated when it comes to living organisms. That fact may seem more important when we take into consideration that incompetent application of cold can induce severe complications such as frostbites, cardiovascular disorders or respiratory system disorders.

Organic results of systemic application of cold

The main result of application of cold during cryo-treatment is lowering the skin temperature even by few Celsius degrees. At the beginning of application rapid drop of temperature of skin and subdermal tissues is observed. The temperature of muscles is also lowered however the process is slower [28]. It is due to contraction of blood vessels which is maintained for about 1 minute after application [7]. Such contraction is induced by reduced blood flow and heat conductivity of superficial tissues. Lower skin temperature is getting closer to the value of environmental temperature which, at the same time, causes decrease of loss of heat through conduction, convection and radiation. The rate of metabolism and action of endocrine glands is changed. It is manifested by muscular trembling, which from energetic point of view can be an effective method of heat production. The volume of heat obtained in that way 2-3 times exceed the volume produced during basic metabolism [14]. On the other side, during muscular trembling increased loss of heat through convection is observed. In result, all heat produced by means of muscular trembling is almost completely lost.

Apart from muscular trembling, the next essential effect that can be observed during treatment is reduction of basic metabolism by even 50% [23]. This decreases the energetic demand of tissues and in result causes drop of oxygen demand [28].

In practice, completely reversed reactions are observed after the treatment. The reinstatement of skin temperature is observed after about 14 minutes and the plateau (35^{o}C) is maintained for over 90 minutes [14, 15]. About 4 minutes after treatment the width of blood vessels is expanded and may exceed 4 times the initial diameter [9, 19]. Such effect can last for a few hours after application.

It brings considerable increase of blood supply of internal organs. Several-hour long excessive blood supply contributes to improved metabolism and elimination of harmful products of metabolism. All these, assisted by kinetic therapy accelerates healing of swelling.

Another important result of excessive blood supply is increased concentration of oxygen in muscles which reduces volumes of lactates and histamine, increases concentration of bradykinin and angiotensin and - as a result - significantly alleviates the pain [9,3 6]. Additional analgesic factor is due to cold-induced inhibition of neural conduction in some unmyelinated fibers [8, 15]. Hypothermia reduces the speed of neural impulses down to 1,2-2 m/s/^{o}C after cooling to 18^{o}C [1]. As a result, the reflexive responses are deteriorated and the pain threshold is raised [3]. For example pain threshold in a healthy shoulder joint after 15-minute application of plastic bag filled with ice was raised to the same level as that after 20-minute short-wave diathermy. However, in case of diathermy the effect is maintained for considerably shorter period [24].

Another noticeable effects of long lasting application of cold are enhanced secretion in adrenal glands and thyroid, and also accelerated cellular metabolism [17]. The morphological and biochemical examination performed after 2 weeks from treatment indicated increased level of hemoglobin, leukocytes and thrombocytes in comparison with initial values [29, 32, 34, 35]. However, the highest acceptable level was never reached [21].

The next effect of application of low temperatures is manifested by relaxed tension of muscles [2, 18]. Physiological mechanism responsible for such relaxation has not been fully investigated. Probably it is connected with inhibited neural conduction and reduced reactivity of circumferential sensorimotor endings, including specific receptors - Golgi apparatuses in tendons and neuromuscular spindle in muscles - responsible for regulation of muscular tension [6, 8, 15]. Obviously, the relaxation of muscles mainly contributes to improved rehabilitation of patients with spasticicty.

The fact that achievement of reactions and therapeutic effects such as analgesia, anti-swelling action, exceeded blood supply, relaxation of muscular tension and increasing their strength does not have to be limited to areas directly subjected to cryostimulation. The systemic effects are as well observed even in remote areas [18, 36]. It is worth mentioning that above organic reactions occur during "rebound" time

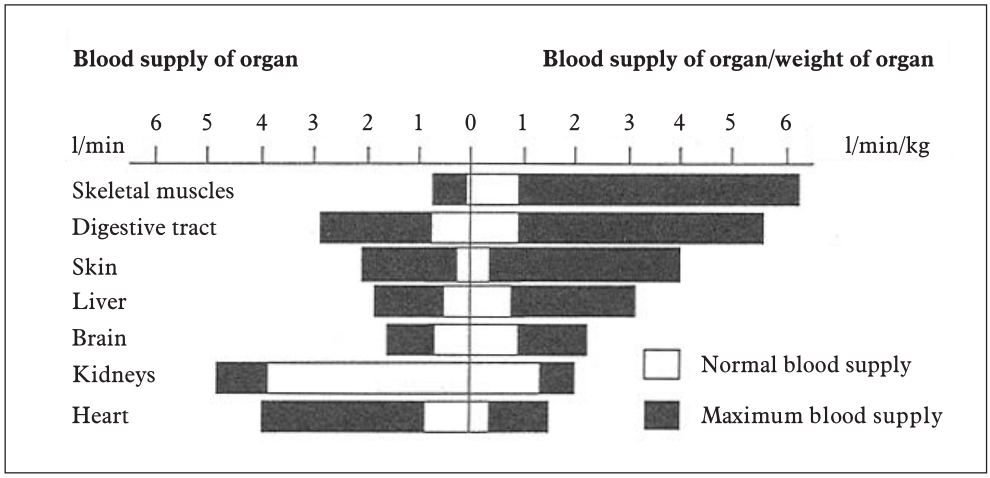

Fig. 3. The change of blood supply in organs as the result of application of cold (the blood supply was expressed in litres per minute, and ratio of blood supply versus weight of the organ was expressed in litres per minute per kilogram) [28]

[2, 18, 19], which means after withdrawing of cold factor, and when operating collectively contribute to anti-inflammatory properties of that form of therapy[4, 5, 11-13, 16, 21, 22, 27-30].

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Thermophysical processes of cryotherapy

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Abstract: Cryogenic physiotherapy means treatment based on cold gas influence on a surface of human body. The patient is being immersed in a gas, cooled up to the temperature of -130°C, within short time (2-3 minutes). The temperature and time of the procedure are matched with thermal inertia of a human body. First of all the thin, superficial layer of the skin, in which thermoreceptors are located, is being cooled during the treatment. The interior of the body is not subjected to overcooling.

Key words: cryogenic physiotherapy, thermophysical processes

Introduction

The cryogenic physiotherapy mobilizes immunological system, displays anaesthetic properties, intensifies peripheral circulation etc. This procedure is used in bronchial asthma, rheumatoid disease, psoriasis, eczemas, allergy, burns, contusion and many other illnesses treatment. Nevertheless, the positive results are achieved on condition that, the human body will be subjected to appropriately physiotherapeutic activity in a contact with cryogenic gas. The lack of quantitative criterion as well as accurate concept of the mechanism of this activity evaluation lead up to the fact many people think that it is enough to walk into the chamber with cooled air to recover.

The development of cryogenic physiotherapy as preventive and treatment method is restrained because of the lack of the scientific basis of technology of cryogenic temperatures therapeutic influence on the skin integument of the patient. In order to evolve such technology, the research workers of the National University of Cryogenic and Food Technology (SPb GUNiPT) in Sankt-Petersburg as well as the Chair of Physiotherapy of the National Medical Academy of Postgraduate Education in Sankt-Petersburg (MAPO) suggested thermophysical theory of cryotherapy. The assumptions of the theory describe the reasons of the effects that were observed during cryogenic treatment, include the system of quantitative efficacy evaluation as well as safety of technological and structural solutions. The thermophysical theory of cryogenic therapy facilitated and accelerated the analysis process of possible variants of practical realization of the method, created conditions for exchange of physical experiment into examination based on mathematical model.

Basic assumptions of thermophysical theory of cryogenic therapy

The human being is not provided with a sense organ capable of temperature evaluation. The evaluation of exterior conditions of temperature is based on the information derived from cold exteroceptor that controls the surface temperature of cutaneous integument.

Cold receptors are located closer to surface (0.17 mm) than thermoreceptors (0.3 mm). The general quantity of the receptors counts about 280 000 in which cold receptors about 250 000. The cold receptors lead leans towards presumption the low temperature

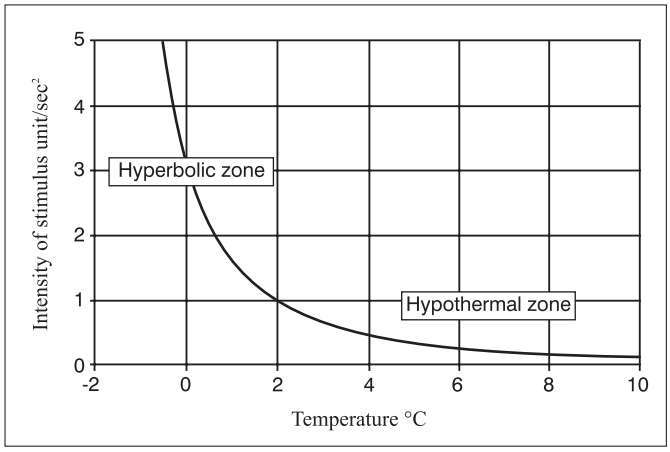

Fig. 1. The intensity of hypothermal stimulus in various conditions of cutis temperature surface.

interactions will produce greater stimulation effect. The way of receptors distribution allows to observe the temperature changes of epithelium surface, which is determined by the intensity of heat loss to the environment.

It is known body integument is unaffected by the cold, tissues, refrigerated by 10-12 ^{o}C stop working properly [1]. In order to apply widely cryogenic physiotherapy, the size of the cooling zone should be limited to the nucleus magnitude.

The cold receptors code the information about skin temperature which are transformed into the universal for brain signals - nervous impulses. The enlargement of stimulus intensity involves the increase of frequency impulse activity.

The quantitative connection between stimulus intensity and signals frequency is characterized by Stevenson's Principle, i.e. raised to the power dependence takes place between perception and stimulus intensity.

It is important, for the body and cutaneous integument especially, to protect against superficial congelations, which are probable in these cases in which the cutaneous temperature decreases below -2.5 ^{o}C [3]. The control of such processes is hold by cold receptors of PUC sensory system. PUC receptors are activated only by strong stimulus, which can create possibility of reversible damages of tissues. The most important, as regards cryotherapy, PUC characteristics can be formulated in the following manner:

1. The system is characterized by low ability to intensity and localization of external stimuli evaluation. In this way local cryotherapy evokes anaesthesia of the organs that were not subjected to refrigeration.
2. Signals, that flow in from PUC receptors, are located in the whole thermoregulatory center in a brain, therefore strong but localized signal does not cause significant reaction and vice versa. Systemic cryotherapy allows to use the whole thermoregulatory center for stimulating action.
3. Information loses its discreet during the transfer - significant piece of knowledge about localization is lost. In order to achieve therapeutic effect within the specific part of the body, it is not necessary to have this particularly area cooled - the results of cryogenic stimulation distribute regularly on every part of the body as well as this ones, covered with clothing. It is important, the maximum surface of the body has contact with cryogenic gas.
4. To activate the system, strong, close to destruction action concerning cutaneous integument is necessary. The cryogenic stimulation will be effective if the temperature registered by cold receptors approaches to minimal threshold: t_{final} = -2.5 ^{o}C.
5. The system integrates coded signals that flow in from every areas of cutaneous integume. Therefore, the total range of information about danger threatening the organism is described by not only intensity but also surface and long duration of hypothermal stimulus. The therapeutic effect is characterized by long duration of the period in which the temperature of the cutaneous surface is similar to the final value.

The intensity of the hypothermal stimulus Ib, in any given moment, can be evaluated on the basis of:

$$I_b = \frac{a}{\left(t_{epith} - t_{final}\right)^n}$$

where tepith- temperature of epithelium surface, tfinal = -2.5 °C - temperature of the beginning of the damage as a result of cold activity, constant: a=2, n=2.

Equality 1 allows to describe quantitatively the signal intensity that flow in from the cutaneous integument surface, when the values of the temperatures are various in different parts of this surface. The intensity of hypothermal stimulus changes, dependant on epithelium temperature, is presented at the Fig. 1. When the epithelium temperature is higher than 2°C, the intensity of the cold receptor signals is insignificant, but as the temperature grows up to the threshold value of -2°C, the intensity of the alarm signals increases hyperbolically.

The EUC adds up the signals that flow in from the various areas of cutaneous integument at any moment as well as gathers information about the general intensity of given stimulus.

When the hypothermal stimulus of cold receptors Ib is equal for every point of the body the summary stimulation effect is described by following formula:

$$S_{ds} = f \cdot \int_{\tau=0}^{\tau \le \tau_{max}} I_b \partial\tau$$

where f - The contact surface of warmth carrier and epithelium, τ_{max} - the maximum safe time of procedure.

The maximum time of cryogenic procedure duration is determined by means of the patient hypothermal safety conditions [4]. The procedures, connected with the surface of cutaneous integument refrigeration, are safe for the patient as long as the cutis temperature is higher than -2°C (the external condition of hypothermal safety), and the temperature of the internal boundary of fatty layer should not decrease below 36°C (the internal condition of hypothermal safety).

In practice it is hard to ensure an uniform and synchronous cooling of every part of the body. The greatest temperature non-homogeneity of the skin surface is observed along the vertical axis of the body. The sensory system will add up the signals that flow in from various levels of the body.

The cryotherapy stimulation effect can be described according to formula:

$$S_{ds} = \int_{y=0}^{y=y_{max}} \cdot \int_{\tau=0}^{\tau=\tau_{max}} fy \cdot I_{bp} \cdot d\tau \cdot dy$$

where f_y - contact surface of the warmth carrier and epithelium on the specific level, I_{bp} - stimulus intensity on the specific level, y_{max} - height of the patient.

To simplify the records connected with therapeutic efficacy of cryotherapy analysis, the jb unit of stimulus measurement was introduced:

$$jb = \left(m^2 \cdot s\right)/K, S_{ds} = [jb], I_b = \left[j_b/\left(m^2 \cdot s\right)\right]$$

The subjective sense of the consequences of superficial surfaces of the body contact with the cooled environment is distorted by the fact the cutis temperature is controlled also by other group of receptors. These sensors respond cutis temperature changes. The impulse for the receptors is not, as before, the surface temperature of cutaneous integument value but the velocity of its changes. These receptors belong to different sensory canal - lemniscus sensory system.

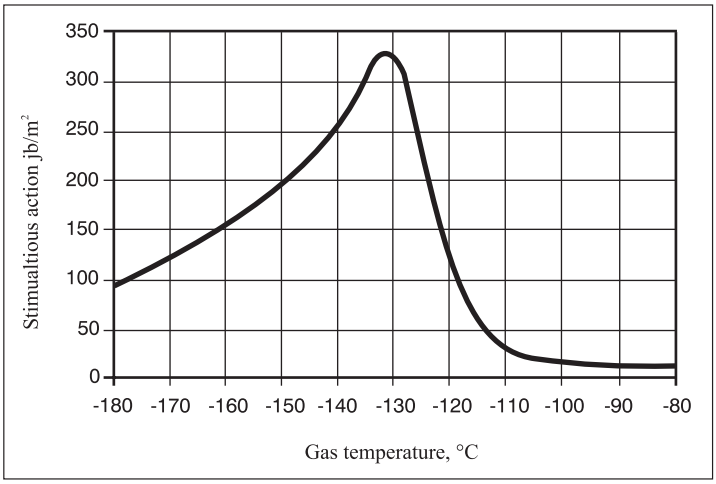

Fig. 2. summary impulse dependence on the temperature.

The lemniscus sensory system (WUC) appeared much later on the way of evolution. It is fully developed only in primates and the human being. This system conducts the accurate information about the localization as well as intensity of stimulus, it is conductive pathway "fast" temperature sensitivity. The system is not responsible for stimulus interpretation but only discerns and localizes the impulse. The subject experiences the WUC signals stronger, thanks to these features. For this reason the therapeutic effect of cryogenic procedure is bound very often with sensations exerted by a quick temperature decrease of the cutis - hypothermal discomfort. Some authors of cryogenic technique aim at hypothermal discomfort intensification during the procedure. Such attitude to the problem is a threat to patients, because WUC cold receptor signals provoke the same reactions as pressoreceptors. When the cooling rate of the cutis surface is high, the hypothermal discomfort is perceptible as either acute pain or burning sensation. These feelings can evoke intense, negative consequences, even heart attacks. It is important to aim at hypothermal discomfort reduction during cryotherapy. The concept of hypothermal discomfort index was introduced, in order to estimate the quantitative evaluation of sensation during the cryotherapy procedure, which equals numerically the temporary value of cutis temperature changes rate:

$$k_{dh} = \frac{\partial T_n}{\partial \tau}, \left[\frac{K}{s}\right]$$

where T_n - epithelium surface temperature

The hypothermal discomfort index allows to evaluate the negative sensations of the patient during the refrigeration. For instance the cooling rate of the skin amounts to 5,5 K/sec during the ice-cold water bath. It comes out cryotherapy is more comfortable than icy bath threefold.

The total index of hypothermal discomfort is used to evaluate the sensations of patient during the procedures, when the body cooling process proceeds irregularly:

$$K_{dh} = \int_{y=0}^{y=y_{\max}} f_y \frac{\partial T_n}{\partial \tau} \partial y \left[\frac{K \cdot m^2}{s}\right]$$

The selection of optimal temperature in cryogenic chamber

The heat emission from body surface is determined mostly by the temperature level in the cryogenic chamber. Discrepancies of specialists opinions are extremely broad in this

issue. These procedures are performed in the temperature from -180°C to -100°C. In local cryotherapy temperatures up to -30°C are recommended.

The selection of temperature is usually determined by refrigerant apparatus potential, not physiotherapeutic requirements.

The methods of mathematical modeling as well as physical theory of cryotherapy allowed to perform quantitative experiment in order to estimate the optimal temperature of the gas applied in cryotherapy. The range of the gas temperatures was assessed from -180°C to -100°C. The procedures modeling has lasted as long as the skin surface temperature was higher than -2°C (external condition of hypothermal safety).

As a result of the examinations, characteristics of the procedures were estimated, presented in table 1, as well as diagrams, demonstrated in figures 1-4.

Safe duration of the procedure changes significantly along with temperature increase, what was presented in table 1. Commonly accepted exposure in -180°C tallies with data received for the temperature amplitude from -130°C to -120°C.

Compared procedures differs from each other with heat stream magnitude emitted from the cutaneous integument surface. The heat stream of the skin surface varies from 1,2 kW/m^2 to 5,9 kW/m^2 in the limits of preseted range of temperatures. The temperature emission from the total surface of the cutaneous integument (1,6 m^2) achieves the value of 9.5 kW (in -180°C). It is very hard to reduce such amount of the heat, that is why low temperatures application can be justified only by high therapeutic efficacy. Nevertheless, as it is presented in table 1, extremely low temperatures application does not guarantee high effectiveness. The stimulation action of procedure with extremely temperatures usage brings three times worse results than therapy performed in -130°C.

The influence of gas temperature on therapeutic effect was demonstrated in figure 2.

The application of temperatures below -130°C leads to monotonous cryogenic efficacy decrease. When the temperature in the cryogenic chamber is higher than the optimal one, the decrease of efficacy of physiotherapeutic effect is observed. The temperature increase, from -130°C to -120°C, decreases results almost twice, and if the temperature oscillates about -110°C the therapeutic effect is ten times smaller and amounts to only 32 jb/m^2. The results correlates well with subjective patients evaluation.

In devices equipped in cooling system based on compression it is impossible to maintenance the temperature of -130°C, which is why the their manufacturers passes over the therapeutic efficacy.

Table 1. Results of quantitative experiment.

estimated parameters, units of measure	temperature of warmth carrer										
	-180	**-170**	**-160**	**-150**	**-140**	**-130**	**-120**	**-110**	**-100**	**-90**	**-80**
procedure duration, sec	43	57	74	96	124	159	193	200	208	216	225
minimal epitelium temperature, °C	-2	-2	-2	-2	-2	-2	-2	2.9	6.3	9.4	12.3
minimal muscular tissue temperature, °C	36.7	36.6	36.6	36.5	36.4	36.2	36	36	36	36	36
max. warmth emission from the cutis surface, kW/m^2	5.9	5.0	4.2	3.5	3.0	2.5	2.1	1.9	1.6	1.4	1.2
maximum warmth emission from the nucleus,W/m^2	57	58	60	65	75	95	115	113	110	107	104
minimal hypothermal discomfort index, K/s	3.7	3.2	2.7	2.3	2	1.7	1.5	1.3	1.1	0.9	0.8
stimulation action, jb/m^2	92	119	153	196	251	325	118	32	19	13	11
warmth emitted from cutis surface, kJ/m^2	278	310	340	374	407	446	462	416	372	333	296
warmth emitted from the nucleus kJ/m^2	2.3	3.1	4.1	5.4	7.3	10.2	13.6	14.0	14.4	14.9	15.4

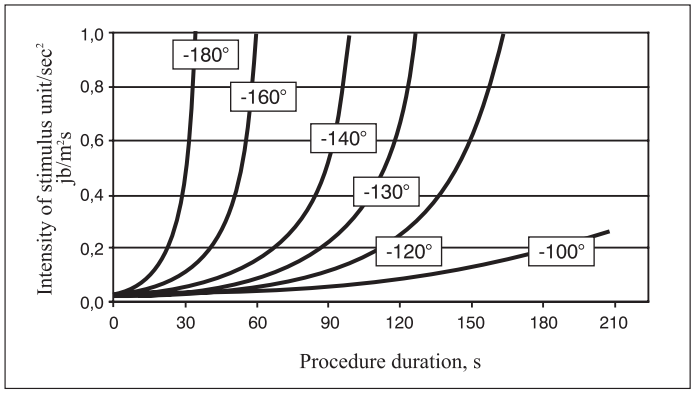

Fig. 3. Changes of stimulation activity of cryotherapy during the procedure.

Figure 3 describes the changes of stimulation activity intensity Ids of cryotherapy in various temperature conditions. At the beginning of every procedure the magnitude of stimulus intensity is described by relationship Ib<1. At this stage, the therapeutic effect is so small that can be omitted. This preparatory period proceeds along with the body surface to the optimal temperature refrigeration.

The procedure comes into effective phase, when skin surface refrigeration starts to exerts significant stimulating activity. Taking into account, the therapeutic effect of the procedure begins from the moment, when: Ib>1 jb/s*m^2, duration of preparatory phase and stimulation using Fig. 3 can be determined.

The variants of high efficacy are characterized by longevity of stimulation phase and vice versa. For the temperature of -120^{o}C, the duration of stimulation phase is close to zero.

Depending on warmth carrier temperature, the heat stream from body surface, according to numerical experiment results, amounts to 1 kW/m^2 to 6 kW.m^2. The human body emits up to 6 kW/m^2 of the heat in the temperature of -180^{o}C, therefore already after 35 seconds, the temperature of skin decreases to 1.5 ^{o}C (Fig. 4).

The procedures, in which cutis temperature changes so quickly, evoke sense of discomfort and are called as extreme cryotherapy. The procedures with gas temperature not higher than -160^{o}C can be numbered among extreme cryotherapy. In numerical experiment, this group operations were finished due to dangerous decrease of cutis temperature: t_{final} = -2^{o}C (Fig. 4). The efficacy of this group of procedures is not higher than 200 jb/s)m^2.

Table 2. Duration of procedure phases.

temperature,	-180	-170	-160	-150	-140	-130	-120	-110	-100
preparatory phase, s	34	45	59	77	99	127	163	200	208
stimulation, s	9	12	15	19	24	32	31	-	-

Table 3. The classification of cryogenic procedures.

name	**gas temperature**	**parameters**			
		Sds, jb/m^2		**Khd, K/sec.**	
		max.	**min.**	**max.**	**min.**
extreme cryotherapy	below -150	152	92	3.7	2.7
cryotherapy	from -150 to -130	325	196	2.3	1.7
low-temperature gas hypothermia	over -120	118	11	1.5	0.8

The variants with gas temperature from -150°C to -130°C describes the idea of cryotherapy to the largest extent because it assures high efficacy of the stimulus (325 jb/s•m²) along with high sense of the comfort during therapy.

The procedures in which temperatures amount to over -120°C do not allow to decrease cutaneous integument temperature to the values that assure intense cryostimulation. For example, in temperature of -100°C the cutis temperature at the end of the procedure amounts to over than +5°C.

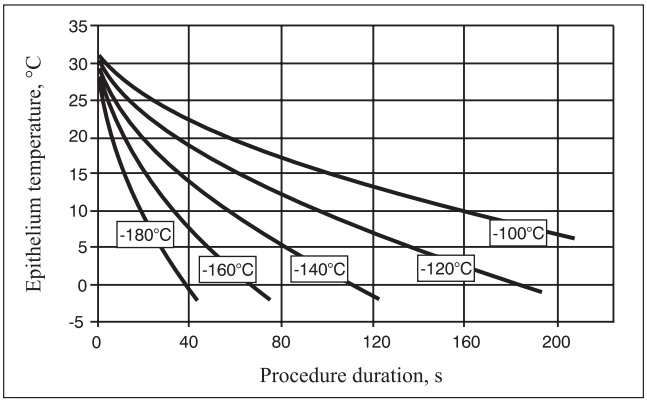

Fig. 4. The changes of cutis temperature during the treatments with various gas temperature usage.

The parallel temperature distribution can be obtained in body refrigeration in hypothermal bath. Because of low efficacy and similarity to traditional hypothermia, the procedures performed along with gas temperature over -120°C can not be numbered among cryotherapy. This procedures may be distinguished as low-temperature gas hypothermia.

In cryotherapy (CT) and extreme cryotherapy (CTE) the epithelium temperature was reaching the minimal acceptable value -2°C. The estimations were interrupted due to external condition of hypothermal safety infringement. In the event of low-temperature gas hypothermia (LTGH), the interruption occurs because of overcooling, of the internal layers of the body, up to 36°C.

Analysis demonstrates the narrow range of optimal gas temperatures used in cryogenic chambers (-150°C to -130°C). The significant part of devices is useless in cryotherapy. The results are described as "perfect" because it was assumed, gas temperature stayed unchanged from the first to the last second of the procedure. In reality, the observation of cryogenic installations shows the cryogenic temperature changes significantly during the procedure what points at refrigerant system shortage. The fluctuations of temperature decrease therapeutic effect, that is why observation can conflict with numerical analysis result in practice.

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The cryogenic chamber in Wrocław

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Abstract: The cryogenic chamber in Wrocław has operated since 1996. The technical guidelines as well as possibilities of this arrangement structure usage in therapeutic process were presented.

Key words: cryogenic chamber, technical guidelines

The therapeutic application of cold has great traditions and high effectiveness. In order to obtain maximum advantages of systemic cryotherapy it was necessary to construct devices that would ensure effectiveness, safety and easy assembling. In Poland the first cryochamber was built in 1989 in Wrocław in the Institute of Low Temperatures and Structural Research of Polish Academy of Science. It began the whole series of devices that were installed in many clinical and sport centers all over the country. In 1996 the second cryochamber was built and installed at Academy of Physical Education in Wroclaw (Fig. 1.).

The construction of the chamber, methods of insulation and preparation the atmosphere in special cryo-purifiers are patented. The specific technical innovations and presented therapeutic parameters, when compared with foreign constructions, show that Wroclaw cryochamber is one of the most advanced devices currently available in the world.

The cryochamber consist of two compartments: antechamber where the temperature reaches -60°C and main chamber where temperature can drop to -110°C or even -160°C. The schematic construction of the chamber is shown in the Fig. 2.

Fig. 1. The cryochamber in Academy of Physical Education in Wroclaw.

The walls of the chamber are made of materials bearing unique insulative properties which enable maintaining of room temperature in the outer part of the chamber despite extremely low temperature inside.

In the cryochamber liquid nitrogen is utilized as the cooling agent. The construction features very quick cooling down to preset temperature and also very stable operation during many hours. Due to that fact groups of 4-5 persons can enter the chamber every 3-5 minutes which gives average capacity of 50-80 persons per hour. All parameters concerning operation of the chamber are independently controlled by two electronic

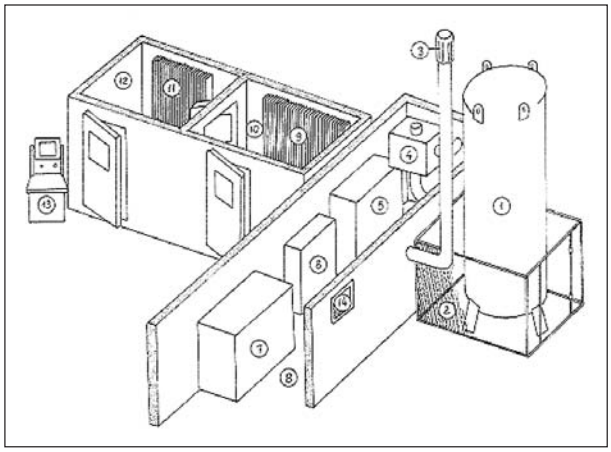

Fig. 2. Schematic of the chamber including service rooms.

systems and supervised by cryogenic engineer.

Conditions inside: air which was filtrated to separate all contamination and practically zero humidity make the persons entering the chamber feel only pleasant, dry cold which is completely different than common belief about extremely low temperatures. Feeling of cold is gradually intensified and mainly concerns lower parts of the body and in very low temperatures may also include thorax. Duration of the treatment is carefully regulated in order to achieve the maximum stimulating effect and eliminate all possible dangers of application of low temperatures.

Patients before entering the chamber must be clinically qualified for such treatment. During qualification the doctor must examine indications, possible contraindications, set the number of treatments and establish the character of kinetic therapy. Just before the treatment blood pressure of each patient is measured. Each time the temperature and duration of treatment are set individually.

Patients enter the chamber wearing swimsuits. They also protect their feet (wooden boots), shins (woolen socks), head (cap), mouth and nose (surgical mask with double layer of gauze).

After entering the antechamber patients accompanied by servicemen stay there for few seconds in temperature of -60^{o}C and then proceed alone to main chamber (exceptionally, patients who enter the chamber for the first time or show difficulties in moving are accompanied by servicemen). Patients spend 2-3 minutes in the chamber slowly walking around and calmly breathing.

The therapeutic series begins from 2 minute treatment in -110^{o}C and is gradually expanded to 3 minutes in -150^{o}C.

Low temperatures induces many reactions in the organism which outstandingly improve the effectiveness of kinetic therapy performed immediately after treatment. These reactions are of following types:

- hormonal - increased concentrations of ACTH, cortisol, POMC (precursor of beta-endorphin), adrenaline, noradrenaline and testosterone (in men),
- circulatory - contraction of skin blood vessels followed by their widening and extensive blood supply,
- neuromuscular - loosening of muscular tension, inhibition of neural conduction, impact on chi-motoneurons,

Fig. 3. The patients before therapeutic series.

- immune - increased humoral and cellular immunity,
- analgesic - interaction of beta-endorphins (analgesic factor) with inhibited conduction in afferent, pain-conducting neurons and control gates which select impulses reaching central nervous system
- anti-swelling

The whole process of thermoregulation, even under operation of temperatures of -160^{o}C during specific time (up to 3 minutes), occurs mainly in external parts of the body whereas internal temperature does not change (the drop of temperature on the thorax equals 3^{o}C, while in limbs 12^{o}C - it is due to different mechanisms of thermo-regulation in these parts of the body and also different temperature at the level of feet and thorax - the difference even by 10^{o}C). Thus, there is no possibility of occurrence of frostbites or hypothermia.

After leaving the chamber, patients feels the warm spreading within the whole body, features perfect mood and relaxation, shows reduced sensitivity against pain and finally can perform exercises that would be impossible in normal conditions. The above effect is maintained for three hours from the treatment.

Having completed 10 applications the evaluation of expected improvements can be performed. However, within first days of therapy some minor intensification of symptoms of disease may occur but it should be considered as normal reaction. If after 10 treatments no noticeable improvement is observed the chance of achieving it practically falls to zero. Fortunately, it is observed very rarely - only in 1-2% of overall cases.

Main indications:

- rheumatic inflammation of joints,
- chronic, developing rheumatism,
- spastic inflammation of spinal joints,
- psoriatic inflammation of joints,
- discopathy,
- degenerative and deforming diseases,
- posttraumatic states,
- diseases resulting from overload of kinetic organs,
- biological restoration

Contraindications:

- claustrophobia
- hypersensitivity against cold,
- insufficiency of circulatory and respiratory systems,
- feverish state,
- thromboembolic and inflammatory diseases in venous system,
- open wounds and ulceration

In Poland a large number of cryotherapeutic treatments have been performed which has helped thousands of patients. The technological solutions implemented in Wroclaw cryochamber and therapeutic experience are unique in the world and arouse general respect.

Energetic basis of cryotherapeutical installation efficiency

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Abstract: The temperature in an executive cabin is considered to be the main point, which cryotherapeutical effect is based on. According to the temperature indexes, three classes of treatment using cooled gas are determined. It was shown that being treated in cryogenic installation does not always give a high medical effect.

Key words: Cryotherapeutical installation, extreme low temperatures.

Temperature gas index determinates the temperature in skin tissues of a patient by the end of treatment. Using an extreme cryotherapy the skin surface is cooled too fast, so the treatment lasts not very long, that's why its result is rather small. Cooling doesn't influence on internal outerskin boundary. In low temperature gaseous hypothermal action, recooling of internal outerskin boundary appears before the temperature skin surface reaches necessary index. Only using gas with suitable cryotherapeutical temperature synchronizes internal and external cooling processes.

Cryogenic installations being cooled by machines don't provide necessary temperature level in executive cabin.

Refrigeration systems are not able to operate at temperature below - 120°C because of low energetic technological efficiency. According to temperature level these installations should be regarded as low temperature physiotherapeutical equipment.

Cryogenic installation cooling system decreases the temperature of air in cabin, up to optimum level and maintains it constant as well. Often required temperature (-150°C - 130°C) is reached only in empty cryogenic installation and after a patient came in the cabin the temperature increases up to - 90°C or higher. Such fluctuations are not permitted, as instead of

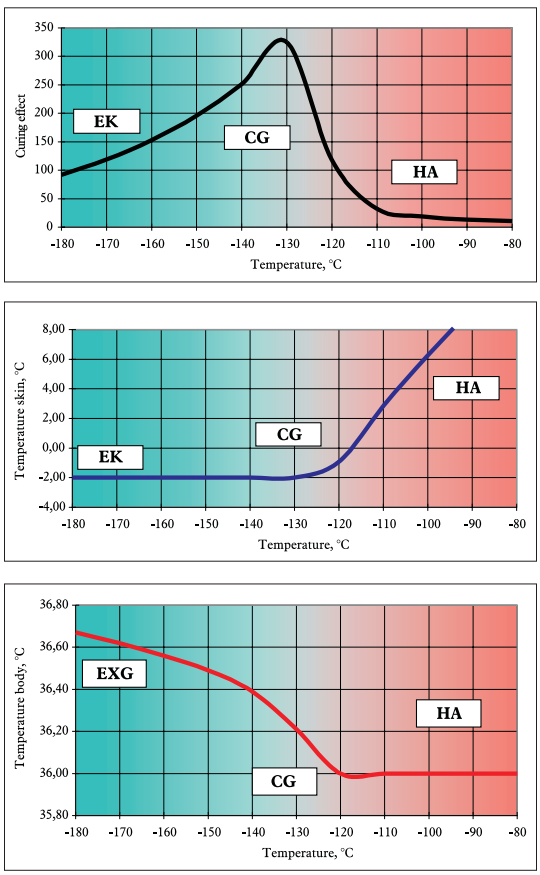

Fig. 1. Changing of a physiotherapy effect and max temperature and min temperature of the outside and inside skin larger of the body depending on gas temperature in the cryogenic camera.

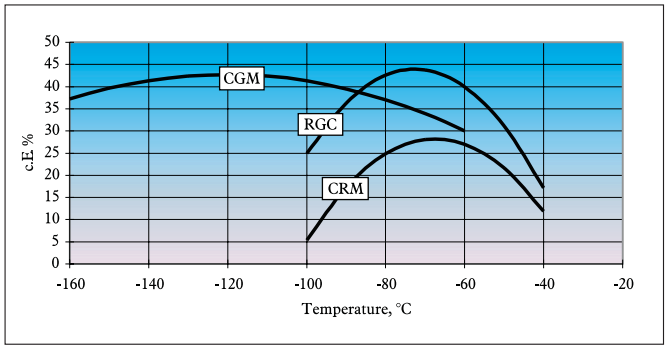

Fig. 2. Exergetic coefficient efficiency of coolants (-cryogenic gaseous machine (C.G.M) (- refrigeration gaseous cycle (R.G.C), cascade refrigeration machine (C.R.M)

cryotherapy, patients are influenced by hypothermal action.

Taking into account that the number of cryogenic installation producers is increasing, it is necessary to determine minimum requirements to the cooling power of cryogenic installation. It will help practising doctors to avoid buying low-quality installations.

Cryotherapy is based on skin surface cooling to -2°C - +2°C temperature region. In order to low the surface body temperature to this level and to avoid recooling of a body. Cooling should be very intensive. A body looses about 600 kDg of heat almost for 2-3 min., that is 3 kW of one patient.

Cooling systems using liquid nitrogen are preferable to use in cryogenic installations. These systems compared with others are simpler and possess large latent power.

For example, the consumption of 1kg. of liquid nitrogen per minute allows to drain heat flow of 4 kW. power from cryogenic installation. Nitrogen is necessary not only to cool a patient, but for other needs, too. Minimum necessity in liquid nitrogen can be determinated, as 1kg/min. per 5 patients should not consume less than 5 kg. per minute. If producers show less consumptions you should not buy it. Not to admit the increasing of gas temperature when a patient enters the cabin the cooling system of cryogenic installation should be provided with electrodrive. Energetic efficiency of cooling mechanisms at low temperatures is extremely small (fig. 2). Figures of coefficient efficiency for refrigeration cycle of cascade refrigeration system and cryogenic gaseous machine working on inverse cycles used in group installations, coefficient efficiency is lowering so fast at -100°C temperature region, that serious doubts about capacity for work of cryogenic installation with these coolants appear.

For cryogenic gaseous machine specific relation required heat to energetic consumption for the work of cooling system in the temperature region (-150°C - 130°C) will be 15-25% (fig. 3).

In order to remove 1kW of heat from executive cabin, cryogenic gaseous machine with consuming electric power of 6kW will be required. Therefore to compensate mean heat emission from body surface of a patient during treatment a machine with electric power not less than 18kW is needed and this is together with using the most effective coolant, which is not used in cryogenic installation because of high cost and small resource. At the same time, installations with cabin per 5 patients which cooling system has only 16kW of power are sold in Russia. With such lack of power the installation is not suitable for treatment.

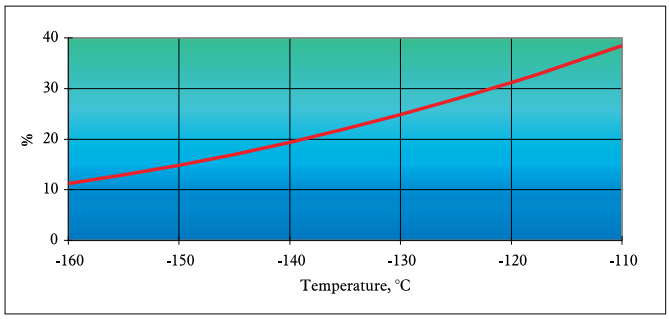

Fig. 3. Specific refrigeration capacity of cryogenic gaseous machine at low temperatures.

Taking into account the essential distinctions in principle of operating, size and construction of compared installations, to evaluate its work capacity we can determine the power of electrodrive of cooling system for carrying out cryotherapy with patient.

For example, if coolant power consumption of cryogenic installation per 5 patients is 16kW, so about 3kW of electric power per one patient. Will be it is possible to calculate electrodrive power of a perfect coolant which is able to drain the same quantity of heat as a nitrogen coolant with 1kg of cryogenic liquid consumption per minute. As it was mentioned above such coolant can drain from a cabin about 4kW of heat, that is equal to refrigeration installation work with 25kW electric power consumption.

Cryogenic installation cooled by liquid nitrogen gives every patient some energetic influence, where power is eight times higher than in installations with refrigeration machines.

To illustrate negative power lack results of cooling systems by mathematical model of cryogenic installation a numerical experiment was made to investigate the line of treatment with different indexes of cooling installation power. To increase visuals of analisis results some simplifying assumptions were made. The temperature is supposed to be -13^{o}C by the beginning of treatment and the patient is the only source of heat.

In simulating of cooling system work the dependence of cooling coefficient efficiency on the temperature in cabin was taken into account. (fig.3). the simulating processes results in executive cabin are shown in figure 4.

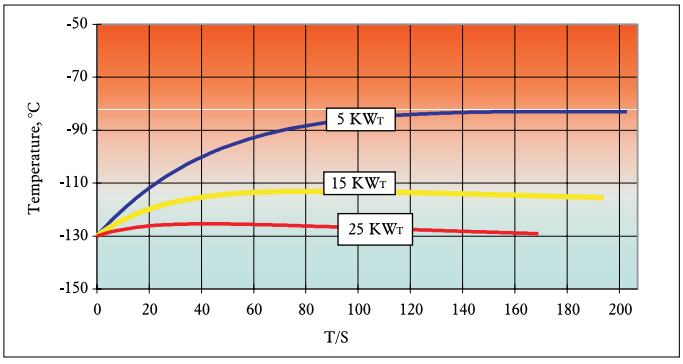

Fig. 4. The changing of gas temperature in executive cabin with different indexes of cooling system power.

If a patient gets no more than 5kW of a cryogenic system power, just after the beginning of treatment the temperature in cabin increases fast. Heat-emitting from a patient body surface exceeds the refrigerating capacity of cooling system. Gas in an executive cabin is getting hot at 4^{o}C/C velocity, till the refrigeration capacity of cooling system will balance heatemitting from a patient. In case of 5kW power the balance is reached only at -30^{o}C.

The real gas temperature increase coordinates well with the practice of using the same systems. For the lack of cooling system power some large intervals are supposed to be. During one hour only four treatments which last for 16 min. can be done. So, an interval lasts about 10 min. Only for this period of time a low power cryogenic system is able to recover the temperature in empty executive cabin. As we can see from figure 4, in order to stabilize temperature conditions in cryogenic installation is necessary to increase power up to 25kW per patient. By using mathematical model of cryogenic installation, the experiment in determining the physiotherapeutical effect of treatment was made with using cooling system of different electric power. Two possible indexes of gas temperature in executive cabin (-120^{o}C and -130^{o}C) are regarded.

The works of cryogenic installations with cooling power from 5 till 30kW per patient are also investigated. The dependence of physiotherapeutical effect on cooling power index is shown in figure 5. This figure shows that being not in dependence on temperature index maintained in empty cabin by small index of treatment effect. In all cases, with the power less than 50 u.d.a/m^{2}. (u.d.a. - unit of disturbing action).

So the lack of power leads to the fact that cryogenic installations with the inside temperature no more than -130^{o}C give the patient hypothermic influence.

The increasing of power up to 25kW leads to some essential changes in the effectiveness of compared variants of cryotherapeutical organization. The rated effect in cryogenic installation with the temperature of -120°C increases up to, 110 u.d.a/m^2 it remains on hypothermic level. The lowering of temperature up to -130°C allows the installation of 25kW power to increase the effect to 335u.d.a/m^2

Taking into account the fact that the coolant of 25kW power corresponds to liquid coolant with nitrogen consumption of 0.6kg/min (15kW) give the patient a hypothermic influence.

Only when liquid nitrogen consumption is more than 1kg/min and temperature level is no more than -130°C, cryogenic installation provides effective cryotherapy. Nitrogen consumption in individual cryogenic installations made in Russia corresponds to these requirements. And group cryogenic installations (per 5 patients) have a power lack equals to 100kW. Today's cost of these installation is rather high (250.000 Euro). Together with the increasing of refrigeration machine power which is necessary for effective cryotherapeutical level, the price is also increasing (about 5-6 times).

Besides, placing of such installations of 125 kW power in medical organizations is connected with a complex of additional problems.

The influence of the whole body cryotherapy on the psychical condition of a human being

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Abstract: The mood changes of patients during systemic cryotherapy procedures were observed what imply the positive therapeutic influence on general feeling. The preliminary results of extremely low temperatures application in patients suffering from depressive syndromes were presented.

Key words: systemic cryotherapy, psychical condition, depressive syndromes

Introduction

The observation of people exposed to extremely low temperatures allowed of its positive influence on a psychical sphere. It was observed that after leaving a cryogenic chamber there was a change in patients' frame of mind, who report stress relief, deep relaxation and soothing effect. Their mood improves significantly. This state lasts a few hours or even longer. These observations haven't been confirmed by any scientific research so far. In some reports, which deal with the topic of the whole body cryotherapy the beneficial influence of low temperatures on psyche was emphasized.

Emotions which remain in a close relation with other psychical functions such as perceiving, thinking and acting are one of the aspects of psychical life. The notion "mood" in psychiatric terminology means an emotional state which lasts longer. The mood can be elevated or lowered, anxiety or disforic. A pathologically lowered frame of mind characterizes long term hopelessness, sadness, low spirits, malaise and lack of happiness. Depressive frame of mind is characterized by low self-esteem, evaluation of past, present and future with a feeling of being guilty and finally suicidal thoughts. Disfory is accompanied by the feeling of regret for fate and people, harm, exasperation, and even anger. The feeling of unjustified threat, strong jactitation and some behavioral symptoms (sleeping and attention dysfunctions, irritability, panic) and autonomous system problems (palpitation, sweats, hot flashes, dizziness, headaches, etc.) are typical for anxiety. Mood dysfunctions can appear once or repeatedly during the a life time. Social, professional and family functioning dysfunctions are the consequences of a depression episode. Depression, especially in a hard form and strong intensity can lead to disability. The suicide risk in affective disorders is 19 %.

Nowadays it is thought that the risk of depressive episode occurrence during a life time concerns only 15-20% of people in highly developed societies and twice as often the victims are women. The prevalence of depressive disorders is still increasing, not only in connection with better diagnostic and availability of specialists, but also due to the lengthening of human life, societies ageing, stressful environment factors' exposure and access to chemical products causing depression. Despite better and better psychopharmacological and psychotherapeutic methods, still the measures helping in

psychic dysfunctions therapy are being searched for. From non-pharmacological biological methods the most common are: phototherapy (exposition to light - radiant flux density 2500-10000 lux, effective in seasonal depression), sleep deprivation and electro-shock.

Whole body cryotherapy and depressive symptoms - pilotage research

The observations made during cryotherapeutic treatment need a scientific confirmation of its positive influence on mood. In Wroclaw Institute of Clinical Physiotherapy the research evaluating the influence of a whole body cryotherapy on humans' psyche was administered.

In the introductory pilotage research the changes of mood at of people with depressive dysfunctions were analyzed after the application of the whole body cryotherapy cycle. It was assumed that the impact of extremely low temperatures on peoples' mood causes the increase of activity of serotoninergic and noradrenergic of some parts of the brain and probably through this mechanism it leads to clinical depression symptoms' withdrawal.

Method

The research was administered among the group of 23 patients: 18 women and 5 men, aged 37-70, who agreed in a written way to participate in this project. They were patients of psychiatric day department or hospital dispensary, who were treated for depressive dysfunctions. These patients were under pharmacological treatment at the same time. Before the examinations patients were familiarized with the construction of the chamber and some safety measures. The sick had some general examinations done which was the condition to administer the treatment. Before each entrance to the chamber the sick had their blood pressure measured. Patients were wearing swimming suits inside the chamber but had their nose and mouth protected by a surgeon mask, their ears by a woolen band and their feet by shoes with wooden soles.

Patients had ten cryotherapeutic treatments between the 14th of May and the 31st of July 2001. The cycle of treatments, which lasted two weeks for each patient, consisted of two series of five treatments carried out only on weekdays. Between the series there was a weekend break. Each time patient was in the chamber for 160s. The temperature applied in cryogenic chamber during the first treatment was -110 degrees Celsius and with the analysis of organism adaptation was gradually lowered to -150 centigrade in case of a last treatment.

The twenty one point Hamilton depression rating scale (HDRS, Hamilton 1967) was used to measure the level of depression intensity. This method is a popular and confirmed scientific tool used for depression diagnostic and rating of its intensity (with the 3-and 5-level scale of quantity rate).

The measurement was carried out in two time points, T0 - before cryotherapeutic intervention and T1 - after the cycle of 10 interventions. While analyzing the position from the scale where the pointing rate was zero during the first measurement was omitted, because this signified the absence of a given symptom at the examined person. In such cases in T1 for the same positions the pointing rate was also zero. As a result of such procedure the number of answers for particular questions was not identical. Additionally, due to the small number of answers for questions of position 16-B and 17 in Hamilton scale (only 1-5 patients from 23 gave the answer for question concerning the loss of weight in the past and for question about the insight into experienced depression symptoms), they were excluded from further analysis.

Results

For each of the depression symptoms assessed by a Hamilton scale the value of chi-square test was counted. Almost in all cases the value exceeded two- or three times the

critical value (range between 9,2 - 15,1), for the critical level a = 0,001. On these bases it can be stated that the attenuation of depressive symptoms intensity observed after the cycle of treatments is statistically significantly connected with their application.

Only for position 'daily general feeling fluctuations' (position P18-A of the scale) no significant dependence was confirmed, however, the position 'obsessions, phobias' (P21 0f the scale) is correlated on a critical level of a = 0,05 (the critical value of chi-square test on this level equals 7,8).

Basing on assigned values of chi-square statistics, the following Pearson's contingency C factors were counted, which can be interpreted as a measure of the strength of the connection between the conducted cryotherapeutic treatments and their effectiveness in depressive dysfunctions. It should be emphasized that these are not strict counterparts of correlation ratio counted for continuous features (for example, the maximum value of contingency factor equals in this case 0,71). For most of the positions in Hamilton scale Pearson's contingency C factors were very high (between C=0,56 and C=0,71), with the exception of position P18-A and P21 mentioned earlier (C=0,36 and C=0,38, respectively). The above data was collected and summarized in table 1.

Table 1. The values of chi-square test and the Pearson's contingency C factors for each position of scale.

Hamilton depression rating scale positions	chi	Critical value (0,001)	C
P1 - depressive mood	38,0	13,3	0,67
P2 - the feeling of guilt	42,2	13,3	0,69
P3 - dispiritedness	46,0	13,3	0,71
P4 - sleeping dysfunctions	46,0	11,3	0,71
P5 - shallow, intermitted dream	40,5	11,3	0,69
P6 - early waking up	44,0	11,3	0,71
P7 - complex activity	33,8	13,3	0,65
P8 - tardiness	33,1	11,3	0,65
P9 - jactitation	36,4	13,3	0,66
P10 - fear, depressive symptoms	39,8	15,1	0,68
P11 - fear, somatic symptoms	38,8	15,1	0,68
P12 - alimentary canal	17,5	9,2	0,56
P13 - general somatic symptoms	30,5	11,3	0,63
P14 - libido, month cycle	32,8	11,3	0,65
P15 - hypochondria	39,3	13,3	0,68
P16 - the loss of body mass	30,3	11,3	0,68
P17 - presence of daily general feeling fluctuation	6,9	11,3	0,36
P18 - intensification of daily general feeling fluctuation	35,4	11,3	0,66
P19 - depersonalization, derealization	21,5	13,3	0,57
P20 - illusions	28,0	13,3	0,62
P21 - obsessions, phobias	8,0	11,3	0,38

To compare the effectiveness of the conducted cryotherapeutic treatments in relation to particular depression symptoms, the change of each symptom's intensity in T1 was recounted as a percentage of intensity of measurement T0; the results are illustrated in Fig. 1.

Among all the examined clinical depression symptoms the most spectacular was the improvement in sleep disorders. It concerned disorders of falling asleep, dream shallowing (numerous waking up during the night sleep), and early waking up in the morning (the change of intensity of symptoms equals 91%, 98%, 100%, respectively). Such symptoms as tardiness of thinking, activity, jacitation, general somatic symptoms (headaches and others) and the loss of body mass were changed in over 80% in comparison to the state before cryotherapy. The fact of 80% improvement in position of Hamilton scale dealing with dispiritedness, suicidal thoughts and tendencies seems to be quite significant.

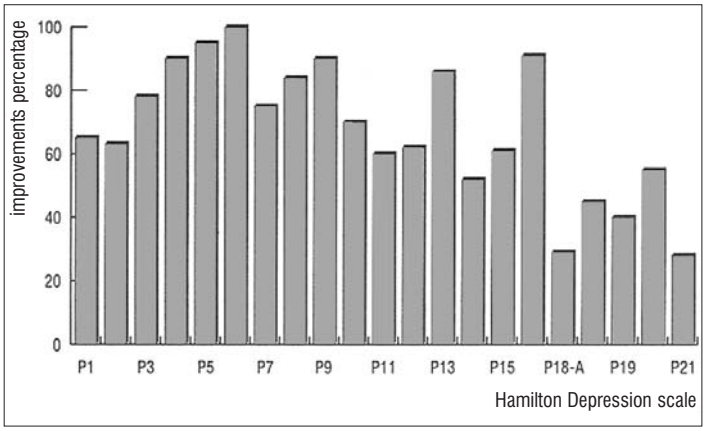

Fig. 1. Intensity change of symptoms in HDRS after a cycle WBCT (%).

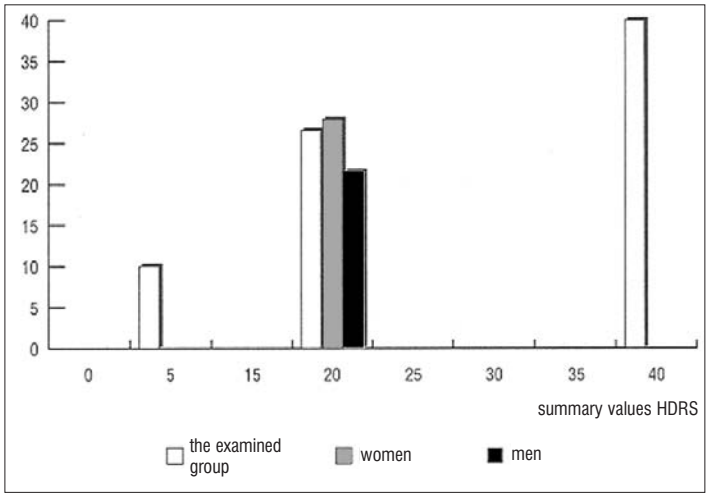

Fig. 2. The average value of overall point rate in HDRS scale for the whole group T0 and T1 and the differences of these averages for women and men.

Average values of points sum in HDRS scale in T0 and T1 were counted, their standard deviation (SD) and differences between averages for the whole group, and also for men and women (Fig. 2). The average change of points sum in the group of women is higher than in the group of men (27,89, SD = 5,05; 21,6, SD = 5,94) and this difference is significant statistically ($p = 0,03$). Big differences in multiplicity of comparable groups limit the interpretational value of the result.

The sum of points in Hamilton scale can be treated as quasi-continuous. Test t-Student for dependent samples confirms the statistically significant change of points sum in relation with conduction of cryotherapeutic treatments for T0 chi = 38,4 (SD = 4,4); for T1 chi = 11,8 (SD = 4,6); $t = 22,41$, $p < 0,001$.

To illustrate the distribution of depression symptoms intensity (pointing rate sum in HDRS scale) these values were grouped into sectional intervals with the span of 5 points (sectional intervals closed left-sided) for measurement T0 and T1 (Fig. 3).

The results of the administered pilotage research let presume that short-term exposure for extremely low temperatures evokes numerous changes in neurotransmission o.u.n. They probably behave similarly to changes observed after application of anti-depression medicines or after electro-shock therapy.

The attenuation of depression symptoms which occurred under the influence of extremely low temperatures can be the result of, among others, level of catecholic amines' increase in the areas of the largest concentration of noradrenergic neurons (blue place, the side part of the cover). According to noradrenergic theory of depression, intensification of noradrenergic transmission observed after application of anti-depressive medicines, which inhibit the capture of noradrenalin to neurons, is responsible for the improvement of patients' psychical state.

The results of Zagrobelny's research [8] prove the noradrenergic mechanism of anti-depressive effect of cryotherapy. It appears that the concentration of noradrenalin in serum of

women and men after one cooling process of the whole body in cryogenic chamber are much higher than the concentration of this hormone before cooling (Zagrobelny, 1993) [8]. The mechanism of increasing the concentration of noradrenalin in serum is connected with a stressful reaction caused by a rapid coolness of the body. Undoubtedly the whole body cryotherapy treatment is a strong stressful stimulus. Surveys proved the start-up of different processes in an organism which is exposed to extremely low temperature, and activation of hypothalamus structures, the increase of endogenous catecholamines release, ACTH, cortisol and beta-endorphins [8]. The role of catecholic amines (noradrenalin, and dopamine) in regulating the mood has been proved. Steroid hormones, also ACTH, also influence emotions, as they usually improve the mood. If they are applied protractedly in too large doses, they can evoke some psychical aberration, such as manic states, more rarely depressive states, dysfory, emotional lability, or even consciousness disorders and schizophrenic psychosis.

Low temperature of the surrounding stimulates skin receptors of cold, warmness, nocyceptors, and sensitive to warmness mechanoreceptors. The transmission of these impulses to o.u.n. by reflexive arcs, which are not very well known, causes the emission of corticotrophin releasing hormone - CRH in hypothalamus. CRH not only increases the emission of ACTH by a hypophysis but also activates the emission of beta-endorphins' precursor - proopiomelanocortin, and 13-endorpninum. 13-endorphins are probably also emitted from adrenal glands' nucleus (core). But endogenous catecholic amines also have their part in releasing 13-endorphins. At the end of 70s endogenous opiodic peptides were called endogenous neuroleptics. In the light of contemporary data the activation of central opiodic neurons influences inflectionally processes connected with learning, memory consolidation and recalling, acting directly through noradrenergic and serotoninergic neurons. A lot of data indicate that opiodic receptors are placed on the endings of presinaptic dopaminergic neurons. Endogenous opioids decrease the emission of dopamine by activating these receptors. This leads to compensatory intensification of dopaminergic transmission. Dopamine influences the prize system in brain. Its deficiency can cause the loss of joy of life and abilities to feel pleasures. Opioids decrease also the emission of noradrenalin in some brain structures, modulate the emission of acetylcholine and increase the emission and revolutions of serotonin. Their role in psychosis' pathogenesis and treatment is not known, however the discovery of endogenous opioid system gave new prospects in c.u.n. researches. First casuistic operations, which indicated anti-depressive influence of 13-endorphinum was published by Kline in 1979. The hypothesis, that depressive syndrome correlates with the decreased activity of opiodic systems, is also confirmed by the research of electroshock mechanisms. This kind of treatment causes a significant increase of 13-endorphinic system's activity. In Zagrobelny's research it was shown that the concentration of 13-endorphinum in women and men's serum was after the cooling process in the chamber significantly larger than the concentration of this neurohormone before the treatment. It can be assumed that the series of ten

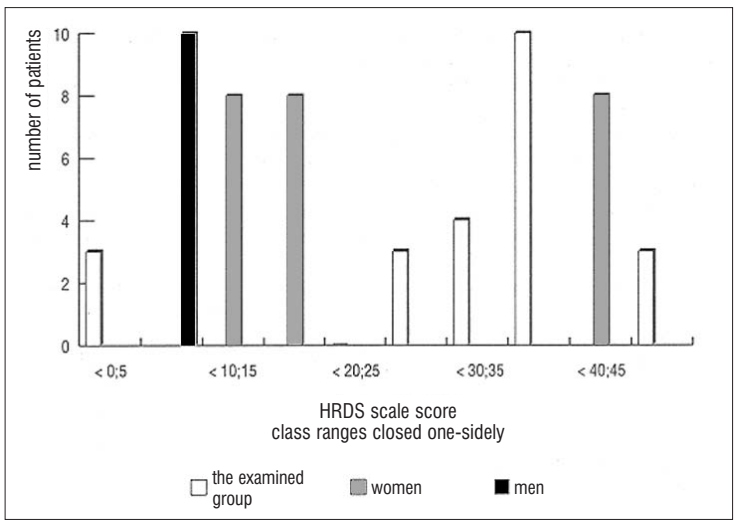

Fig. 3. Distribution of points sum HDRS before and after the whole body cryotherapy.

treatments of the whole body cryotherapy caused bigger secretion of 13-endorphines in o.u.n. than the average.

Sleep dysfunctions which were reduced the most in this research are the indication of hypothalamus regulatory system and brain stem dysfunctions. Low temperatures can lead to normalization of functions of these brain structures and changes in serotonin system. This hypothesis can be proved also by the fact that clinical picture of sleep dysfunctions at IN people with depression is similar to sleep dysfunctions observed with the application of compounds which perturbs serotonin's synthesis. The increase in serotonin's synthesis by application of big doses of its precursor - L-tryptofan, makes the process of falling asleep quicker and decreases the number of waking ups during the night. Serotonin is transformed in pineal gland into melatonin which plays a big role in regulation of the cycle - dream-wakefulness. Clinic research indicates that the inhibition of reflexive capture of serotonin in synapse correlates positively not only with anti-depressive effect but also anti-fear and calming down effect.

An interesting thing observed during the following research was the fact that after completing a series of treatments WBCT, there was a significant improvement in libido. The gathered data suggest, however, that the change in this parameter should concern mainly men. In this research the change covered both sexes equally. According to Zagrobelny, who measured the concentration of testosterone in serum before and after one treatment of cooling the body, these concentrations were almost similar as far as women are concerned but men had the concentration of testosterone significantly higher after the cooling [8].

Disorders in menstruation cycle during the depression were also normalized. It seems that this fact has to be explained by the rationalization of hypothalamus functions, as it was in the case of biological rhythms disorders. Other mechanisms, which have not been proved so far, can also have some influence on mood after the application of the whole body cryotherapy.

The permanency of cryotherapy effect on treating depression is not known. At the time of finishing the observations the sick who took part in the research still felt better psychically, similarly to the effects after the last of the series of treatments. It suggests the durability of the effects of the treatment and can be an additional argument to continue this research.

The above ideas and the results of the pilotage research let the authors assess the application of low cryogenic temperatures as an additional help in psychic dysfunctions' therapy.

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Changes of level of immunoglobulins and C3 and C4 proteins in serum during whole body cryotherapy

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Abstract: A new direction of treatment is a cryotherapy, especially a systemic cryotherapy using low temperature chamber. The induction and causing organism's physiological reactions on cold leads to the creation of advantageous circumstances of rehabilitation proceeding, which is not encounter while using impulses other than cryogenic temperatures (from -110°C to -180°C). The influence of systemic criotherapy on immune system of patents was tested. We shoved some fluctuations of the levels of IgA, IgG, IgM and C 3 and C 4 proteins in the serum during whole body criotherapy. The concentrations of immunoglobulins and complement proteins sigificantly raised in the first half of series of whole body cryotherapy and never fell down below initial level during all therapy.

Key words: cryotherapy, immunoglobulins, complement.

A new direction of treatment is a cryotherapy, especially a systemic cryotherapy using low temperature chamber. The induction and causing organism's physiological reactions on cold leads to the creation of advantageous circumstances of rehabilitation proceeding, which is not encounter while using impulses other than cryogenic temperatures (from -110°C to -180°C). Using exercises and kinesitherapy we can strengthen our organism in respect of efficiency and immunity [1, 2, 4, 8]. The improvement of general feeling, increasing of circulation, better tightness of capillary system, increase the force of muscle are the easiest to measure outer attributes and effects of cold therapy and exercises. The rehabilitation of ill people using low temperatures generally and locally is being performed in Wroclaw's centre since several years and so far experience shows its very high effectiveness of various illness treatment. It is still an innovative therapy and the specification of low temperature rehabilitation work mechanism on effecting human organism is extremely important and can help in verification, improvement and wideness of treatment methods.

Cryotherapy is non-invasiveness application of cooled to extremely low temperatures air, vapours of liquial nitrogen, cooling locally or systemic the radiation of integument of body, for time period not exceeded their 3-minutes exposition. Sudden cooling almost "suction" relatively very small amounts of warmth from tissues is strong enough local or systemic impulse, which activates local or central reactions and thermoregulatory centers for preservation, redistribution of temperature and - when it is necessary - to its production.

The cooling of organisms localy or whole-body is one of modern methods of treatment and rehabilitation of patients affect with rheumatoid arthritis diseases [1, 2, 4, 8].

The effects of extremely low temperatures action are extraordinary differential and wide. For patients which are subjected to cryotherapeutic procedure (local or systemic) can be observed different symptoms such as healthy muscles relaxation and increase of their strength, and also the reduction of muscles spasticity, when it exist, increase of secretion of ß-endorphin and improvement concentration of neurohormones [3, 6].

Table 1. The concentrations of immunoglobulin and complement proteins in sera.

Immunoglobins and complement proteins	Time [day]	Mean of concentration [mg/dl]	Standard deviation [SD]	Pearson's correlation	
				coefficient	probability
IgG	0	1216,67	298,23	-	-
	5	1386,26	392,68	0,96	0,001
	12	1281,35	281,95	0,93	0,002
	19	1301,30	344,45	0,74	0,060
	49	1269,88	270,09	0,75	0,054
IgA	0	277,40	62,08	-	-
	5	297,11	47,77	0,85	0,015
	12	288,19	62,43	0,54	0,210
	19	272,20	56,64	0,41	0,360
	49	269,17	62,62	0,53	0,220
IgM	0	174,44	59,50	-	-
	5	194,98	77,75	0,87	0,010
	12	198,47	59,96	0,74	0,060
	19	195,76	52,40	0,94	0,002
	30	178,44	59,50	0,87	0,010
C3	0	141,42	29,15	-	-
	5	149,76	30,04	0,81	0,030
	12	152,05	30,04	0,94	0,002
	19	139,44	20,92	0,53	0,213
	49	142,23	15,91	0,20	0,670
C4	0	29,28	6,56	-	-
	5	32,12	7,26	0,50	0,240
	12	30,67	8,01	0,31	0,490
	19	24,80	6,29	0,46	0,290
	49	26,65	4,68	0,40	0,37

Widely presented research results determine systemic cryotherapy effects by indication and comparison of heamodynamics index, the level of proteins and the measurement of organism effort tolerance. Most of those relays were stated on patiens directly after procedure or only after short series of entries to the freezing chamber. The data regarding cryotherapeutic procedure running in longer time period are published occasionally [5].They do not give any objective and straight answer to the question what would be the effects of e.g. the changes of the level of hormone and the level of serum protein with reference to the essential physiological processes and how long those functional changes can be observed [9].

By exposition of the organism to the extremely low temperatures the level and enzymatic activity of system proteins can be modified indirectly impacting on opsonisation and phagocytosis processes effectiveness, incorrect activation of C3 component, antibody level (IgM mainly). In consequence the degree of activity of complement system and level of bactericidal activity of serum can change[5].

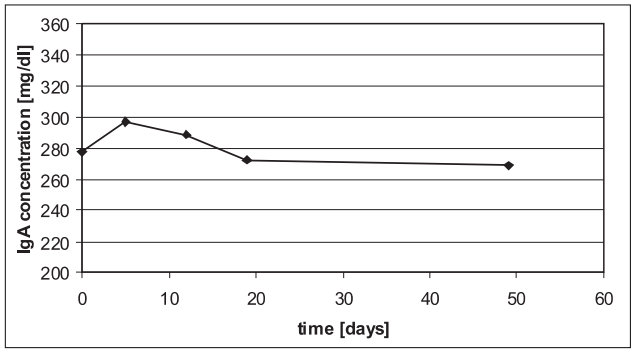

Fig. 1. The level of immunoglobulin A in serum.

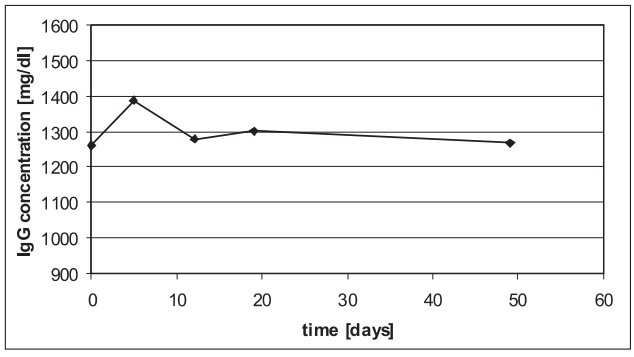

Fig. 2. The level of immunoglobulin G in serum.

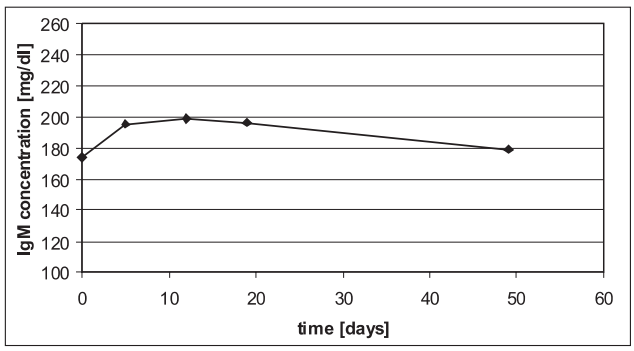

Fig. 3. The level of immunoglobulin M in serum.

Materials and methods

The research was based on entering the freezing-chamber by examined group of seven healthy people subjected to three series of systemic cryostymulation procedure within three cycles. Each cycle included five daily entries from Monday to Friday, together 15 exertions. In each cycle the freezing-chamber (from -110°C to -180°C) and staying time (from 2 minutes to 3 minutes) was respectively changed. A blood was sampled from elbow vein on the first day of each cycle before entry into the freezing-chamber and on the fifth day after the procedure termination. After 30 days from finishing the last cycle the blood samples of each individuals were taken one more time (49 days from the begining of the treatment).

The level of serum proteins; immunoglobulins Ig A, IgG, IgM, and constituents of the complement C3 and C4 were detrmined by the Mancini method. Briefly, the plates with

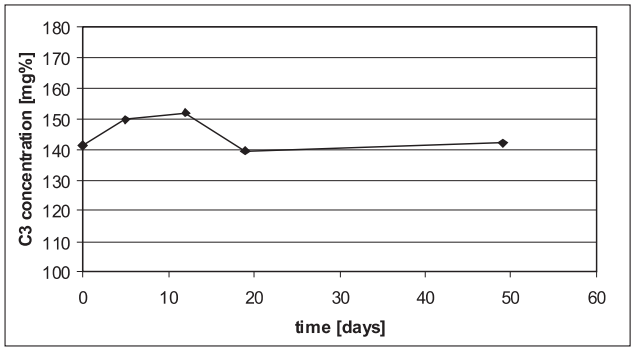

Fig. 4. The level of C3 protein in serum.

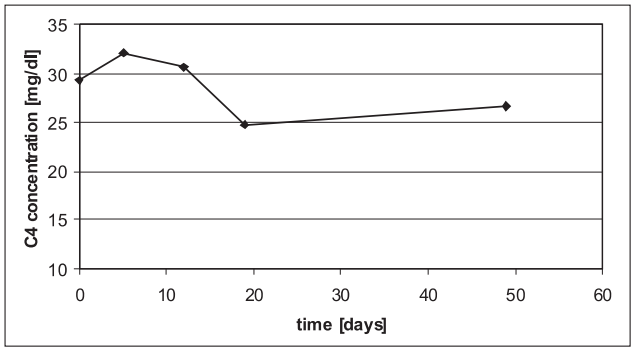

Fig. 5. The level of C4 protein in serum.

agar gel with monospecific, polyclonic antibodies against a particular protein of ME-GA-TRADING limited company (Gliwice) were used. The examinations were done according to producer's instructions by putting into sumps agar of 5 μl of the examined serum and incubation of plates for 48 hours in temperature of 20 degrees centigrade. The diameter of the precipitative ring was measured with the help of nomogram MEGA. The concentration of a given protein was read in the concentration table enclosed by the producer.

Results

The levels of immunoglobulin in each time interval during whole body therapy are presented in Table 1 and visualized on Figures 1, 2, and 3. The level of IgG and IgA increased significantly after 5 days of cryotherapy in comparition with the starting level. During the following cycles the concentrations of IgA slowly declined and after 49 days reached the value of initial serum level (Figure 1, 2). The IgM value hold up on raised level after 5, 12, 19 days of therapy (Figure 3).

The complement proteins C3 and C4 showed similar changes of concentrations like as IgA immunoglibulins (Figure 4, 5). All tested parameters reached the initial levels after 49 days of cryotherapy.

The relationship between the level increase of tested serum proteins, time and number of cycles of cryotherapy was indicated by Pearson's correlation. This dependency was linear for all classes of immunoglobins and C4 protein during the first five days of therapy ($p < 0.05$). The C3 protein concentration increased significantly during 12 days ($p < 0.05$). It was proved that the low temperatures have the influence of immunodeterminants direct in the act of the cryotherapy. The presented above results are a starting point for further investigations and precisely done analysis of obtained results will enable the objective evaluation and verification of actually used therapeutic procedures. It will also enable the elaboration of correct and modern methods of low temperature therapy and continuous modifications of those methods to get the best effects in both the biological restitution and the treatment of numerouspathological changes.

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Application of cryotherapy in fibromialgia (FMS) treatment

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Abstract: The possibility of systemic cryotherapy usage in fibromyalgia treatment was analysed. The results of own researches were presented.

Key words: systemic cryotherapy, fibromyalgia

Introduction

FMS is an disease characterized by persistent arthrodynia and myalgia and also tender points painfulness (Fig. 1). The frequency of prevalence in Poland is evaluated at 4% for adults. The etiology of disease is unknown. The genetic predispositions, dyssomnia, abnormal concentration of serotonin, somatomedin C, prostoglandine E2 and disorder of hypothalamus-hypophysis-adrenal glands axis were considered in seeking of pathogenesis [1-6].

The main ailments of patients suffering from primary FMS are persistent arthrodynia and myalgia, sensation of rigidity muscular weakness, dyssomnia and according to American Rheumatologic Board, tenderness of 11 from 16 tender points. Pains are localized in muscle-tendon attachment region including mostly shoulder and pelvic girdle as well as upper and lower segment of spinal, chest, rarely elbow, tarsal, hands or mandible jonts (Fig. 2) [7, 8].

In recent years the increase of FMS interest has contributed to researches and reports to the point of disease etiopathogenesis development. The researches of the role of FMS pathogenesis transmitters have been undertaken as well. Investigations that were carried out proved reduced concentration of tryptophan, serotonin and endorphin in serum. The reduced level of somatomedin in serum C (IGF-1) was revealed by Bennet and co-workers. Other researches suggest disorders of hypothalamus-hypophysis-adrenal glands axis what leads to decrease of cortisol excretion in 24-hour urine [3, 4, 7]. Nevertheless, because of unclear causes and mechanisms of disease development, possibility of effective treatment of patients suffering from primary FMS are limited. It is recommended to apply painkillers, nonsteroid, anti-inflammatory drugs that relax muscles, simultaneously with physiotherapeutic procedures [7, 8]. The very good analgesic and relaxing effect that facilitates kinesitherapy is observed after systemic cryotherapy procedures.

The aim of the research

The preliminary examinations:

- The usefulness of systemic cryotherapy in FMS treatment evaluation.
- The demonstration of cryorehabilitation influence on course of a disease and evaluation if the method represents only symptomatic treatment or modifies the course of a disease.

Scheduled examinations:

- ditto,
- ditto.

- The influence of cryostimaulation on selected biochemical indexes of patients suffering from FMS examination, i. e. the level of serotonin, P-substance, beta-endorphin, somatomedin in serum C (IGF-1), concentration of calcitonin, cortisol, prolactin and estradiol in serum.
- The role of biochemical selected parameters in hyperalgesia evaluation.

Material and methodology

The group of 15 women (10 have finished the test) at the age of 26-54, in case of which, in accordance with criterions of the American Rheumatologic Board (ACR), the primary FMS was diagnosed were subjected to examination [7].

Patients were qualified for further researches by The Institute of Rheumatology of Medical Academy in Wrocław. The women were subjected to 2- and 3-minute procedures of cooling the organism in temperature from -110 to -150 Celsius degree, at the physiotherapy faculty of Academy of Physical Education in Wrocław. The aim of the program, which lasted 4 weeks, amounted to 20 procedures of systemic cryotherapy, and one hour gymnastics, according to detailed planned patterns of loosen, calming and the whole organism efficiency improving exercises, after procedure.

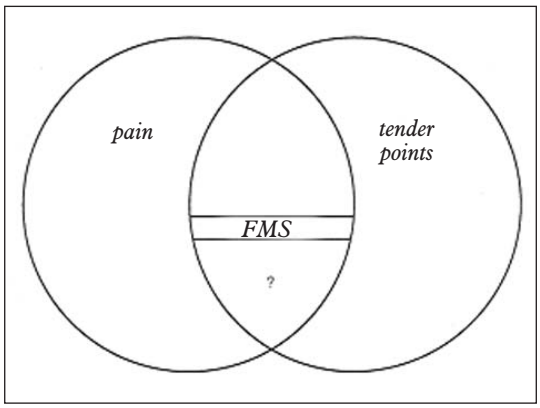

Fig. 1. Relationship between pain and occurrence of tender points.

The inquiry examination, that was performed, concerned:

- the character, intensity of ailments and disease duration,
- patients' physical efficiency,
- course of a disease.

Cryotherapy efficacy, before, after 10 and 20 procedures, according to VASP, that is Visual Analogical Scale of Pain (0-lack of pain, 10-very intense pain) was evaluated by examinations of intensity and ailments localization.

After finishing the research program patients estimated their health state as:

- high deterioration,
- deterioration,
- lack of meliorations,
- change for the better,
- significant betterment.

Results

Results of inquiry examin ation:

	percentage improvement of health (%)
myalgia	100
arthrodynia	100
body rigidity	60
oedemas	50
headaches	100
vertigos	40
diarrhoeas and constipations	10

cryaesthesia	40
tiredness sensation	100
sleep disorder	70
emotional lability	60
dissatisfaction with life	10
dyspasia (stairs)	80
difficulties with every days duties performing	30
lack of physical activity	60
painkillers administration	80

Pain intensity

The average intense of perceptible pain was evaluated according to analogical scale 0-10. It amounted to 4,6 before therapy, 5,2 after 10 and 3,1 after 20 procedures.

Pain localization

The number of tender points before procedure amounted to 12, 4, 8, 1 after 10 procedures and 5, 9 after 20 procedures.

The subjective estimation of patient

All of patients affirmed their health state has improved after 20 procedures.

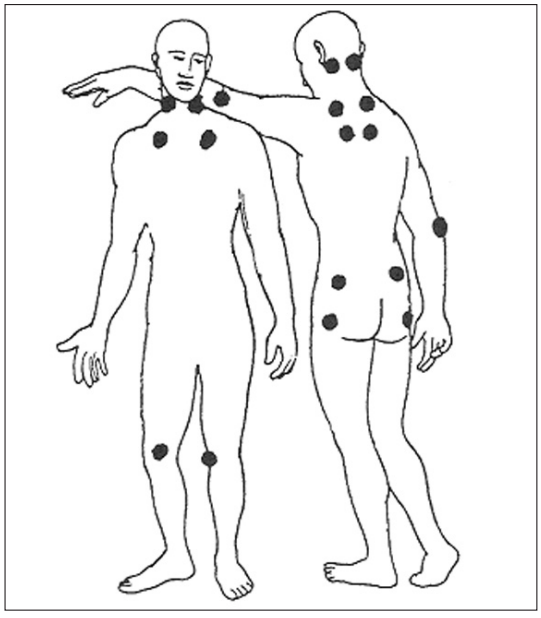

Fig. 2. The number of tender points in primary FMS according to American Rheumatologic Board.

Discussion

The inquiry examination that were carried out proved the presence of characteristic of FMS symptoms such as persistent arthrodynia and myalgia, tender points painfulness, body rigidity, decrease of muscular strength what affect unfavourably general efficiency of organism, sleep disorder, emotional lability and others dysfunctions.

The initial observations of cryotherapy influence on patient suffering from FMS, showed significant alleviation of pain ailments from 6,4 to 3,1 according to the scale as well as improvement of clinical state. The Visual Analogical Scale of Pain was used which is somewhat simplified but fairly easy way of receiving experimental data. The number of painfulness tender points decreased significantly, from 12,4 to 5,9 points after 20 procedures, as well.

The mechanism of analgesia, under the influence of extremely low temperatures, relies probably on blocking the passage of pain impulse within spinal cord so as not to reach cerebral cortex. The endogenic opioid system is also mobilized that is inter-systemic beta endorphin production [9, 10].

On the basis of preliminary observations on ONE may say that cryostymulation has significant impact on decreasing of pain and can be one of the most effective method of FMS treatment. The examination of 50 patients permit to develop additional, effective way of FMS treatment. The monitoring of some biochemical parameters concentration will contribute to:

- explanation of observed symptoms pathogenesis,
- determination of some factors in hyperanalgesia,
- confirmation of treatment efficacy.

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Antinociceptive effect in rats induced by the cooling of their whole body

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Abstract: The effect of rats' whole body cooling on their reactivity to the thermal nociceptive stimulus was determined by means of a hot-plate test. It has been found that a single exposure and a four time daily exposure to a cold temperature (-90°C) induced a significant antinociceptive effect. A possible mechanism of this effect was discussed.

Key words: cryo-treatment, cryogenic chamber, antinociceptive effect, rats.

Introduction

The development of the whole-body cryotherapy of patients with rheumatoid arthritis has been observed since 1980s [1,2]. This method of therapy was also widely used for the treatment and rehabilitation of patients suffering from other: degenerative and posttraumatical syndromes of arthromuscular system as well as the rehabilitation of patients after a stroke [1]. Among the numerous beneficial effects the antinociceptive activity, and the increase of ACTH, cortisol and ß-endorphin serum levels were observed [3].

The aim of the present study was to prove an experimental model the antinociceptive effect of the cryotherapy. Therefore the effect of the whole-body cooling in rats on their reactivity to the thermal nociceptive stimulus was determined.

Methods

Experiments were performed on adult male Wistar albino rats obtained from the Animal Farm of the Medical University of Silesia. During the experiment the animals had free access to tap water and a standard diet (Murigran, Motycz, Lublin). Animals were divided in the following experimental groups:

1. Control, untreated rats.
2. Rats exposed to 1 min in cryogenic chamber (cold air of -90°C) every day of the week (Monday to Friday) for two weeks. For the time of the cooling rats were placed in the cryogenic chamber in the individual wooden cages of our own construction. The dimensions of the cage were: 30 cm long, 21 wide and 15 cm high.
3. Rats were exposed to cold air in the cryogenic chamber in the same way as the animals of the previous group, but 40 min before the exposal on the 1st, 4th, and 8th day of the experiment they were injected ip with naloxone hydrochloride (Polfa, Warszawa, Poland) at a dose of 1 mg/kg.

4. Rats were exposed to cold air of -60°C in the cryogenic chamber for 1 min every day of the week (Monday till Friday) for two weeks. The same individual wooden cages of our own construction were used.

Rats were exposed to the cold air in the cryogenic chamber at the Center of Rehabilitation and Physical Medicine, Ruda Śląska, Poland.

The antinociceptive effect (latency time of nociceptive reaction) of rats was determined by means of hot-plate test [4] before and at 5, 15, 30, and 60 min intervals, using apparatus HP-41 (COTM, Białystok, Poland). Latencies were converted to percent of analgesia according to the formula:

$$\text{\% of analgesia (\% of maximal antinociceptive effect)} = \frac{T_x - T_0}{20 - T_0} \times 100$$

T_x - individual latency time determined in time intervals after administration of the peptide

T_0 - individual latency time determined before the injection of the peptide

20 - maximum latency time (in sec).

Obtained results were subjected to the ANOVA test and the post-ANOVA Dunnett's test [5]. The experimental protocol was approved by the local ethical committee of the Medical University of Silesia number 29/01 (04.09.2001).

Results

The single insertion of the rats into the cryochamber with temperature -60° or -90°C caused not large, but significant antinociceptive effect, lasting up to 15 min. after the exposure (fig. 1). After four days of low temperature treatment the antinociceptive effect was even more distinct (fig. 2). But in the 8th day of the experiment the result became unsignificant, though the mean percent of analgesia was similar to the results from the first and fourth day of the experiment (fig. 3). The pretreatment with naloxone 40 min. before the exposure to the low temperature did not influence the antinociceptive effect.

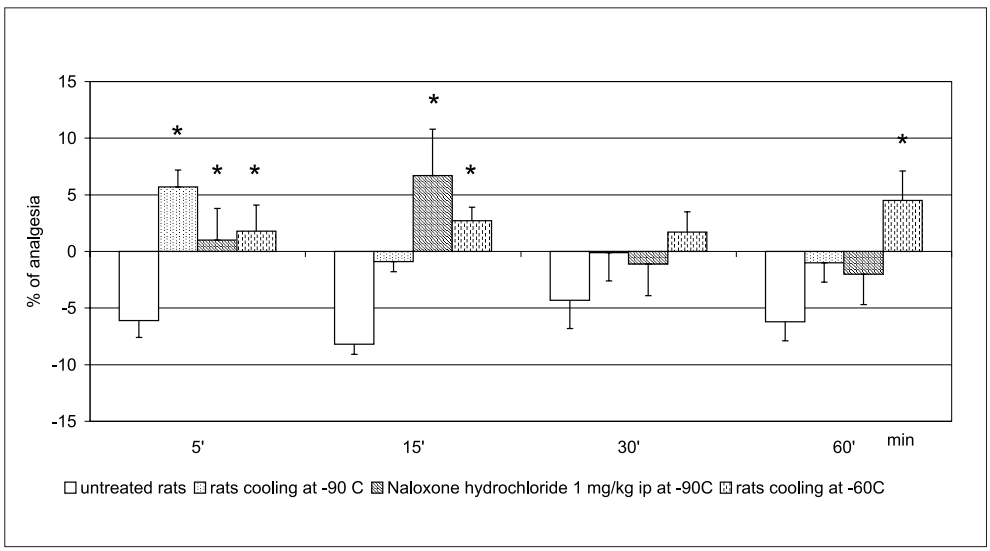

Fig. 1. Antinociceptive effect of one-fold for 1 min cooling rats in the cryogenic chamber. All groups consisted of 6 animals. (*) significance versus group of untreated rats ($p<0,05$).

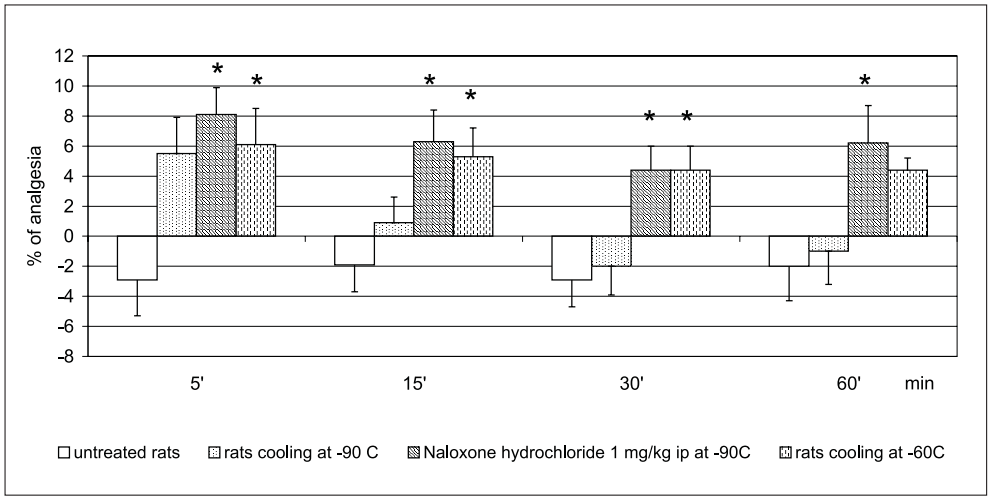

Fig. 2. Antinociceptive effect after four-time daily for 1 min cooling rats in the cryogenic chamber. All groups consisted of 6 animals. (*) significance versus group of untreated rats ($p<0,05$).

Discussion

The obtained results show that both single and two-week duration cryotreatment of rats in the cryogenic chamber causes small, but significant antinociceptive effect reaching 5-10% of analgesia factor. The results were similar after application of the air with both the -60° and -90° C temperature. This confirms the reported decrease of pain intensity in patients with rheumatoid arthritis [6, 7].

Because of reported increased b-endorphin, the endogene opioid peptide [3], serum level in patients treated with the cryotherapy, the opioid mechanism of this effect was suspected. But this effect was not influenced by the pretreatment with naloxone - the antagonist of both central and peripheral opioid receptors. This result seems to deny the mentioned mechanism.

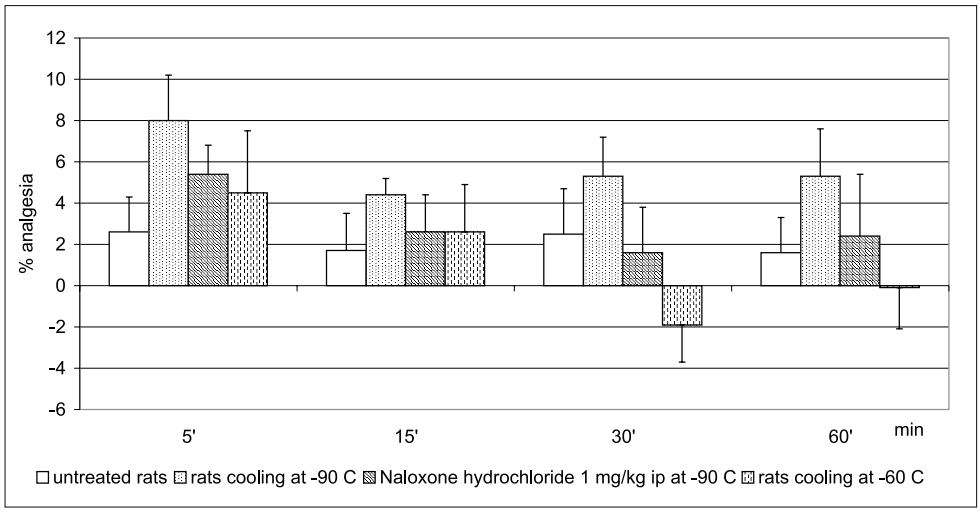

Fig. 3. Antinociceptive effect after eight-time daily for 1 min cooling rats in the cryogenic chamber. All groups consisted of 6 animals.

The second probable mechanism is the adrenergic mechanism. Bondar et al. [8] proved that the exposure of the rat body to low temperature by immersion in cold water (+2° or +15°C) for 3,5 min caused the significant antinociceptive effect. This effect was modulated by central a-adrenergic receptors. It was also proved that intraspinal noradrenaline injections cause the antinociceptive effect in rats, which is antagonised by the pretreatment with the phentolamine [7,8].

Both these experimental models of the exposure to the low temperature: cold water immersion and cold air exposure in cryogenic chamber strongly differs one of each other, so we can not exclude the participation of two different mechanisms of analgesia. Nevertheless both ways of body cooling are surely the reason of considerable stress in experimental animals.

Acknowledgements

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Influence of whole body cryotherapy on trunk muscles velocity and force parameters of men suffering from chronic backbone disorders

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Abstract: Evaluation of speed and force of trunk muscles under an influence of cryotherapy of whole body was the aim of the study. It was assumed that strength, total work, power and endurance of trunk muscles will increase. Cryotherapy of whole body decreasing pain and neuromuscular conductivity improves conditions of muscles work. Increase of all measured parameters was a result of this imoprovement

Key words: physiotherapy, cryotherapy, low back pain

Introduction

Backbone pain is a common phenomenon; it requires proper diagnosis, treatment and physiotherapy. The variety of reasons of backbone pain makes it necessary to continuously search for new methods to support the therapy effects. There are many different reasons of backbone pain, for example "sitting" style of life, reduced activity, overweight and obesity causing excessive backbone load, impropriate posture or body mechanics, injuries and repeated microinjuries. Listed factors, that never come individually, contribute to overloading and fatiguing articulation structures. Operation of forces exceeding efficiency of muscle and ligament system cause backbone damage [1-4].

Impropriate posture is a basic risk factor leading to backbone pain. Overload occurring during casual life-activities often leads to muscle imbalance between agonistic and antagonistic muscles. The imbalance causes further posture defects, various tensions, headaches, anxiety and backbone pain. Muscle relaxation is impossible while strong anxiety and vice-versa - high tonus does not foster psychical relaxation.

Improper therapy, lack of prevention as well as disrespecting initial syndromes of the disease lead to irreversible changes in motor segment structure. The reason of biggest ailments are inter-vertebra discs disease. Affictions accompanying the disease are non-homogenous and occur as pain that is deep, protracted, radiant, peracute or procracted with peracute periods. Vertebra disk disease can be imitated by various inflammable states within motor segment, eg. early stage of rigor arthritis of backbone. Such state, in opposition to vertebra disk disease, is characterized by lack of additional pain during motion and no relief while lying. Backbone retrogressive changes may also suggest a vertebra disk disease, however, that is a disease of advance age while vertebra disk damages are domain of young and middle-age people [1-4].

Protracted backbone diseases result in perturbations of trunk muscles functions that followingly lead to intensity of changes in backbone areas. Objective of physiotherapy

is to cut this vicious circle by optimization of muscles performance. Only for a reason of huge amount of methods and techniques applied in modern therapies of pain syndromes, choice of a proper method is a difficult task.

One of factors supporting physiotherapy is a system cryotherapy. It is an efficient and non-invasive method that uses physiological abilities of organism and is well tolerated by patients. Low temperatures (from -110 to -160^{o}C) cause many reactions of organism that enable intensive kinesitherapy and improve its effectiveness. Among many local and system physiological reactions for low temperatures, there are: decrease of pathological tension of muscles and increase of muscle strength [5-8].

Evaluating efficiency of treatment of patients suffering from motor organs diseases, the malfunction parameters that are most difficult to determine are: evaluation of pain and examining muscles strength. Pain is difficult to determine as it is individual and subjectively felt and every person experiencing pain describes it differently. Pain perception and patient's behaviour is influenced not only by nocyceptic reaction from damaged tissue but many psychological, environmental and physiological factors, as well [8-10].

Fig. 1. Example of izokinetic examination of backbone extensors.

Fig. 2. Example of izokinetic examination of backbone flexors.

Determining muscle strength causes equally serious troubles. Methods available up to now have been based either on subjective evaluation in Lovett scale or dynamometric methods in condition of muscles static performance. Recent development of active dynamometry enables izokinetic evaluation of muscle capability of concentric and eccentric operation. Due to this method muscle strength, power, resilience, tiredness, relations between muscles and many other parameters can be evaluated in dynamic conditions at determined velocity and constant resistance. Application of izokinetic research gives very precise data upon biomechanical properties of muscles. It allows to reliably analyze many obtained functional muscles parameters not only on the diagnosis stage but also selection of mobility parameters, treatment monitoring and specifying treatment effectiveness [11-13].

The main goal of this research work was to evaluate changes of velocity and force parameters of trunk muscles as well as intensity of pain ailments of patients with protracted backbone affections after physiotherapy applying system cryotherapy.

It was assumed that combining system cryotherapy with kinesitherapy may beneficially influence muscles function that brings about moment of force, operation and power of the muscle as well as relations between muscles. It was also presumed that obtained results would be to a high degree dependent on lower pain threshold.

Material and research methods

In Pracownia Krioterapii i Leczenia Obrzęków Niezapalnych AWF we Wrocławiu (Laboratory of Cryotherapy and Non-ignitable Edema Treatment at the Academy of Physical Education in Wrocław), 37 patients (25 females and 12 males) aged between 38-72 (at the average 56) were a subject of research; 26 patients with diagnosed backbone protracted retrogressive changes, 11 patients with inter-vertebra discs disease.

All of the patients were qualified to physiotherapy consisting of system cryotherapy and physical exercises. System cryotherapy was performed in cryotherapy chamber in

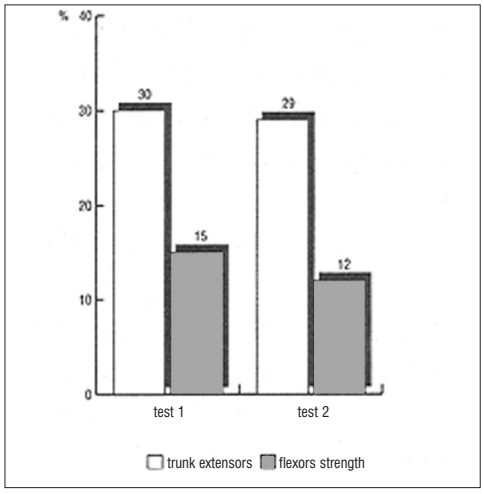

Fig. 3. Improvement of maximal moments of force after applied treatments in percentages.

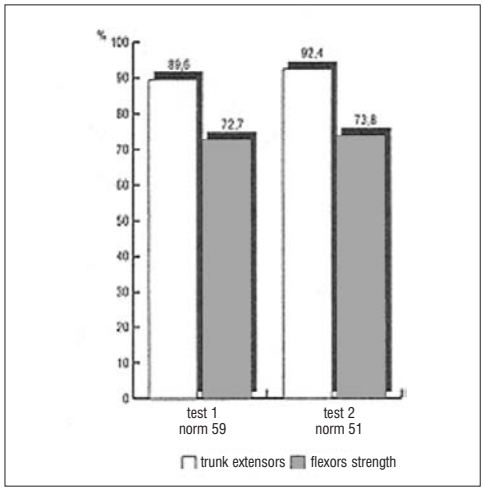

Fig. 4. Improvement of maximal moments of force after applied treatments.

temperature of -110 to -150°C in time periods of 1-3 minutes and at oxygen concentration level of 21-22%. 10-30 treatments were carried out (at the average 21) five times a week. Directly after coming out from cryotherapy chamber, 45 minute gymnastics was performed at the gym. The gymnastics included, among others exercises, improving range of mobility and normalizing muscles operation due to strengthening, relaxing as well as exercises improving posture and balance.

All of the patients were examined at a stand for izokinetic research Multi Joint 3 (by Biodex) in relation to check activity of backbone extensors and flexors before and directly after the last system cryotherapy treatment. Every time, standard tests were carried out at velocities of 900/s (test 1) and 1200/s (test 2).

The research were conducted according to particular procedure including a warm-up, positioning of a patient and stabilization, oral instruction explaining the way of carrying out the test, control trial, conducting the test at defined velocity, 5-10 repetitions of movement and a rest of 10 sec. between the tests. For izokitetic tests evaluation, authorized computer software and IZOMAP program for graphic presentation of results were applied.

Tested muscles were divided into two groups: group I - backbone extensors (Fig. 1) and group II - backbone flexors (Fig. 2).

To determine level and intensity of pain, visual and analogue scale (VAS) was applied. Patient specified intensity of pain ailments using 10-degree scale, before and after applied physiotherapy (0 meant no pain at all and 10 - pain impossible to bear).

Results of research

In the test 1 comprising 31 patients (84%) improvement of extensors operation and in case of 27 patients (73%) of flexors operation was observed, whereas in the test 2 the improvement concerned 29 patients (78%) and 27 patients (73%), accordingly. Maximal moment of force of extensors in test 1 increased after physiotherapy by 50.1 Nm and in case of flexors by 16.7 Nm. At higher angular velocity (1200/s - test 2) examined moments of force increased by 44.2 Nm and 12.7 Nm, accordingly. Absolute work of flexors increased by 46.2 J and 47.9 J, accordingly. Average power of extensors grew up 1 by 54.3 W in test 1 and by 58.1 W in test 2. Power of flexors increased by 15.5 W and 23 W, accordingly (Table 1, Fig. 3).

Ratio of trunk extensors to flexors strength should equal 59 in test 1 and 51 in test 2. Assigned muscle ratios distinctively differed from the standard, even though they improved after applied treatments: from 89.6% to 72.7% in test 1 and from 92.4% to 73.8% in test 2 (Fig. 5).

Talking over the results and discussion

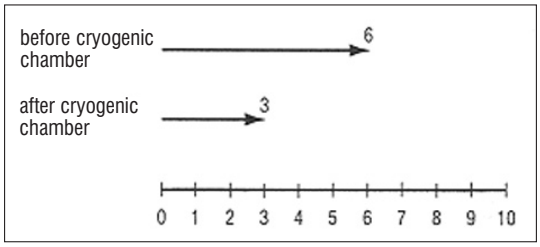

Fig. 5. Decline of pain ailments after applied treatments.

Physiotherapy with system cryotherapy application had essential impact on changing velocity and force parameters of examined muscles as well as feel of pain of patients suffering from protracted backbone affections. Analysing influence of extremely low temperatures on human body, it was found that analgesic reaction comes first. In The examined group of patients this effect was observed very distinctively - pain decreased from level 6 to 3 in a VAS scale.

Stimulation by cold makes cerebral gland to emit factor releasing precursor of beta-endorphin, i.e. prepiomelanocortin and beta-endorphin itself as well as ACTH. Beta-endorphins are probably also emitted by adrenal glands. Analgesic and euphoric effect of cryotherapy resulting from operation of endogenous beta-endorphins lasts about three hours.

The mechanism of analgesic effect has been discussed in chapter 3, System cryotherapy.

System cryotherapy treatment is followed directly by increase of blood flow and oxygen concentration in cell environment. Chemical reactions can undergo from oxygen-free to oxygen reactions and cell pH shifts towards inert. Such conditions favour decreasing concentration of lactates and histamine and this way alleviates pain [5, 9, 14, 17].

In conducted izokinetic researches of muscles strength, distinctive tendency to improve velocity and force parameters in backbone area were shown. Analysis of relations between moments of force of backbone extensors and flexors in both tests showed considerable attenuation of extensors strength. These proportions were varying between 89 and 92%, whereas proper values should equal 51-59% depending on velocity. More than 3 times higher increase of moment of forces of extensors comparing to flexors confirms that thesis, as well. It brought us to approaching ratios of examined muscles to proper values. That proves that in physiotherapy of patients with protracted backbone affections, strengthening extensors is the most essential issue. It is also confirmed by values of total work and average power of examined muscles. Whereas values for both groups of muscles were at the similar stage before physiotherapy, after the session the

Table 1. Change of velocity and force parameters of trunk muscles under influence of applied treatment.

Detailed list	Cryotherapy	test 1 - 90		test 2 - 120	
		extensors	flexors	extensors	flexors
Moment of muscular force [Nm]	before	117.1	105.0	107.2	99.1
	after	167.2	121.7	151.4	111.8
Absolute work of muscles [J]	before	311.7	311.0	236.8	246.7
	after	479.6	357.2	379.8	294.6
Average power of muscles [W]	before	98.5	99.9	89.5	96.3
	after	152.8	115.4	147.6	11.3
The ratio of trunk extensors to flexors strength	before	89.6	norm 59	92.4	norm 51
	after	72.7		73.8	

parameters for extensors exceeded ones for flexors by app. 25% not only at velocity of 900 but 1200, as well. Obtained changes of velocity and force parameters of trunk muscles are mainly an effect of total withdrawal or distinct decline of pain as well as normalization of excessive tension of trunk extensors as an effect of cryogenic temperatures operation and exercises. Conditions of muscles performance were improved as muscles in pain and improper tension could not release their full strength that results in disturbance of their action [6, 14, 17, 18].

Lowering feel-mobility conduction and tension may be another reason of improving velocity and force parameters of muscles. Long-time cramp requires alternation of motor units operation, due to which one set of cramped fibres frees another from the cramp and every stimulated fibre of motor unit, cramps maximally according to the rule "everything or nothing". If muscle operation is long and engages many motor units, muscle dives into tiredness and is unable to work effectively. Lactic acid arises that results in handicap of a muscle conduction and causes cramp. We meet such a phenomenon in case of defence mechanism of a muscle resulting from pain. Cryotherapy declines nerve conductivity that causes drop of muscles tension and rest. Also intensified blood flow through acidified muscles hastens carrying lactic acid and products of metabolism away that leads to shortening required time of rest. Described phenomenon probably allows engaging more motor units during cramp and in this way enables growth of maximal moment of force, absolute work and average power of muscles [5, 6, 8, 9, 16, 17].

Improvement of functional muscle capabilities might be explained in another way, too. Cryogenic temperatures decrease conductivity of neocyceptic neurons, especially C-fibres. Reduced inflow of pain stimulants to spinal cord may explain segmental hamper of gamma-motoneurons stimulation and muscle tension decrease.

It might be possible that decline of nerve conductivity also causes some kind of blockade of motor plate, that is decrease of reactivity of peripheral feel and motion nerve endings including Golgi apparatus in the fibres as well as nerve-muscle spindles [5, 6, 10].

Conducted electromiographical researches suggest further explanation of muscles strength growth due to low temperatures performance. Analysis of frequency of endurance test showed an increase of muscle strength (expressed in recorded frequency) after cryotherapy. Extremely low temperatures have positive impact on motor discharging and in this way increases an amount of motor units taking part in work leading to growth of muscles strength [5, 6, 11].

Conclusions

Treatments of system cryotherapy included in the recovery process caused essential pain decrease.

System cryotherapy significantly influenced growth of a moment of force, total work and average power of examined muscle groups, that caused improvement of relations between moments of force of antagonistic muscles.

System cryotherapy, with its analgesic properties, moderating nerve-muscle conductivity and decreasing excessive muscles tension, creates better conditions for muscles performance.

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Cyrotherapy in treatment and rehabilitation process of multiple sclerosis patients

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Abstract: The abilities of cryogenic chamber in rehabilitation of patients suffering from multiple sclerosis were used. The initial results of carried out researches were presented.

Key words: cryotherapy, multiple sclerosis

Introduction

Multiple sclerosis (sclerosis multiplex, SM) is multifactor, heterogenic and partly unspecific disease. Disease process is placed in central nervous system, where focus of demyelination with sequent proliferation of fibrous glia are created causing various neurological symptoms. Its quantity and variety is a serious therapeutic problem in neurology and rehabilitation field. For these reasons treatment process must be comprehensive and should include individually planned pharmaceutical therapy, psychotherapy, kinesitherapy and physical therapy [2, 4, 5].

Indications to kinesitherapy of multiple sclerosis patients are very wide and they are a result of symptoms variety, kinetic defects and exacerbation of disease degree.

Utter contraindication for rehabilitation are:

- new attack of disease or long lasting exacerbation of disease,
- active phthisic process,
- circulatory insufficiency.

Sclerosis multiplex is characterized by great variability with exacerbation and remission periods. Lapse of time between attacks of disease is individual and range from several weeks to several years. Increasing of efficiency should be applied from first exacerbations of disease and during disease, with intensity and state of disease adjustment. While periods of exacerbation, kinetic activity should be limited, restricted to bed kinesitherapy or even interrupted completely.

Compete rehabilitation process is started in remission of disease periods and should include main disease symptoms, such as: spasticity, reduction of muscle strength, contractures, limitation of joint mobility, incoordination, intention tremor and pathologic myasthenia gravis.

Application of physiotherapy in treatment process of SM patients is relatively rare. Cyrotherapy, diadynamic, electrostimulation and ultrasounds are recommended. The spasticity is lesser, the pain is alleviated and blood follow FLOW is improved thanks to these procedures [2, 4, 8].

Cyrotherapy is treatment method based on application of extremely low temperatures. Cyrotherapy appliance is recommended because of its analgesic,

antihydropic, antihemorrhagic, decreasing muscular tone activity. Increase of blood flow in tissues causes increase of oxygen concentration (pO2), which leads to supply greater amount of oxygen to muscles and connects with pain alleviation through decrease of lactates and histamine concentration. Increase of endorphin concentration and decrease of bradykinin and angiotensin concentration - compounds responsible for pain sensation - is observed. Cold influence on nervous conduction of nociceptive tract, especially non-myelinated free ending fibers, is additional inhibitory pain factor.

Advantageous low temperatures activity effects on muscle tone decrease. Physiological mechanism is not fully recognized. It is probably connected with speed decline of nervous conduction and with reactivity decrease of peripheral sensomotor ending, also responsible for specific receptors of muscle tone regulation - Golgi apparatus placed in tendons and neuromuscular spindle in muscles. Obtained decrease of muscle tone further increasing of efficiency in spasticity states [1, 3, 6, 7].

The aim of the research

Designation of applied cyrotherapy and kinesitherapy influence on multiple sclerosis patients is the aim of the work.

Detailed research process has been planned, which has described neurological, neurophysiological changes, and also metabolism changes, in objective and exact way.

Clinical material and applied physiotherapy method

Clinical material has been consisted of 28 patients with unquestionable diagnosis of multiple sclerosis, in remission of disease period. Patients have been pointed by SM Outpatient Clinic. There has been 10 women (35%) - age average 35-, and 18 men (65%) - age average 40, chosen among the patients. Average disease duration has been 7.2 years. Every sick person has been ambulant (1.5-6.5 grade of EDSS scale), in 25 cases spinal symptoms has been predominant , in 3 cases - cerebellar syndrome has been predominant.

Patients have been undergone treatment and rehabilitated in Outpatient Clinic and in Cyrotherapy Laboratory of Rehabilitation Institute of Physical Education Academy in Wroclaw. SM patients have been undergone whole body cyrotherapy in low-temperature chamber for 5 days, in temperature from -110^{o}C to 118^{o}C, each time from 1.5 minutes to 3 minutes, 2.2 minutes average.

Patients have been rehabilitated according to individually planned scheme for 1 hour directly after cyrotherapy. The scheme has included strength and general physical condition efficiency, also coordination, balance, alternating movements, maintenance of full range active movements, muscle tone normalization and walk efficiency.

Increasing of efficiency in deep paresis cases begins with adjunct exercises. Active exercises in isolated positions have been conducted in cases of greater muscle strength. Resistant exercises or exercises with equipment are applied for muscles, which strength has been higher than 3 in Lovett's scale. In these cases, condition exercises have been realized by riding a bicycle strengthen work of upper and lower limbs.

Relaxing exercises have been used in spasticity controlling and began with muscle tension without making limb movement and in the next step active muscle relaxation. Jacobson training or H.J. Schulz autogenic training has been used. Exercises in case of increased muscle tone have started with the less spastic muscles. Passive and active relaxing exercises have been the most frequent.

In cases of patients with contracture and mobility limitation of joints, correction of deformity exercise has been applied, exceeding insignificantly pain threshold. Exercises have been done carefully, especially when demineralization of bones had been diagnosed.

The main purpose of exercising patients with motor ataxia symptoms was to alleviate ataxia, turning on subconscious control of each movement. To achieve this aim Fraenkle

exercises have been used. Exercises have been done in lying, sitting or standing position, depending on motor ataxia symptoms. Beginning with easy motions, exercises gradually became more and more complicated. Movements have been alternate, at the beginning in quick tempo, and later in slower tempo, which is more complicated and demand greater control from patient. Patients have been doing exercises with eyes opened at the begining, then with eyes closed.

Significant element of increasing efficiency process was patient preparing to self-dependent walk. A lot of balance resistive and locomotion exercises using orthopedic and rehabilitation equipment has been applied. Process began with sidewalk, and afterwards straight walk has been introduced, using drawn traces. Patients have been learned to take turns as well.

Methods

All patients have gone through examinations three times in Cyrotherapy Laboratory:

- before first cyrotherapy treatment,
- after first cyrotherapy treatment,
- after 5 cyrotherapy treatments.

Examinations have been led by Medical Academy and have been divided into three groups.

First group of neurological examinations describes:

- patients efficiency in EDSS scale,
- spasticity of lower limbs,
- other neurological disorders.

Because examinations have been time-consuming, they have been taken only twice - before and after treatments.

Second group of neurophysiologic examinations consist of:

- Evaluation of psychomotoric skills based on conscious light reaction, sound reaction and differential reaction. Test has been done using MRK-80 reaction meter.
- Orthostatic test has been done, based on pulse and arterial blood pressure measurements, after 15 minutes of lying on the back and every 30 seconds during 3 minutes after tilting of the patient.
- Tremometric test has been done. Study of hand tremor during contour outlining of testing plate has been done using tremograph. The time of test and number of errors caused by hand tremor have been automatically enumerated.

Biochemical tests defining changes in blood serum of patients after cyrotherapy is the third group. Blood has been drawn three times. Endopeptidase cysteine inhibitors have been determined. They are natural, autogenic organism protection against development of pathological states. Bounded in complexes show defense ability of organism. Determination of activity changes of endopeptidase cysteine and their inhibitors is the main purpose of this research.

Preliminary results

First group preliminary analysis of neurological examinations shows that patients' condition has not got worse during increasing of efficiency and cyrotherapy. Improvement in EDSS scale has been noted among 20 patients, average improvement value is 0.5 degree. Among three of the others 8 patients dominant cerebellar syndrome has occurred. Among 13 sick persons lower limbs spasticity has decreased, among 5 of them decrease or regression of nystagmus has occurred. In case of one SM patient regression of symptomatic trigeminal nerve neuralgia has been noted. Among 3 patients exacerbation of disease has occurred three months after cyrotherapy.

Tendency to efficiency of psychomotor functions and organism defense ability has occurred in other examinations. Though, more detailed elaboration is necessary.

Carried out researches are the first part of wide range study cycle, which demand greater research material and longer time of cyrotherapy and kinesitherapy application. Examination results after 20-30 cyrotherapy procedures will allow to justify in reliable way equity of general cyrotherapy appliance in treatment and rehabilitation process of multiple sclerosis patients.

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Cryotherapy in multiple sclerosis treatment

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Abstract: The experiences of Victoria Rehabilitation Centre in Radzyń concerning rehabilitation of patients suffering from multiple sclerosis were demonstrated. The group consisted of 21 persons. The results of systemic cryotherapy treatment were presented.

Key words: systemic cryotherapy, multiple sclerosis

Introduction

Multiple sclerosis patients stayed from 25. May to 10. June 1998 in Therapeutic Rehabilitation Center "Victoria" in Radzyn near Spala, Poland. The group has been consisted of 12 women and 11 men, aged from 21 to 62 (41,08 average). The duration of disease has been ranged from 2 to 40 years (13,08 average).

The patients undergone systemic cyrotherapy in cryogenic chamber twice a day, afterwards took part in group and individual rehabilitation.

Cryogenic chamber consists of two compartments:

- antechamber, with temperature from -50°C to -70°C,
- chamber, with temperature regulated from -110°C to 150°C.

Small groups of SM patients (4-5 persons) have been let in to antechamber and after several seconds of adaptation they have entered a chamber. Systemic cyrotherapy parameters were quite low at the very beginning of the treatment. Time of staying in cryogenic chamber was set on 2 minutes in -110°C temperature. The temperature was lowered down gradually after few treatments. After 10 enters into cryogenic chamber a group of 10 SM patients - volunteers - have agreed to lower down the temperature systematically to -150°C and to prolong the time of treatment to 3 minutes. Others patients, after the adaptation period, entered cryogenic chamber for 2-2.5 minutes in temperature from -120°C to -130°C.

At the beginning and at the end of the whole treatment, patients have undergone efficiency test in order to define influence of complex therapy to physical efficiency of each sick person. The efficiency tests were based on effort enforcement through going up on stepper. The number of steps taken has been registered. The test were interrupted after the pulse rate exceeded the value of 120/min, or earlier - in case of patient's refusal.

Table 1. Physical efficiency rate (%)

Wskaźnik %	bz	0-10	11-20	21-50	51-75	76-100	110-150	151-200	over
Number of examined patients	1	3	1	1	1	4	2	2	6
%	4,7	14,2	4,7	4,7	4,7	19	9,5	9,5	28,5

The percentage rate of physical efficiency was calculated from the difference of work, that was performed.

Inquires have been completed and returned by 17 SM patients. Afterwards, the inquiry was carried out. The patients were to fill it in (about 24 June, 1998) after two weeks of the last entry to cryogenic chamber.

INQUIRY

Inquiry of physical efficiency and general health state after rehabilitation treatment from 25. May to 10. June 1998 in "Victoria" Center in Radzyn

We kindly request you to express your subjective feelings referring to efficiency and general organism state two weeks after last entry to cryogenic chamber (about 24. June 1998).

Please match one of three possibilities.

Mind

Is your general feeling:

1 better	12 persons - 70.5%
2 the same as before cyrotherapy treatment	4 persons - 23,5%
3 worse	1 person - 5,8%

Locomotion - straight walk, going up/down the stairs is:

1 better	11 persons - 64,7%
2 the same as before cyrotherapy treatment	5 persons - 29,4%
3 worse	1 person - 5,8%

The distance you cover without break is:

1 longer	10 persons - 58.5%
2 the same as before cyrotherapy treatment	7 persons - 41.1%
3 is shorter	no answers

Balance is:

1 better	10 persons - 58.5%
2 the same as before cyrotherapy treatment	6 persons - 35.5%
3 worse	1 person - 5,8%

Spasticity:

1 has decreased	10 persons - 58,8%
2 is the same as before cyrotherapy treatment	6 persons - 35,3%
3 has increased	1 person - 5,8%

If you had any speech difficulties, sphincter difficulties, troubles with sleep, gastric complaints, did they get:

1 better	2 persons - 11.76%
2 the same as before cyrotherapy treatment	14 persons - 82.3%
3 worse	1 person - 5,8%

If you had any sight difficulties, did they get:

1 better	4 persons - 23.5%
2 the same as before cyrotherapy treatment	12 persons - 70.58%
3 worse	1 person - 5,8%

If you had any involuntary movements did they get:

1	lesser	3 persons - 17,6%
2	the same as before cyrotherapy treatment	8 persons - 47%
3	deeper	1 person - 5,8%
4	do not concern	5 persons - 29.4%

Conclusions

- Systemic cyrotherapy is safety method of SM patients' organisms stimulation.
- General acceptation and good toleration concerned to this method of therapy have been observed.
- Excellent effects concerning the spasticity decreasing were observed, what made the locomotion and therapeutic exercises easier.
- Considerable rise of physical efficiency among majority of SM patients who have been subjected to systemic cyrotherapy was achieved.

Application of cryotherapy in treatment of patella-thigh syndrome

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Abstract: The application of low temperatures in treatment of patella-thigh syndrome were used. The results of researches concerning rehabilitation of patients suffering from this chronic illnesses were presented.

Key words: patella-thigh syndrome, low temperatures

Introduction

Syndrome of patella-thigh overload (patella chondriomalation) is a pathological state consisting in entire or partial destruction of patella articulation cartilage depending on degree and duration of the overload. Most commonly, it concerns young and active people, often practicing such sports disciplines as: light athletics, football, judo, handball, ice-skating, karate, volleyball.

Patella chondriomalation manifests itself by:

- pain after long-time bend of knee joints,
- pain accompanying jumping,
- pain when knee twisting (in and outside),
- uncertainty of articulation when overloaded,
- knee edema after long-time training,
- feel of patella leaping while bending and straightening a knee,
- pain intensification when descending [1-4].

Numerous researches and clinical observations showed anatomic and functional complexity of capsule-ligament apparatus, dynamic system of knee articulation and functional interdependence of its elements. The complexity of knee articulation and the fact that etiology of patella chondriomalation is heterogenous and not well known make many troubles during treatment of the disease.

Many authors pay attention to significance of traumas and mikroinjuries that result from damage or wear of articulation cartilage. Perturbation of kneecap balance such as:

- high patella position (Fig. 1, 2),
- knee articulation sprain,
- patella dislocation,
- are considered to be very detrimental and significant.

Dandy [1] points out that damage of meniscus is to a high degree caused by processes of articulation sprain degeneration.

Fig. 1. Female patient, 23yo. patella risen substantially.

Among other factors predisposing to patella chondromalation, there is a handicap of knee articulation stabilizer against the background of desmopathy (mainly PLL). Such defects cause instability of knee joint.

In a degeneration process of patella-thigh articulation, the most essential factors are:

- improper adjacency of kneecap to thigh and tibia condyle resulting from high kneecap position, kneecap displasion or aplasia,
- impossibility of kneecap to stay in a block (partial or total dislocation) caused by abnormality of lateral side of a block or untypical shallow block furrow,
- perturbations of active and passive knee stabilizers balance [1-7].

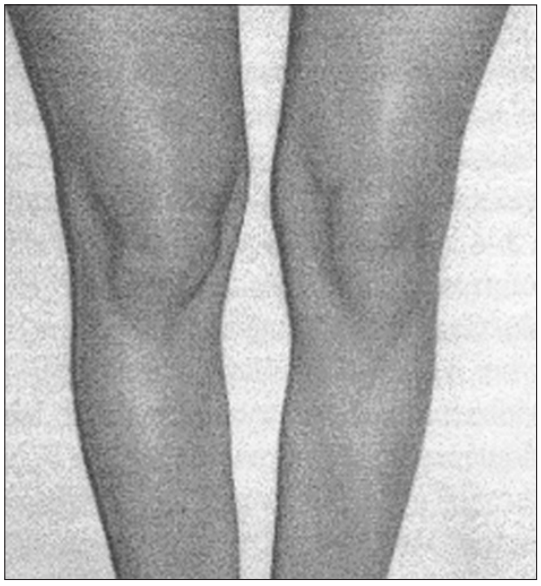

Fig. 2. Female patient, 23yo. - observation of knees varus deformity.

Untreated knee articulation instability causes increase of damages resulting in functional insufficiency of the articulation that leads to patella hondromalation. Treating the disease without diagnosis and determining its etiology leads to "vicious circle" (pain-immobilization-muscles decay) [1, 2]. This interdependence intensifies damages in the area of articulation structures and leads to invalidism.

Because of the difficulties in patella chondromalation treatment, some solutions should be found in:

- prophylaxis of knee articulation overload,
- proper treatment of meniscus damages,
- correcting knee stability perturbations,
- properly planned physiotherapeutic program applying cryotherapy [6, 7].

Prior researches and observations show many positive effects after local cryotherapy in a sport injuries therapy. Increased arterial blood flow hastens heeling of damaged ligaments and sinews. Analgesic and anti-inflammable treatment is more effective. Better lymphatic drainage (drainage of intercellular spaces) causes edema reduction [8, 9].

Purpose of this research work is to show effects of applying cryotherapy and other physical treatments involving kinesitherapy in conservative therapies of patients suffering patella-thigh syndrome.

Material and method of treatment

Proprietary material was represented by two groups of patients suffering patella-thigh syndrome. The first one consisted of sportsmen at the age of 17 to 24 (at average 21), with a few to several year experience in training light athletics and football. The group contained 10 patients (5 females and 5 males). Thanks to applying cryotherapy treatments, time of the therapy was essentially shortened and lasted 3-4 weeks. The second group of patients were represented by 5 patients (including 2 females) that had been never practicing any sports professionally. Their age hesitated between 17 and 24 (at average 20). Rehabilitation time in this group was elongated to 1.5 months.

Method of treatment:

1) Doctor's diagnosis based on clinical research, complete set of radiological photographs or knee articulation arthroscopy.

2) Pysiotherapeutic treatments: at first lignokaine or butapyrazole ionophoresis alternatively for 14 days and during breaks in technical training, subsequently 10 treatments of local cryotherapy.
3) Accompanying kinesitherapy with individually selected program:
- rehabilitation exercises,
- isometric exercises of lower limbs,
- active exercises with lower limbs resistance (at first stage only in extension position of knee articulation),
- exercises in water,
- swimming (excluding classic style).

Methods of research

Researches were conducted before and after rehabilitation. Conducted anamnesis allowed to determine bodybuilding, walking troubles, body statics perturbations, upper and lower limbs appearance (muscles decay, feet and knees setting). Followingly, precise examinations were carried through twice:
- circular measurements
- range of mobility in particular backbone segments,
- angular measurements of ranges of mobility of lower limbs (including pain ailments during motion),
- measurements of lower limbs muscles strength [10].

Results of research

In the first group (professional sportsmen) the most probable reason of kneecap chondromalation was either motoric overload of articulation or wrongly prepared training. 90% of patients are light athletics sportsmen that confirms former statistics. In the second group the reason could have been excessive load resulting from improper loads dosing.

Conducted interview showed that there were former traumas in case of 90% of patients, such as: concussions, sprain of astragalar or knee joint.

Pain while rest before the rehabilitation withdrew in case of 89% of patients. Pain occurring when walking was decreasing gradually in both groups during rehabilitation. It lasted longer in the second group of patients.

Results of lower limbs circumference examination showed considerable differences before rehabilitation (at average 1.6 cm). In case of 60% of patients the differences were leveled and in case of 40% they declined to 0.5 cm at average. No functional and motoric changes were observed in the area of lower limbs. Muscles strength of ill limb was slightly weakened but not lower than 4 in Lovett scale. Ranges of mobility did not change. Moreover, no pain occurred during examination.

Conclusions

1. There are numerous evidences that the reason of patella-thigh articulation ailments are mostly microinjuries of knee joint, intensifying individual posture defects.
2. After rehabilitation with application of local cryotherapy, considerable improvement of knee joint functions is observed.
3. Rehabilitation time in case of all patients applying local cryotherapy is distinctively shortened.
4. Cryotherapy is an important factor increasing efficiency of kinesitherapy in a therapy of patella-thigh articulation ailments.

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Application of systemic cryotherapy in rehabilitation of children and youth suffering from infantile cerebral palsy

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Abstract: The aim of research work was systemic cryotherapy application in process of rehabilitation of suffering from infantile cerebral palsy children and youth along with therapeutic advantages evaluation. The rehabilitation connected with systemic cryotherapy was performed in 26 diseased (children and youth) suffering from infantile cerebral palsy.
The individual rehabilitation program included 10 procedures of systemic cryotherapy. All of therapists working with children and youth, their carers as well as parents were performing systematic observation of children. The systemic cryotherapy that was applied in children and youth suffering from infantile cerebral palsy affected mood improvement as well as activity enlargement in motor activity along with spasticity decrease.

Key words: infantile cerebral palsy, rehabilitation, systemic cryotherapy.

Preface

The medical application of low temperatures is dated back to 1851 along with administration of mixture of ice and common salt (-20 Celsius degree) by James Arnott in carcinoma treatment.

The middle of 20th century presents the end of pioneering tests and beginning of systematic researches that contributed to interest of modern application of cold in medicine. The application of liquid nitrogen vapours, performed by Toshima Yamauchi then next Reinhard Fricke, as adjunctive treatment and rehabilitation of diseased suffering from rheumatism, broadened possibilities of cryotherapy [1, 2].

Cryotherapy means stimulogenic, superficial application of cryogenic low temperatures (below -100 Celsius degree) within short time - up to 3 minutes, in order to produce and make use of physiologic reactions to cold as well as adjunctive treatment and kinesitherapy facilication.

Cryotherapy presents not only symptomatic activity but also reveals actual therapeutic effect in pathological states in which effectiveness of the method was examined [3, 4, 5, 6].

According to actual views, the infantile cerebral palsy is not homogenous pathological syndrome. It includes the group of non-progessive but evolving motor and postural disorders

as a consequence of central nervous system injury in early stage of development. The problems of children suffering from disorders of central nervous system origin are extensive and concerns all features of psychomotor development [7, 8]. Many elements involved with correct pattern of motion does not appear within abnormal development. For this reason child learns to replace (compensate) them. It makes use of primitive motion that is not modified in further stages of development and also does not transform into more complex. This motion becomes irregular in a short time.

Fig. 1. Systemic cryotherapy of children suffering from infantile cerebral palsy.

Fig. 2. Systemic cryotherapy of youth suffering from infantile cerebral palsy.

The antigravity flexors work develops insufficiently or sometimes does not develop at all in order to balance extensors work. Unfortunately, it does not allow to execute correct movement. The difficulty of stabilization of one part of the body, while the other one is in the motion, appears what leads to incorrect both stabilization and movement. It is the reason of fixation appearance that stops development of following movements of individual parts of the body, leading to stereotypia that limits more and more the motion of individual joints and parts of the body [7, 8, 9, 10].

Abnormalities within motion system:

1. Child compensates the lack of correct head control for shoulders lifting what gives possibility of head stabilization. The elevation of shoulder girdle prevents from unrestrained moving of both head and neck and also increases extensory tonus. Immobilization of shoulder-blades in primary high positions appears what limits upper limbs efficiency.

2. The continuous maintenance of a head turned round on one side causes spinal column torsion and transfer of the body mass to facial side. The rotation and lateral spinal curvature intensifies what predisposes towards primary scoliosis with anterior pelvis rotation as well as its elevation at the occiput side.
3. The intense extensory tension of lumbar spine area produces anteversion of the pelvis, extension of hips and thigs adduction. The motion of flexion and abduction do not thrive. Moreover, abdominal muscles are poorly active and do not balance extensors tension. It limits the motion within hip joints and lower extremities.
4. The shortening of hips extensor is compensated by bending of knee joints what causes weakness of knee flexors.

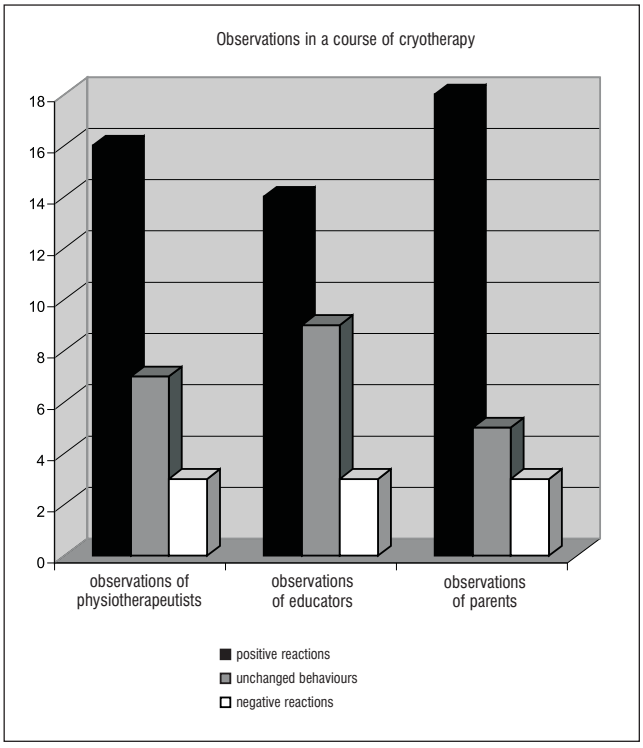

Fig. 3. Results of observations in the course of rehabiliation of suffering from infantile cerebral palsy children and youth.

5. The lack of ability to hands raising up to mouth causes necessity of head bending during eating meals what in consequence increases inclination of the trunk, hips and knees bending.
6. The same kinetic patterns are used in playing and manipulation of upper limbs. It is conductive to contracutes in flexion occurrence.
7. All of daily activities are performed incorrectly [7].

The main aim of rehabilitation of infantile cerebral palsy is to develop such motor activities which, despite constant brain injury, will be most similar to correct ones and prevent from irregular patterns fixation, muscular contracture as well as secondary deformity of osteoarticular system appearance. Such situation demands complex therapy including both rehabilitation (neuro-kinesiphysiological, neuro-developmental and functional) and daily care of the child, staying in correct and variable positions, dressing, feeding, playing, kindergarten and school activities [9, 10].

Application of systemic cryotheprapy to children and youth rehabilitation process suffering from infantile cerebral palsy should affect positively therapeutic effect and life quality of these people.

Well known clinical effects of cryotherapy indicate that fact, especially regression of pain ailments, massive, reflex congestion of integuments and limbs as well myatonia and increase of its strength. The improvement of the mood, will to perform the motion and increase of humoral and cellural response were observed what make cryotheapy very special physical procedure. The application of cryotherapy before therapeutic exercises allows to intensify the rehabilitation of dysfunction threefold.

The aim of research work

The aim of research work was systemic cryotherapy into rehabilitation of suffering from infantile cerebral palsy children and youth incorporation as well as determination of achieved therapeutic benefits.

Materials and research methods

Research material:

The pilotage rehabilitation programme with systemic cryotherapy usage was performed under the patronage of the Health Department of Municipal Office in Wrocław. Twenty six people, in the age of 4 to 24 years old, of low fitness from Association for Children and Youth in Wrocław "Ostoja", took part in the programme. Parents consented participation of their children in programme before rehabilitation.

The method of rehabilitation:

I. Systemic cryotherapy:
   10 procedures of systemic cryotherapy in cryogenic chamber (NZOZ KAR-MED - Medical Centre in Wrocław, at the temperature of -110°C within time of 1,5 to 2 minutes were performed in doctors' presence with ruthless obeying of safety principles during the procedure [1, 3, 4, 5, 11], (Fig. 1, 2).

Table 1. The comparison of observed reactions of children and youth subjected to systemic cryotherapy.

	educators and assistants		**physiotherapists**		**parents and carers**	
	behaviours	*patient quantity*	*behaviours*	*patient quantity*	*behaviours*	*patient quantity*
positive reactions	better mood, increased activity during exercises, decreased spasticity - easier dressing and feeding	14	better mood, exercises acceptance, better contact with a child, decreased spasticity, increased activity in spontaneous motor activity	16	better mood by day, calm sleep by night, increased activity in spontaneous motor activity, decreased spasticity - easier dressing and feeding, decreased incidence of disease	18
negative reactions	increased sialosis, hyperexcitability, somnolence by day	9	weeping, nagative excitability	7	nagative excitability, difficulties in falling asleep	5
unchanged behaviours	3		3		3	

II. Individual programme performed in Rehabilitation-Educational Centre:
- poli-sensorial simulation of development:
  Bobath method, the method of controlled teaching - Peto and finally the method of developing movement by W. Sherbone,
- relaxation massage,
- music therapy
- activities with speech therapist
- pedagogical therapy

Systemic cryotherapy was included as additional therapeutic element of existing individual programme of children and youth. It enabled to evaluate cryotherapy effects in observed group of children and youth.

Methods of observation:
Before the cryotherapy the neurokinesilogical evaluation was performed (neurologist, physiotherapist) [8, 10].

All therapists, working with children and the youth, their carers as well as parents, were performing systematic observation of potential changes of children's behaviour, using specially prepared observation cards.

Results

During rehabilitation and 1 month after observations were performed in order to evaluate therapeutic benefits.

The observations of educators, physiotherapists as well as parents and carers prove positive change in behaviour of most children and youth. Detailed observations are shown in Table 1 and Fig. 3.

Taking into account all observations, positive changes in 14 patients were achieved. However 3 children revealed negative changes. Most of positive changes were observed among home environment.

Discussion

Significant increase of interest of treatment with cold usage has been observed in recent years.

On the basis of actual literature reports as well as experiences, following indications for cryotherapy as an individual method and also element of complex rehabilitation must be noted:
1. inflammatory diseases and various etiology degeneration of motion organ,
2. diseases of centrifugal and peripheral nervous system,
3. psyche based diseases,
4. autoimmunological based diseases

as well as sports medicine and also biological renewal [1, 3, 4, 5, 6, 12].

On this basis the authors applied rehabilitation, of suffering from infantile cerebral palsy with cryotherapy usage.

The application of cryotherapy in neurological patients is indicated for its congestion, analgesic, antioedematous and also decreasing spasticity actions [3, 12, 13]. Direct influence of extremely low temperatures onto muscular tissue does not cause muscle force decrease but along with suppression of reflex movement of spinal cord mainly, determines decrease of muscle spasticity as a result of either algaesthesia (analgesia synergy) or central nervous system damage.

In conditions of low temperatures, in which steam and expiratory carbon dioxide change into ice dust, respiratory anoxia can not happened, because oxygen concentration does not decrease below 21%. The safety of method displays also in fact, all of internal organs function in proper temperature of the blood, well oxygenated along with efficient microcirculation. Thus, systemic cryotherapy offers unique combination - both high intense stimulation effect and relatively low discomfort [1, 3, 5, 6, 11, 13].

The observations that were performed by authors indicate evident, positive reactions of majority of patients. However such short time period of cryotherapy allowed only to make up with general observations in children and youth behaviour. It was not indication for analyses of neurokinesilogical diagnosis. On the basis of previously achieved positive behaviours of children, well tolerance of procedure as well as lack of contrindications, rehabilitation connected with systemic cryotherapy should be extensioned to evaluate therapeutic effect of therapy.

Conclusions

1. In the course of cryorehabilitation of suffering from infantile cerebral palsy, therapeutic benefits in the form of mood improvement, increase of activity in spontaneous motor activity as well as spasticity decrease were achieved.
2. Decrease of spasticity facilitated dressing and feeding of the children.
3. Above mentioned results are therapeutic indication for extension of rehabilitation programme connected with systemic cryotherapy.

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Whole body cryotherapy - examining the influence of the method on hormonal and enzymatic changes in peripheral blood in athletes

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Abstract: We present the preliminary results of the experimental trial on the potential influence of cryotherapy on hormonal and enzymatic changes in peripheral blood in sportsmen. It was observed that, cryotherapy caused significant decrease of serum cortisol and lactates.

Key words: cryogenic chamber, athletes, hormones

Introduction

The systemic cryotherapy 2 or 3 minutes series of procedures in cryogenic chamber at the temperature of -140 Celsius (± 10 degrees centigrade), causes many clinical, biochemical as well as hormonal effects in human body [1]. Cryotherapy affects the increase of blood flow within the skin and internal organs, subjective sense of analgesia, has favorable influence on psyche, muscle relaxation and also oedemas abolition. These phenomena remain for 3-4 hours after the procedure of cryotherapy and are of significant therapeutic importance in motor system treatment offering favourable conditions to physiotherapy. As a result of cryotherapy procedures, the the biochemical and hormonal are observed.

Methods

10 procedures of cryotherapy were applied in 9 athletes, of Sport Association of Academy of Physical Education in Wrocław, within 10 days. The temperature of cryogenic chamber interior was -140 Celsius, time of the procedure - 3 minutes. During the therapy and at the end the concentration of following substances: somatothropin - growth hormone (GH), testosterone, cortisol, lactates, creatine kinase (CPK) as well as erythropoietin was investigated. The concentration determinations were executed within following days: before therapy, at the first, fifth day of the therapy then at the end, seventh and finally sixteen days after the end of the procedure. The athletes were continuing training during and after cryotherapy. All measurements were executed at the same day time (midday).

The results were presented in the form of 40 arithmetical means (X) and standard deviations (SD).

The differences among individual parameters were determined, basing on nonparametric equivalent of variational analysis ANOVA Kruskal Wallis. The $p<0.05$ values were recognized as significant. The particle correlations were determined on the basics of Stearman correlation coefficient "r".

Results

The following symbols concerning time periods of measurements of researched parameters are combined in the tables:

I - day 0; II - day 1; III - day 5; IV - day 10; V - day 17; VI day 24.

The day before therapy was denoted as 0, the first day as 1, tenth was numbered as the last day of therapy. The seventeenth meant the seventh day after the therapy and finally the twenty fourth day was determined as the fourteenth day after procedure termination.

The results are presented in the table 1.

The significant statistical differences occurred in determinations of cortisol (I vs III: $p < 0.01$; I vs V: $p < 0.05$; II vs III: $p < 0.01$; II vs V: $p < 0.01$; III vs VI: $p < 0.01$; V vs VI: $p < 0.01$) and lactates (I vs III: $p < 0.05$; II vs III: $p < 0.01$; III vs IV: $p < 0.01$; III vs V: $p < 0.01$; III vs VI: $p < 0.01$) concentrations.

The remaining parameters were not changing significantly within the procedure. The positive linear dependence occurred between lactates and cortisol concentrations ($r = 0.30$; $p < 0.05$).

The positive linear dependence between concentrations of GH and EPO ($r = 0.03$; $p < 0.05$) was noticed.

The negative linear dependence between EPO and cortisol concentrations ($r = 0.31$; $p < 0.05$) was presented.

Discussion

The oxygen resynthesis of stored energy falls behind with its consumption during intensive exercises. The partial resythesis of ATP is executed at the cost of energy which is released through direct glucose disintegration into lactate. Despite the quick lactates penetration into circulating blood, the accumulation of these compounds in muscular tissue appears what leads consequently to it's buffer capacity overfilling, significant pH decrease and also inhibition of enzymes activity [2].

Table 1. The results of concentration measurements of substance during and after cryotherapy procedure.

day		I	II	III	IV	V	VI
somatothropin	X	4.60	8.95	4.67	1.65	3.90	1.61
[ng/ml]	SD	5.30	4.85	3.31	1.77	9.57	2.58
testostherone	X	4.51	4.48	4.82	5.74	5.85	6.48
[ng/ml]	SD	1.78	2.03	1.77	2.01	2.65	1.26
erythropoietin	X	9.08	8.66	10.60	9.58	9.62	8.58
[IU/ml]	X	2.94	2.50	3.15	2.76	3.74	2.51
cortisol	SD	19.55	20.74	11.88	16.01	13.48	20.06
[ug/dl]	X	3.9	7.49	2.66	6.77	2.85	3.72
lactates	SD	2.85	2.94	1.34	2.78	2.18	2.63
[mmol/l]	X	1.15	0.69	0.27	0.72	0.77	1.62
CPK	X	351.66	416.33	839.11	503.42	339.71	315.33
[IU/I]	SD	473.83	718.93	959.38	338.92	180.72	215.64

The additional oxygen uptake, in order to remove the excess of lactate and renew stored phosphatic compounds, is necessary after the exercises termination. The cryotherapy causes active tissues congestion [3] as well as, in the aftermath, oxygenation. It is conductive to damaging products of metabolism elimination.

In the experiment the authors subjected the group of athletes to series of systemic cryotherapy procedures. The increased concentration of lactates in plasma (on average 2.86 mmol/L over the standard up to 2.44 mmol/L) in initial measurements was noticed among the patients. Another researches, performed during the procedures with the cryogenic chamber usage, showed the significant, statistical decrease of lactates level to amount held in the norm. The greatest decrease was noticed in the fifth day of the therapy (on average 1.34 mmol/L). The obtained results show the favourable influence of cryotherapy on muscle metabolism, especially in conditions of increased exercises. The decrease of lactic acid concentration is one of suggested mechanisms of muscles regeneration and pain ailments after overload decrease. The clinical researches affirm systemic cryotherapy application causes the increase of cortisol as well as testosterone in blood serum concentration. However it does not affect the level of somatotrophin concentration [4, 5, 6].

The increasing tendency of testosterone was also noticed but it was not statistically essential.

The initial values of cortisol, in the group of patients, held in the upper limit of the norm (on average 20 microgramme/dL, the standard up to 25 microgramme/dL). In the fifth day of the therapy the significant decrease of cortisol up to, on average 11.9 microgramme/dL, was observed, then the increasing trend followed. After the fourteenth day of the therapy termination the return to the value similar to the upper limit of the norm (on average 20 microgramme/dL) was noticed. Previously quoted researches concerning cryotherapy influence on the change of adrenal cortex gland hormone concentration did not apply to professional athletes. The increased exercises as well as intensity and time period of training part significantly in changes of cortisol concentrations in circulating blood. The influence of the systemic cryotherapy on this parameter concentration in athletes requires further researches.

The study of Howatson and co-authors [7] shows the decrease of CPK concentration after the local cryotherapy of injured muscles. The statistically significant differences of the CPK as well as EPO level in following researches were not observed.

The obtained results were not compared to control group and present the preliminary report. The preliminary data can be designed for further researches concerning the influence of systemic cryotherapy on metabolic parameters of athletes.

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The application of the whole body cryotherapy in sport

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Abstract: Prevalent number of bibliographic data concerns the rheumatoid diseases treatment with low temperatures applications. In this paper we report on own survey dealing with cryotherapy in sport medicine. Good cooperation between Institute of Rehabilitation and coaches of the Polish Track and Field Team, judo and karate enabled to organise special sport camps, during which athletes were exposed to the treatment in cryogenic chamber. 3 groups of all together 33 athletes were exposed to the temperatures ranging from - 110 to - 160°C. Time of exposure varied from 120 to 180 seconds. Every participant had 11 visits at the chamber. Before and immediately after visit blood sample was taken from the cephalic vein puncture. Following parameters were counted by standard methods: RBC; WBC; PBC; and electrolytes level and protein and hormones.

Key words: whole body cryotherapy, sports injuries.

Low temperatures are widely applied in treatment of every description of sports injuries [1]. It adjuncts rehabilitation after surgical procedures, limits secondary lesions of tissues. Nowadays covering the athlete's leg with ice is a common sight. The favourable effects of cryotherapy have been known for many years. In local cryotherapy ice compresses are replaced with the demister of liquid nitrogen at the temperature of [2, 3]. At present to eliminate the negative consequences of professional sport more and more often systemic cryotherapy, also known as the whole body cryotherapy, is applied. It is common knowledge that low temperatures cause reaction cycle in organism which improves significantly the efficacy of kinesitherapy. The influence of low temperatures on training results has not been discovered so far. The innovative examination were performed at University School of Physical Education in Wrocław [4].

The systemic cryotherapy meets with athletes' and trainers' approval. A few cryogenic chambers were installed in sport centers among others in Wrocław, Spała, Zakopane, Warszawa.

In present chapter the results of comprehensive studies carried out with assistance of fight sports contestants are described.

Method

The 24-person group of judo and karate contestants were a subject of observation. Ten cryogenic procedures in temperature from -110 to -150°C were performed. All contestants were examined before procedure. Their ailments, general feeling and also individual, workload tolerance were determined.

Similar research was carried out after each procedure (1, 3, 5, 6. and 10 days after the treatment.

The contestants complained about many ailments that are characteristic of their discipline with tendency to major lesions in pelvic limbs for judo and thoracic limbs for karate contestants.

The ailments and feelings that were noted thanks to questionnaire made grounds for further observations. The main aim of researches was efficacy systemic cryotherapy evaluation to eliminate ailments. The established scale was 0 -1, that is pain or it's lack. The reason and time of it's lasting was not evaluated, except for category "chronic muscle pain syndromes" in which the condition of incorporation was an appearance of symptoms at least twice in the same area and over 14 days.

The improvement was achieved practically in each category, especially with reference to joints of a hand, chronic muscle pain syndromes and oedemas as a result of contusions. The character of low temperature influence that operates in short time seems to cause these changes. The extreme cold, penetrating tissues, causes among others inhibition of oedemas arising and secondary damages of tissues, has an impact on the flow of centripetal pain impulsation, improving metabolism of tissues that affects, at the same time. All of these processes in connection with hormones ejection bring favourable results.

It is important to mention, ten procedures have been carried out, while among patients with rheumatoid chronic illnesses this number rises up to 40. Kinesitherapy, which is important component of rehabilitation procedure after cryotherapy, has not been applied as well. Every day only one procedure of systemic cryotherapy was performed even though initial researches proved that it was possible to carry out 2 or even 3 procedures in a short time by day.

The last element of evaluation were general feeling of contestants and eventual improvement of training load tolerance. The previous experiences affirm that application of cryogenic chamber in sports injuries brings, in some cases, surprisingly good stimulation effects. The mechanisms that led to such changes are certainly

Table 1. The aliments and sensations of contestants before cryotherapy.

Parameters before systemic cryiotherapy	Judo		Karate		Total	
	n	%	n	%	n	%
General feeling - good	11	100	13	100	24	100
shoulder joint	2	18,18	1	7,69	3	12,5
elbow joint	1	9,09	1	7,69	2	8,33
joints of hand	2	18,18	10	76,92	12	50
hip joint	0	0	1	7,69	1	4,16
knee joint	6	54,54	0	0	6	25
astragalar joint	0	0	2	15,38	2	8,33
joints of the foot	2	18,18	4	30,76	6	25
oedema as a result of contusion	2	18,18	13	100	15	62,5
chronic muscle pain syndrome	7	63,63	12	100	20	83,33
tolerance of training loading	11		13		24	

complex. Elimination of ailments, results of injuries and microinjuries seem to increase comfort of training and thereby contribute to better results achvements. It is impossible to exclude the influence on psyche (beta-endorphin, POMC), and also neuromuscular system (increase of strength of muscles as an effect of cold) and hormones for example testosterone. The attempt at explaining foregoing suggestions requires additional researches.

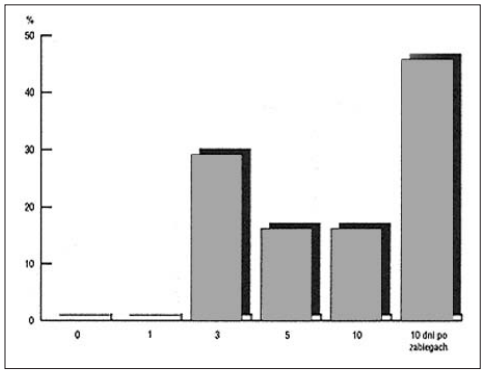

Fig. 1. Percentage improvement of general feeling during treatment.

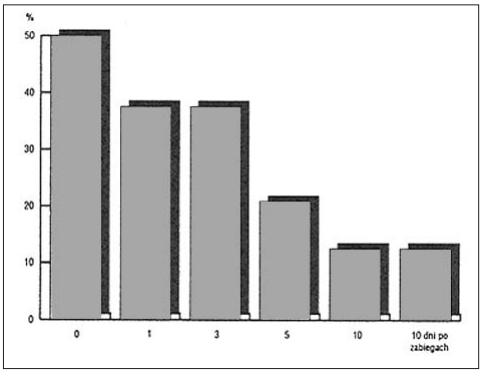

Fig. 4. Percentage of joints of hand ailments.

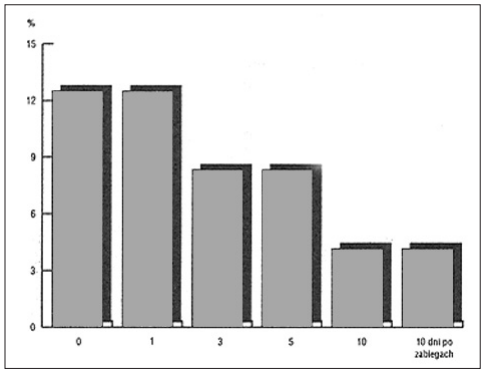

Fig. 2. Percentage of shoulder joints ailments.

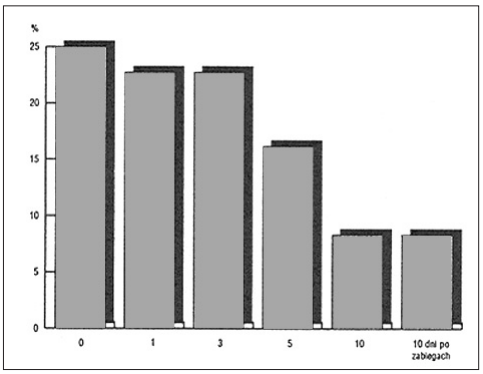

Fig. 5. Percentage of knee joints ailments.

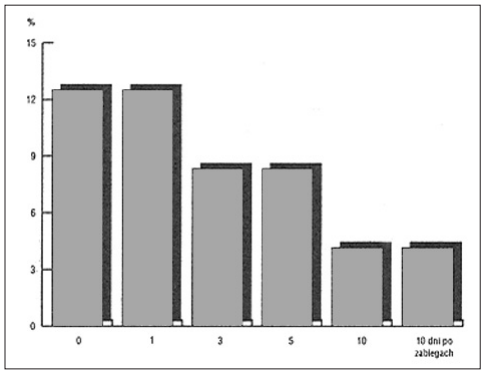

Fig. 3. Percentage of elbow joints ailments.

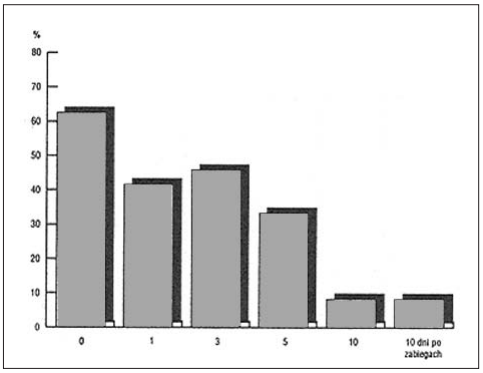

Fig. 6. Percentage of oedemas as a result of contusions.

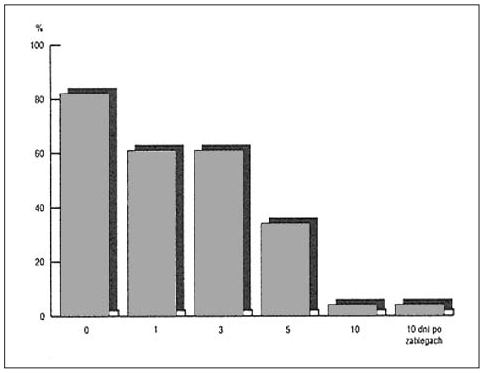

Fig. 7. Percentage of chronic muscle pain syndromes ailments.

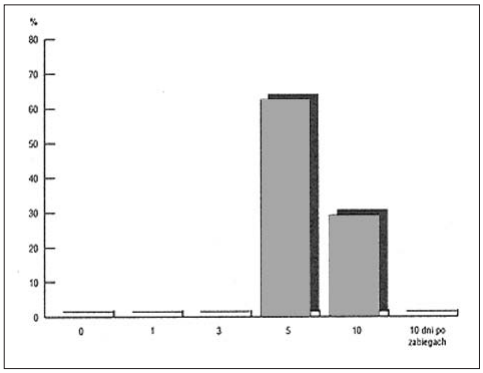

Fig. 8. Improvement of training tolerance.

The results of peripheral blood count

The next group examined counted 14 representants of National Team of Athletes. 11 cryogenic procedures were carried out. Before procedures and after them, the blood from cephalic vain was taken in which, by standard methods the level and parameters of erythrocytes, leucocytes and thrombocytes were indicated; and thus:

- The concentration of iron, sodium, potassium, calcium, phosphorus and chlorides ions and also
- Concentration of plasma proteins.

The essential statistical differences of many parameters were noticed.

Conclusions

The essential statistical decrease of calcium ions concentration in serum was noticed, both in group of men and women. It is probably result of ions transitions into intercellular space, which affects contractility of muscles.

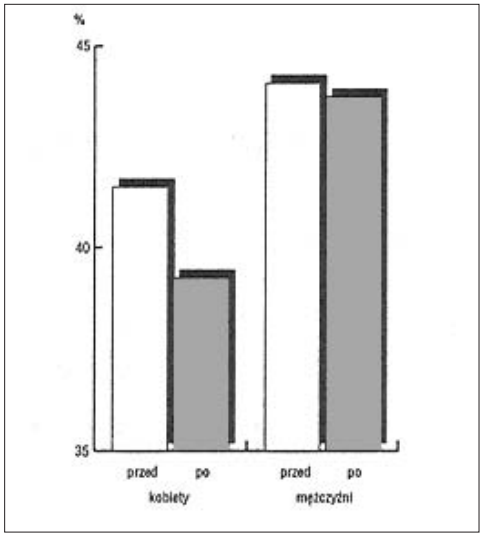

Fig. 9. Haematocrit value in a group of men and women before and after procedures.

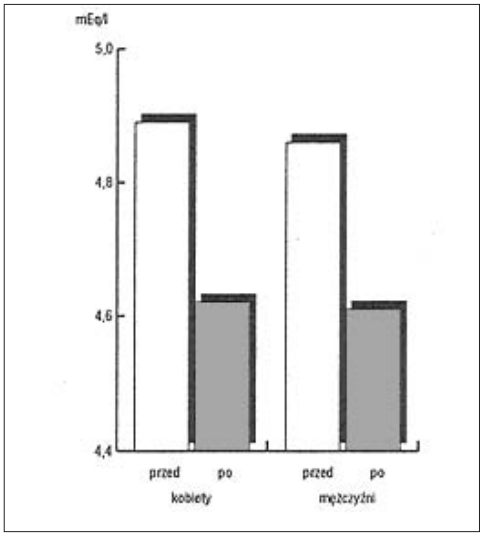

Fig. 10. Calcium ions concentration in a group of men and women before and after procedures.

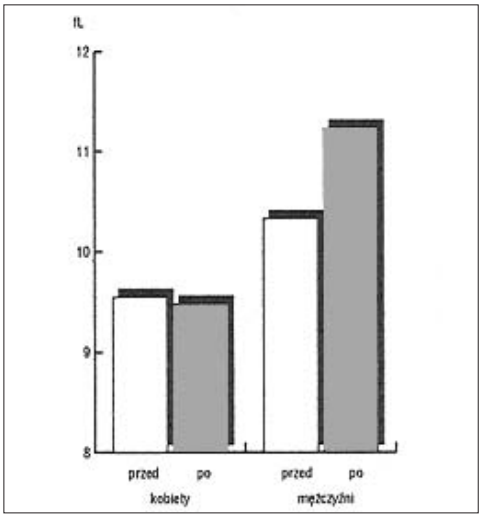

Fig. 11. Average volume of thrombocyte.

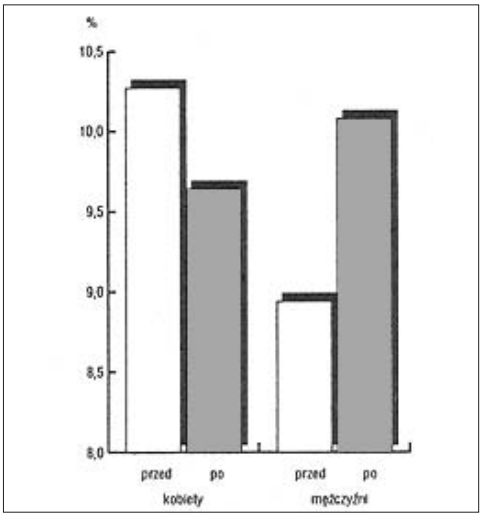

Fig. 12. Beta-globulin concentration.

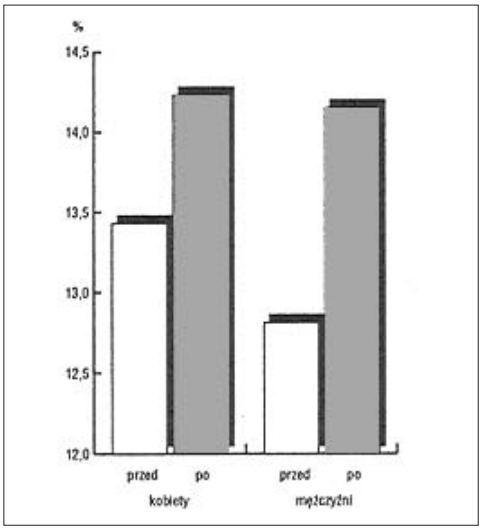

Fig. 13. Gamma-globulin concentration.

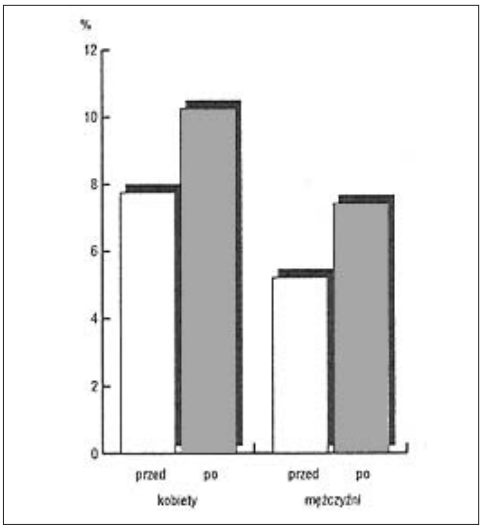

Fig. 14. Reticulocytes concentration.

There following symptoms were observed in the group of men:

- Increase of gamma- and beta-globulin fraction, which can affect inflammatory response of organism;
- Decrease of albumin value, which caused increase of OB;
- Increase of reticulocytes concentration as a result of medulla reserves releasing or stimulation of its growth.

The results confirm systemic character of organism response to extremely low temperatures. The changes of peripheral blood parameters affect both healthy and diseased people who want to use cryotherapeutic procedures to stimulate innate immunity. It confirms also conclusions resulting from observation of athletes.

Summary

The systemic cryotherapy finds multiple applications in sport. It can support convalescence after sport contusions and prepare for greater toleration of workloads. Both systemic and local cryotherapy bring desirable effect. It can be conductive method of improving athletes results.

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Computer aided acquisition and processing of thermovision images for evaluation of cryotherapy results

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Abstract: The applications of thermovision for evaluation of cryotherapy results is reported in this chapter

Key words: thermovision, low temperatures, cryotherapy

Introduction

Recent knowledge and technical achievements accelerate the search for new methods of matching variously acquired data. Due to interaction of optoelectronics and microelectronics the data processing time has been considerably shortened and analytic possibilities were improved.

Thermovision is a method of precise recording of temperature distribution on the surface of the body. As a non-invasive method thermovision was incorporated into medical diagnosis. It is now a valuable supplement of conventional diagnostic methods that may be harmful to patients. Many diseases induce the changes of temperature in specific areas of the body. The application of thermovision in evaluation of rheumatic diseases may contribute to improved diagnosis and successful therapy.

New methods for treatment of diseases locomotory system are still examined. Noninvasive and natural methods are of big importance. Human beings are always looking for some natural medicines in the surrounding environment. Warmth, solar radiation, mineral waters and also cold show beneficial action on our organism. Therapeutic application of cold is based upon lowering the temperature of tissues and inducing positive, physiological reactions of the organism. Cold is one of the strongest remedies against inflammation that are known in modern physical medicine. Liquid nitrogen vapors and extremely cooled air have been introduced as support in therapy of patients with rheumatic inflammation of joints. The evaluation of temperature distribution before and after therapy would visualize the actual effects of cryotherapy.

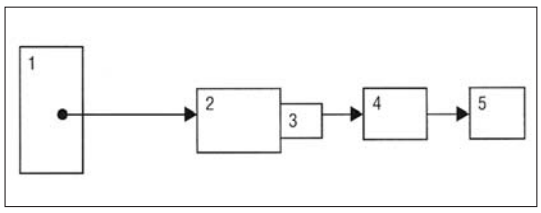

Fig. 1. Schematic thermographic set-up: 1. examined object 2. optical system 3. detector 4. electronic system 5. imaging systems.

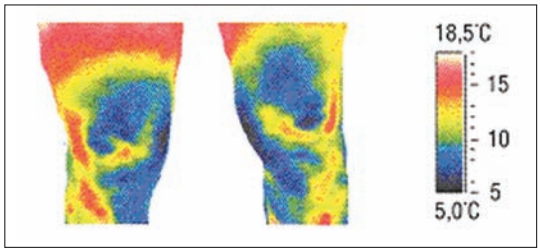

Fig. 2. Palette rain 900 (color scale rain 900).

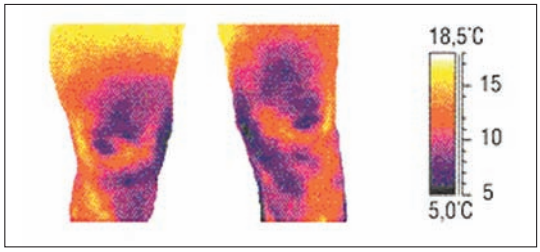

Fig. 3. Palette iron.

Fig. 4. Palette medical.

In this chapter there is also underlined a key role of a system that processes thermovisual images in their correct interpretation. During examination the THERMOVISION ® 900 SERIES system was used. Experiments included patients with rheumatic inflammation of joints who were treated with vapors of liquid nitrogen applied by means of KRIOSAN device and also healthy persons subjected to systemic cryotherapy.

The principles of thermovision

Thermovision as non-invasive, contact-free and painless method can be safely applied to patients. This method utilizes infrared radiation which is emitted by each body bearing the temperature higher than absolute zero. Thermovision enables visualization and recording of distribution of the temperature on the surface of the examined objects. Temperature is measured indirectly - it is the infrared analyzer that detects the radiation while the intensity of that radiation is a function of temperature of the scanned object. Creation of an image is based on capturing the emitted radiation and processing it into A colorful map of temperatures. Thus, the thermovisual system may be described as a kind of thermometer which enables multipoint measurement of temperature at some specific distance [1-3].

Human skin emits and absorbs energy of infrared radiation within A range of 3-15 μm and showing emissivity factor values of 0,98 - 1. Thus, within this range skin can be recognized as black body. Pigmentation of skin does not affect the thermovisual image in any way. The distribution of temperature on the surface of the body depends on the temperature of internal organs, thermal conductivity of muscular and adipose tissue and thermal emissivity of skin. Temperature measured on the surface is a function of temperature of internal organs and thermal properties of tissues between such organs and surface of the skin [6, 7].

Thermovision is based on very well known physical phenomenon of emission of electromagnetic waves by each body bearing the temperature higher than absolute zero. Such radiation is called, following its wavelengths, "infrared radiation" and following its properties - thermal radiation. The intensity of thermal radiation is proportional to temperature of the body. So, measuring the infrared radiation of the body one can indirectly verify its temperature too.

Infrared radiation is highly absorbed by some of atmospheric ingredients - steam and carbon dioxide entirely absorb infrared radiation at the wavelengths between 1,87 - 2 μm and 5,5 - 7,5 μm. Thus, so called "atmospheric gaps (windows)" that enable infrared transmission range between 2,5 - 6 μm and 8 - 12 μm [1, 3, 4].

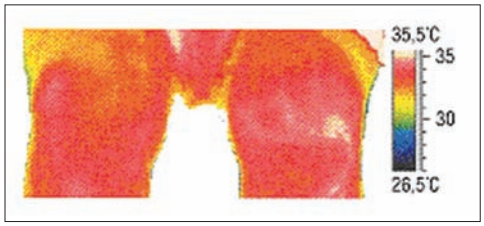

Fig. 5. Patient 2 - before cryotherapy.

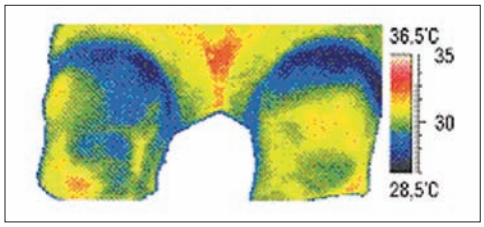

Fig. 6. Patient 2 - immediately after cryotherapy.

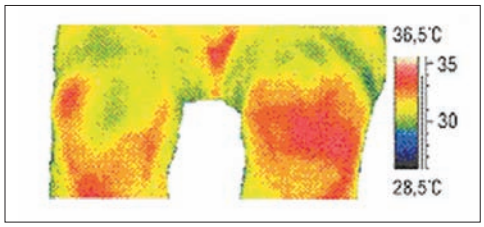

Fig. 7. Patient 2 - 20 minutes after cryotherapy.

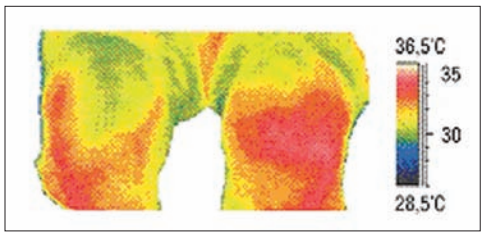

Fig. 8. patient 2 - 40 minutes after cryotherapy.

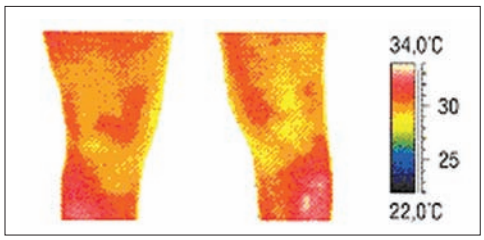

Fig. 9. patient 5 - before systemic cryotherapy - rain 900 scale.

The principles of thermography are presented in the Fig. 1. Infrared radiation emitted by A scanned object falls on optical system of thermograph and is directed onto sensitive surface of the detector. The detector processes radiation into proportional electric signals that are amplified by electric system and transmitted to imaging devices.

Cryotherapy

Cryotherapy is based on impulsive, superficial application of temperatures below -100°C, during a short period (1,5-5 minutes) in order to induce and utilize physiological and organic reactions against cold. Cryotherapy is mainly used in supporting basic treatment of diseases or malfunctions of kinetic organs or spine. After cryotherapeutic treatments several effects were observed: alleviation of pain, excessive blood supply to of limbs and skin, anti-swelling action, increase of muscular strength, enhanced secretion of endorphins and hormones, acceleration of non-infectious healing of scars.

The operation of cold can be divided into two stages. Firstly, cold induces stimulation of sympathetic system causing contraction of blood vessels in skin and hypodermis. It is followed by increased arterial blood pressure and stimulation of metabolism which contributes to intensified production of heat (this is a defensive reaction against cold). Nevertheless, the temperature in the body is lower. Due to contracted blood vessels, cooled tissues are insufficiently supplied with oxygen and nutrition ingredients which, in result, slows down metabolic processes. During this momentary stage skin is pale and goose-flesh or temporary feeling of cold may occur. The second stage begins shortly after first one, blood vessels contract and operation of parasympathetic part of autonomous nervous system starts to dominate. This is followed by excessive blood supply of tissues, reduction of skin paleness, feeling of warmth and good mood.

The expected effects of application of cold are: alleviation of pain, regression of inflammatory states, bleedings or posttraumatic swellings.

Therapeutic application of cold is normally assisted with other forms of physical

therapy such as kinetic therapy after which increased range of movement of diseased joints was observed as well as alleviation of pain, increased muscular strength and improved stamina [7]. In case of rheumatic diseases cryotherapeutic treatment arerepeated is repeated 2-3 times a day with at least A 6-hour interval. Sometimes treatments are applied in more than one place [5, 7].

Experiment and the method of examination

To evaluate the effectiveness of cryotherapy it is necessary to conduct examination of these areas of the body that were subjected to operation of low temperatures. Thermovision is a diagnostic method, utilized in examination of rheumatic diseases, thus, it can be employed to assess the results of rehabilitative action of cryotherapy.

16 patients were subjected to thermovisual examination of knees. Four of them showed rheumatic inflammation of joints and were subjected to local cryotherapy. The remaining group consisted of 6 healthy persons, 5 suffering from sclerosis multiplex and 1 with degenerative disease of joints - they were all treated with systemic cryotherapy. THERMOVISION® 900LW system by AGEMA was used.

Patients with rheumatic inflammation of joints had both their knees treated with vapors of liquid nitrogen during 2 minutes. Kriosan-7 device was used. The preparation of patient included exposing and drying the examined area, in this case - knees, and protecting other parts of the body. When the temperature of nitrogen vapors reached -150^{o}C the current was directed onto uncovered knees - one after another. The thermovisual measurement of the temperature was carried before the treatment, immediately after the treatment, 20 and 40 minutes after the treatment.

The next stage of experiment included the next group of patients consisting of healthy persons, those with sclerosis multiplex and also with degenerations of knee joints. The treatment in cryochamber was conducted according to the procedure, patients were wearing boots, socks, gloves and shorts or swimsuits. Additionally

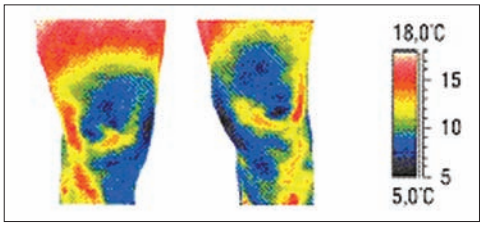

Fig. 10. patient 5 - immediately after cryotherapy.

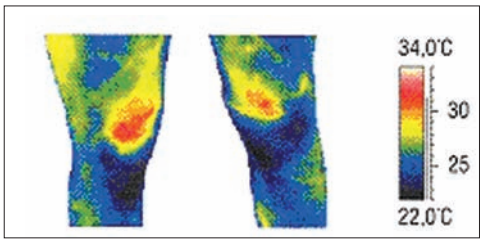

Fig. 11. Patient 5 - 15 minutes after therapy.

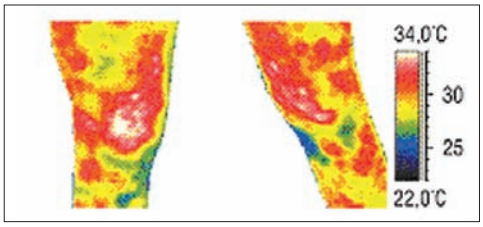

Fig. 12. Patient 5 - 30 minutes after therapy.

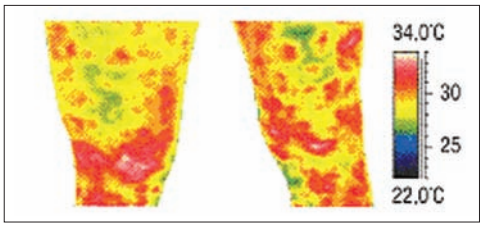

Fig. 13. Patient 5 - 45 minutes after therapy.

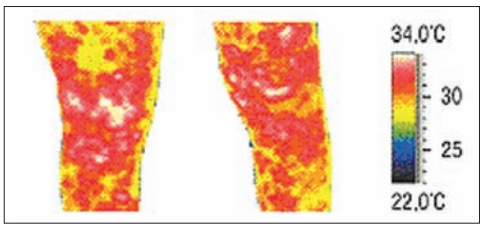

Fig. 14. Patient 5 - 60 minutes after therapy.

Table 1. The gradients of temperature within articular area in patients with theumatic disease of joints [OC].

LEFT KNEE					
patient's number	**disease**	**before treatment**	**0 minutes after treatment**	**20 minutes after treatment**	**40 minutes after treatment**
1	degenerative disease of joints	30,7-32,9	20,0-27,0	29,0-32,0	29,5-32,5
2		32,4-33,2	28,5-31-6	32,7-34,0	33,3-35,0
3		29,3-32,4	28,4-32,0	29,2-33,0	31,1-33,4
4		30,0-33,2	21,0-27,0		27,0-31,0
RIGHT KNEE					
1	degenerative disease of joints	30,8-33,1	24,0-27,0	28,4-31,2	29,3-32,1
2		33,5-35,0	28,0-31,0	30,3-33,7	31,0-34,6
3		29,0-32,1	28,1-31,6	29,0-31,7	30,0-33,0
4		32,9-34,5	25,0-32,0		29,6-34,7

Table 2. Gradients of temperature within articular area measured among the students (OC).

LEFT KNEE							
patient's number	**disease**	**before treatment**	**0 minutes after treatment**	**15 minutes after treatment**	**30 minutes after treatment**	**45 minutes after treatment**	**60 minutes after treatment**
5	various surgical procedures of knees	28,8-31,0	5,7-15,0	23,7-31,0	29,5-34,0	28,4-33,2	28,3-34,5
6	healthy	22,8-29,3	12,0-21,2	28,7-31,4	26,9-32,2	26,6-32,2	23,9-32,2
7	healthy	23,3-25,7	1,6-15,6	26,6-29,3	25,6-29,4	26,2-29,0	23,9-27,1
8	healthy	21,9-26,8	0,5-17,8	29,7-31,8	25,7-28,0	25,9-28,0	27,0-24,5
9	healthy	27,5-32,0	11,4-19,3	27,0-23,0	21,7-27,2	23,8-27,1	23,7-27,1
10	leg fracture	31,7-33,0	16,8-22,0	23,1-29,9	24,6-29,3	25,4-30,2	24,9-29,7
RIGHT KNEE							
5	various surgical procedures of knees	29,6-31,5	6,2-15,9	24,0-31,3	27,6-33,3	27,7-33,4	30,2-34,0
6	healthy	28,7-31,4	12,0-21,1	22,8-29,3	23,9-32,2	26,6-32,2	26,9-32,2
7	healthy	26,8-29,2	1,1-14,9	21,9-25,1	23,7-27,9	25,5-29,1	25,4-29,0
8	healthy	28,7-32,5	0,5-16,9	21,7-26,3	23,7-26,8	25,6-28,0	25,4-27,8
9	healthy	27,7-31,5	11,4-20,8	21,3-27,5	23,0-27,0	23,6-27,2	23,8-27,2
10	leg fracture	31,9-34,5	18,0-26,4	24,2-28,7	24,9-28,7	25,8-29,9	24,9-29,3

special ear covers and double surgical masks over mouth and nose were used. All patients stayed in the chamber for 3 minutes, however, the students who entered the chamber for the first time had the temperature set to -120°C while the rest had -150°C. The the group of six students was examined before, immediately after and 15, 30, 45 and 60 minutes after the treatment. Three patients were subjected to physical therapy after leaving the chamber.

The obtained sequences of imaged images were saved on hard disk as .img files. The correct scale of temperature was chosen to enable proper interpretation of thermograms. All thermograms were processed into colorful images in different color pallets: rain 900, gray scale, iron and medical. In the image matrix the intensity of a pixel depends on intensity of radiation. The color of the pixel depends on its brightness and is represented by the three spectrum components: red R, green G and blue B. As human sight is more likely to distinguish color than level of brightness the introduction of colors may facilitate recognition of details in the picture.

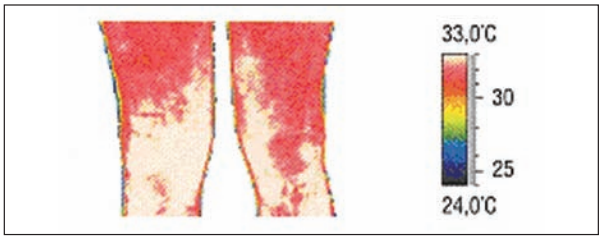

Fig. 15. Patient 10 - before systemic cryotherapy - rain 900 scale.

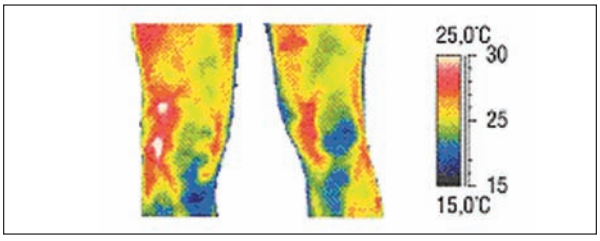

Fig. 16. Patient 10 - immediately after cryotherapy.

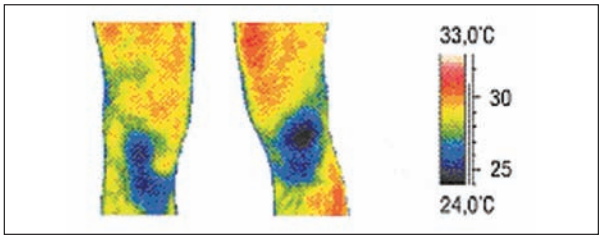

Fig. 17. Patient 10 - 15 minutes after therapy.

The rain 900 scale features wide range of colors, from cold (blue, green) to warm (yellow, orange, red). This scale precisely visualizes distribution of temperature and even its slight change. The iron scale has smaller range of colors and transition between them is very smooth which makes isotherms not clearly visible. In medical scale the colors are contrasted in order to achieve clear distinction between different temperatures. In that paper, for example, thermograms of patient no.5 are presented in all color scales, however the rest of thermograms features rain 900 scale as the one that displays changes of temperature in the clearest way. The examination results in different color scales are shown as monochromatic images in figures from 2 to 4.

Analyzis of thermograms

In the thermograms there were analyzed areas of knee joints. From these thermograms the maximum and minimum temperatures were taken. The data were utilized to draw graphs (figures 21 - 26). After examination and computer processing 81 thermograms were achieved. The obtained photos were taken among members of three groups. First group consisted of patients with diseases of knee joints, including 4 patients with rheumatic inflammation of joints and one with degenerative disease. Second group consisted of healthy students whose knees were in major cases in good condition. The last group included patients with sclerosis multiplex. In this paper the results of three patients with different diseases will be presented.

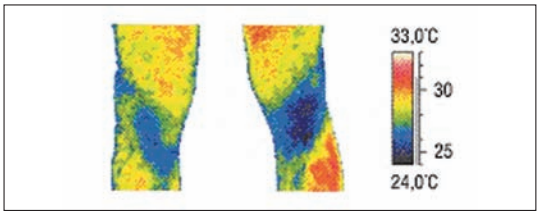

Fig. 18. Patient 10 - 30 minutes after therapy.

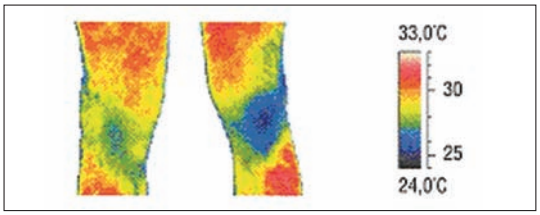

Fig. 19. Patient 10 - 45 minutes after therapy.

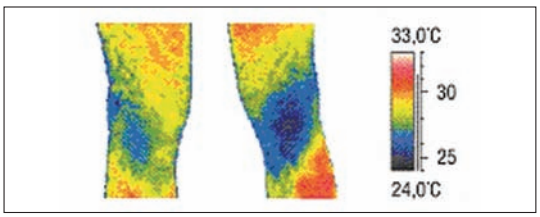

Fig. 20. Patient 10 - 60 minutes after therapy.

The first set of figures (Fig. 5 - 8) belongs to patient no.2 (52-years old man with rheumatic inflammation of knee joints) who was subjected to local cryotherapy. The distribution of temperature in all thermograms features some asymmetry - the right knee is all the time warmer than the left. Before and after cryostimulation the inner knee areas were warmer than surrounding areas. The gradient of temperatures before treatment was 32,4 - 35°C, higher temperature indicates inflammatory state in the joint. Immediately after cryostimulation the body heat decreased, however the change was rather small (28 - 31°C). Probably it was caused by patient's wearing clothes between cryo-treatment and infrared measurement. Figures 7 and 8 show the state of the patient after 20 and 40 minutes from the treatment. The temperature of knees reached back the values from before the therapy and gradients equaled: 30,3 - 34°C after 20 minutes and 31 - 35°C after 40 minutes. The results of that group of patients are collected in the table 1.

The next examined group consisted of students subjected to systemic cryostimulation. Three of them after leaving the chamber were subjected to kinetic therapy. The figures from 9 to 14 show knees of patient no. 5 - 25-years old man, who overcame several knee surgeries. After the treatment patient performed exercises. Thermograms were recorded before, immediately after and also 15, 30, 45 and 60 minutes after cryotherapy. The knee temperature before entering the chamber reached from 28,8°C to 31,5°C and the distribution was symmetric. After cryostimulation body heat decreased considerably and the gradient equaled from 5,7 to 17°C. 15 minutes later temperature increased up to 27°C, however, the distribution was uneven. It might be caused by kinetic therapy. As the time went by the temperature was increasing and after 60 minutes slightly exceeded the initial state (29,5 - 34°C).

Patient no.10 was a 24-years old man after right-leg fracture and featuring good general state. He was subjected to systemic cryotherapy. Kinetic therapy was not indicated.

Knee joints of that person are shown in the figures 15 - 20. The temperature distribution in knees is assymetric. Before the treatment the right knee was warmer (Fig. 15) and gradient balanced between 31,9 - 34,5°C. In case of the left knee gradient of 31,7 - 33°C was observed. After therapy the asymmetry even increased and the right knee was still warmer the the left (right knee: 16,8 - 22°C; left knee: 18 - 26,4°C). The body heat was increasing continuously and symmetry of temperature distribution was also growing. Gradients of temperature: after 15 minutes (Fig. 17) - 24 - 29°C, after 30 minutes (Fig. 18) - 24,6 - 29,3°C, after 45 minutes (Fig. 19) - 25,4 - 30,2°C, after an hour (Fig. 20) - 24,9 - 30°C. the knee joints themselves were colder than the surrounding areas. In the table 2 the gradients of temperature of knee surroundings of students were collected.

In the table 3 gradients of temperature of the third group are shown - patients with sclerosis multiplex (SM) and degenerative joint disease (DJD).

Due to patients' state the gradients were not measured after the treatment, only initial and final states were recorder.

According to measured maximum and minimum values some graphs were created in which one can observe changes of temperature in time. Figures 21 and 22 are graphic images of temperature in patients with knee diseases. Graphs 23 and 24 show change of temperature in healthy persons and graphs 25 and 26 were calculated for patients with sclerosis multiplex. Table 4 shows summary of results of performed treatments.

Conclusion

The conducted thermovisual examination of healthy and diseased knee joints showed that despite some individual differences the temperature distribution features some permanent and characteristic qualities. The temperature of the central parts of the joint is always lower than than remote areas. In a correct thermogram one can notice the differences of temperature within areas of bone connections. The influence of muscular and adipose tissue on distribution of temperature is also visible. The experiments proved that within cooled areas the temperature drops down but after some time the continuous increase of body heat is observed which may lead even to exceeding the initial values of temperature. In patients who were not subjected to kinetic rehabilitation after cryotherapy the increase of temperature was observed after 30 - 40 minutes. In patients who performed exercises after cryotherapy, however, the temperature raised after only 15 minutes.

The thermovisual camera enables observation of trend of temperature changes, thermograms provide us with essential diagnostic information which may be very useful as the first stage of diagnosis of knee joints diseases. However, the proper evaluation of temperature distribution on the surface of hind limbs is impossible without comparison with normal state values.

In patients with rheumatic diseases of joints increased temperature within diseases areas was observed. The more severe diseases the higher was the temperature. Diseased areas were not as much cooled as healthy joints. The higher temperature was also observed in persons after sport-induced injuries and in patients with sclerosis multiplex.

The quality of thermograms depends very much on graphic processing. The THERMOVISION 900 SERIES system enables proper visualization of temperature distribution so that the doctor can easily evaluate the state of a patient. It is possible due to wide range of temperatures and many optionally available color scales.

The incorporation of various scales of temperature in reported experiments enabled more precise visualization of temperature distribution on the surface of knees. The greyscale does not give AN unambiguous display of temperatures. For medical purposes it is better to utilize colored thermograms in which given color represents specific

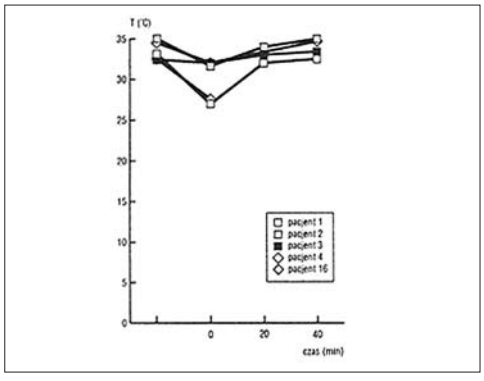

Fig. 21. Changes of maximum temperatures in patients with knee diseases subjected to local cryotherapy.

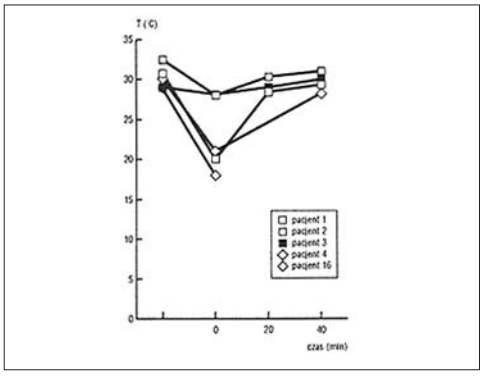

Fig. 22. Changes of minimum temperatures in patients with knee diseases.

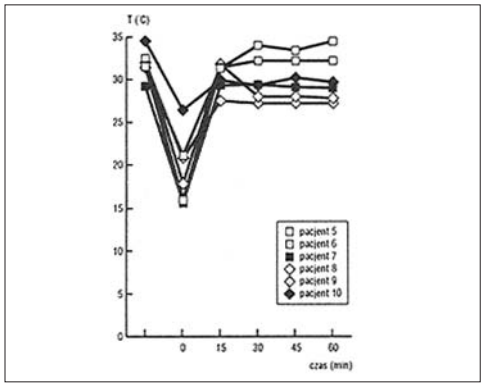

Fig. 23. Changes of maximum temperatures in healthy persons.

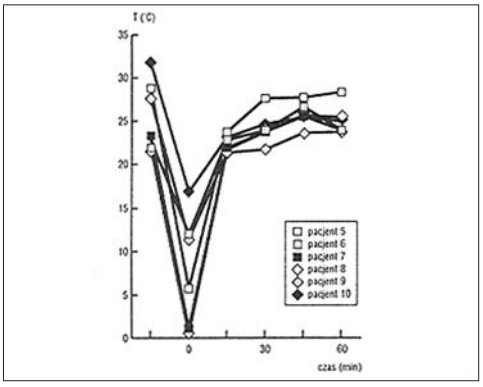

Fig. 24. Changes of minimum temperatures in healthy persons.

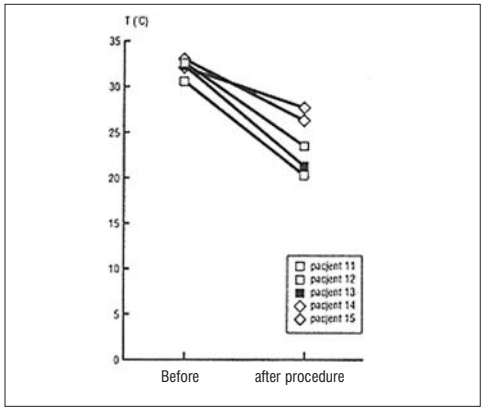

Fig. 25. Changes of maximum temperatures in patients with sclerosis multiplex (SM).

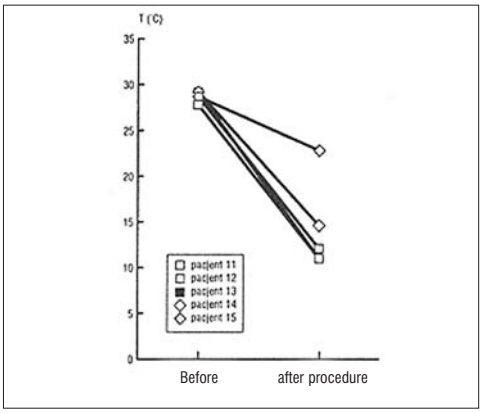

Fig. 26. Changes of minimum temperatures in patients with sclerosis multiplex (SM).

temperature. Then the doctor can easily evaluate the distribution on the surface of the patients' body. The specially created "medical" scale precisely marks specific values of temperature, however, the choice of colors disturbs the interpretation of images. The incorporated in that paper scale rain 900 features smooth transition between colors, thus, thermograms are easily readable and clear. Even the smallest changes are visible. Thus, displaying the distribution exact to a 0,1^{o}C was possible. The computer program of THERMOVISION 900 system proved to be very useful for the purposes of diagnosis, evaluation of treatment effectiveness and creating archives.

Thermography utilized in order to evaluate the results of cryotherapy proved to be a useful method. It contributed to easy estimation of temperature changes after the treatment (10-12^{o}C in healthy persons, and up to 20^{o}C in patients) and also enabled further observation of temperature changes. On the basis of created graphs one can say that in healthy persons the total increase of temperature was greater and occurred after shorter time. Also the initial temperature of patients subjected to kinetic therapy was restored quicker than in diseased persons. The gradients of minimal temperatures are larger than those of maximum temperatures.

Following the conducted experiments some general conclusions can be drawn:

- thermovision enables dynamic registration of temperature changes
- there are individual differences in reactions against cold

Table 3. Gradients of temperature within articular area measured in patients with sclerosis multiplex and degenerative disease of joints.

Patient's number	disease	LEFT KNEE		RIGHT KNEE	
		before therapy	0 minutes after treatment	before therapy	0 minutes after treatment
11	sclerosis multiplex (SM)	28,0-30,6	11,0-19,1	27,8-30,6	12,1-20,3
12		28,7-32,6	12,1-23,5	28,9-31,8	14,5-22,4
13		30,7-32,3	11,2-21,3	29,2-31,3	11,0-19,3
14		29,2-31,1	17,4-26,3	30,0-33,0	14,6-23,5
15		28,7-31,2	22,8-27,7	29,3-32,1	23,4-27,5
16	arhrosis	28,8-32,2	17,9-21,0	30,3-32,5	19,7-27,6

Table 4. Summary of performed experiments.

Patient	Sex	Disease	Type of cryotherapy	Duration of treatment [mins]	Temperature of treatment	Kinetic therapy
1	woman	rheumatic disease of joints	local	2	-150	yes
2	man	rheumatic disease of joints	local	2	-150	yes
3	woman	rheumatic disease of joints	local	2	-150	yes
4	woman	rheumatic disease of joints	local	2	-150	yes
5	man	knee surgeries	general	3	-120	yes
6	man	healthy	general	3	-120	yes
7	woman	healthy	general	3	-120	yes
8	woman	healthy	general	3	-120	no
9	man	healthy	general	3	-120	no
10	man	leg fracture	general	3	-120	no
11	man	SM	general	3	-150	no
12	man	SM	general	3	-150	no
13	man	SM	general	3	-150	no
14	man	SM	general	3	-150	no
15	man	SM	general	3	-150	no
16	man	degenerative disease of joints	general	3	-150	no

- diseased patients were less sensitive against operation of low temperatures and the temperature of joint was higher
- the influence of muscular and adipose tissue on temperature distribution was visible
- the temperature of central parts of knee joints was lower than that of remote areas
- cryostimulation is followed with increase of temperature which is raised to a higher level than before the treatment (stimulating effect).

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Comparison of some parameters of two-stepped cryogenic chamber and chamber with lingering cold

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Abstract: The application of the whole body cryotherapy takes little time, only 2-3 minutes but it triggers of important and varied changes in the human skin temperature, however the body internal temperature changes do not exceed the thermoregulation range during the cryotherapy session. The real temperature conditions on the different heights during cryotherapy session for both types of cryogenic chambers (two-stepped and with lingering cold) were studied. The results show that the low temperature is more stabilized in the chamber with lingering cold while the two-stepped cryogenic chamber is convenient for patients on the wheel chairs. The cryotherapy effects seem to be similar regardless of cryogenic chamber type. It results from the polls and medical history of patients suffered from back pain that the cryotherapy leads to improvement of health state, which increases with the number of sessions. It results in reduction of the level of pain, improvement of physical fitness and the feeling of well-being.

Key words: whole body cryotherapy, rehabilitation, poll

Introduction

Cryotherapy is defined as a method of medical treatment consists on using the cold (ice packs, snow, carbon dioxide - dry ice and cooled air) on whole human body or only on a part of the body [1 - 4].

The development of cryogenic contributed to the application increase of the low temperature in medical treatment [5 -7]. In 1907 Whitehouse made the first cryotherapy device spraying liquid nitrogen. It was used in some dermatological lesions to destroy the superficial localized cancers.

The cold treatment methods are divided due to caused the tissue effects. There is the cryosurgery where the low temperature is used to destroy the ill tissues and cryotherapy in which different physiological mechanisms are stimulated by low temperature. Nowadays cryosurgery is widely used in dermatology, oncology, gastrology, cardiology, laryngology, ophthalmology and gynecology [9-18].

The whole body cryotherapy has its beginning in Japan where in 1978 T. Yamauchi used cryogenic chamber in treating patients suffered on rheumatoid arthritis [8]. In Europe R. Fricke's crew introduced the whole body cryotherapy in Germany. He drew up the first standards of using the cryotherapy in medicine [2, 3, 5, 6, 7].

A design of two-stepped cryogenic chamber by Z. Raczkowskiego from Institute of Low Temperature and Structure Researches of Polish Science Academy in Wrocław initiated the whole body cryotherapy in Poland. The first cryogenic chamber started to work at Janusz Korczak's Rheumatologic Hospital in Kamienna Góra. It was the 2nd cryogenic chamber in Europe and the 3rd in the world.

The aim of whole body cryotherapy is using the temperature below 100°C in short period of time

(2 - 3 minutes) to stimulate human organism by trigger of the defense reactions against the cold, which assist typical treatment. Whole body cryotherapy is mainly used as a part of rehabilitation programme with kinetic therapy (physical exercises) what leads to shortening of the recovery time of the rehabilitation. This therapy is applied in different motion organs diseases: degeneration and inflammatory states of joints (monoarthritis and oligoarthritis) and periarthritis, rheumatism, low back pain diseases and inflammatory, degeneration states of spinal vertebrae joints, fibromialgia and osteoporosis [19, 20-25]. The positive influence of cryotherapy on mental health was also reported what could be explain by increase of concentration of some hormones and destroying the free radicals. After cold treatment subside of tiredness and dream disturbance were also observed [26, 27]. Moreover the cryotherapy has wide application in nervous system diseases - sciatica and spondyloarthrosis [28, 29] and sclerosis multiplex [30-32].

The meaning of using the low temperature in medicine seems to increase so it is important to make the objective researches of the whole body cryotherapy effects, to explain physiological, metabolic and biophysical mechanisms due to cold treatment. In medical treatment reception of psychological attitude of patient to therapy is also important.

This paper presents comparison of some technical parameters of two-stepped cryogenic chamber and the chamber with lingering cold as well as the cold treatment effects in patient's opinion.

Experimental

The studies were carried out at the Provincial Centre of Rheumatologist in Goczałkowice Zdrój (WORR) and Silesian Center of Rehabilitation and Physical Medicine in Ruda Śląska (GCR) where cryogenic chamber with lingering cold and two-stepped cryogenic chamber were installed, respectively. To get very low temperature (-120°C) in the cryogenic chambers liquid nitrogen (GCR) and liquid air (WORR) were used. These both rehabilitation centers with different types of cryogenic chambers were analyzed.

The rehabilitation treatment standards with using the whole body cryotherapy is known and mainly established [2, 3]. The programme included session of whole body cryotherapy and physical exercises.

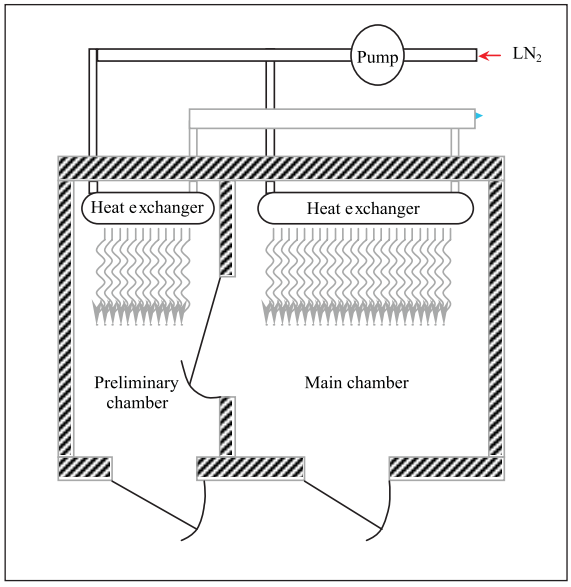

Fig. 1. Schema of two-stepped cryogenic chamber.

The patients group from GCR consisted of 20 females and 20 males in age 53,4 ± 16,4 suffered from sciatica and spondyloarthrosis. Whereas 6 patients suffered from spondyloarthrosis were from WORR (1 female and 5 males in age 35,8 ± 13,9). Whole body cryotherapy required special equipment. Men were asked to wear shorts and women - swimsuits. Everybody had to wear a special protective cold mask, woollen socks and clogs. They were asked to report any continual discomfort or pain. Prior to participation in the experiment a physician examined all the subjects. They were requested not to smoke, drink alcohol or hot drinks for 2-3 hours before experiment to better stabilize their blood flow.

For some cases the patients were undergoing medical treatment even

a few years. In those times they were treated by pharmacology, electrostimulation and magnetostimulation but during the experiment patients were undergoing only whole body cryotherapy and physical exercises.

In order to learn patient's point of view on cryotherapy effect a special questionnaire was prepared. Patients were asked to fulfil it according to their opinion. The questionnaires on the effects of cryotherapy were given to 60 persons but only 46 (40 from GCR and 6 from WORR) were received. The results of rehabilitation (whole body cryotherapy and physical exercises) with respect to pain level and physical fitness were analyzed.

The studies were performed during the normal programme of rehabilitation in the Centre.

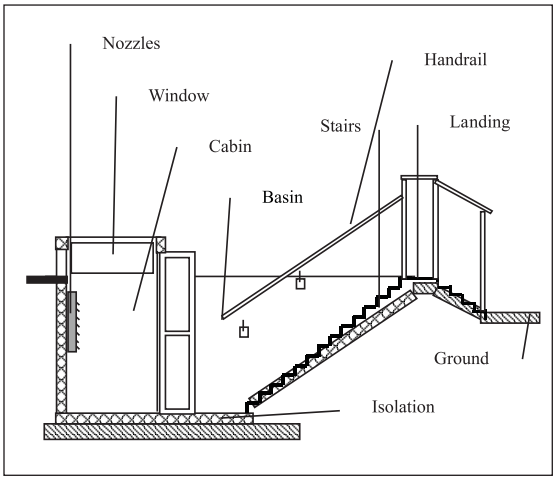

Fig. 2. Schema of cryogenic chamber with lingering cold.

The temperature inside the cooled off empty cryogenic chamber and during the cryotherapy with patients was measured by using a thermocouples class B type "K" (Ni; Cr; Ni; Al). Thermocouples were connected by interface to the computer and the results of temperature measurements were automatically converted to Celsius. In both types of cryogenic chambers temperature was measured at 4 heights without as well as with patients inside. The temperature measurements were performed in the main chamber and in the treatment main chamber of two-stepped cryogenic chamber and chamber with lingering cold, respectively.

Results and Discussion

3.1 The short description of cryogenic chambers

a) Two-stepped cryogenic chamber ("wrocławski" type) installed in GCR.

The cryogenic chamber (KN 01) consisted of two rooms: preliminary and the main chamber (Fig. 1). To get very low temperature the liquid nitrogen (LN2) was used. LN2 was pumped through the pipes into the heat exchanger inside the cryogenic chamber. A driver, connected to a PC, automatically controlled whole cooling process. Patient stayed 60 sec. in the preliminary chamber where the temperature was about -60°C and then went to the main chamber where the temperature was fixed in the computer driver -120°C and stayed there 2 - 3 minutes according to physician directions.

b) Cryogenic chamber with lingering cold installed in WORR.

The principle of operation this kind of cryogenic chamber basis on the physical phenomenon of lingering cold in the basin. Therefore the cryogenic chamber is placed underground what is shown in Fig. 2. To get very low temperature the liquid air with modified composition (21% to 30% oxygen) was pumped from the tank outside the chamber by the pipes into the sprayer nozzles inside the cryogenic chamber.

3.2 The temperature characteristic of cryogenic chambers

The magnitude of low temperature used in whole body cryotherapy has significant influence on treatment effects so it is necessary to check the real temperature at different heights. The mean temperature measured in both types of cryogenic chambers at 60, 110, 145 and 180 cm height (above the chamber floor) are presented in Table 1 and Fig. 3 and 4, respectively.

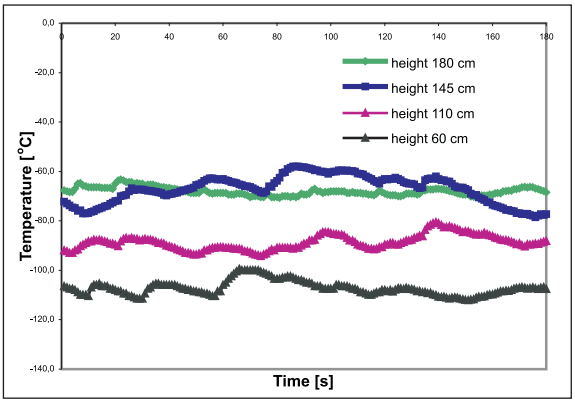

Fig. 3. The mean temperature measured at different heights during whole body cryotherapy in two-stepped cryogenic chamber installed in GCR.

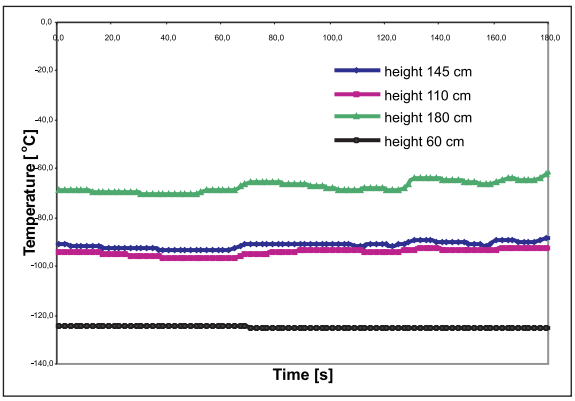

Fig. 4. The mean temperature measured at different heights during whole body cryotherapy in cryogenic chamber with lingering cold installed in WORR.

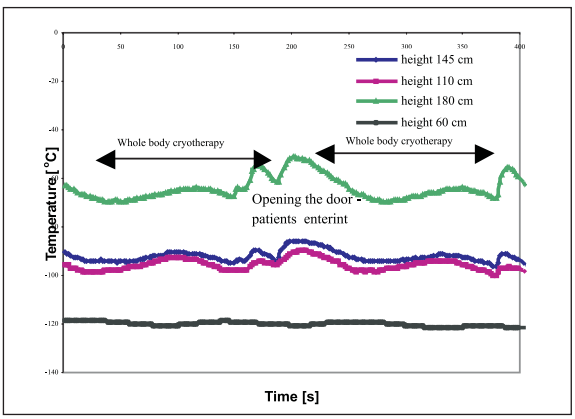

Fig. 5. The temperature changes during to sessions of whole body cryotherapy in cryogenic chamber with lingering cold installed in WORR.

Obtained results indicate the temperature dependence with height in both types of cryogenic chambers.

In the main chamber of two-stepped cryogenic chamber the temperature difference (DT) between 0,6 and 1,8 m is about 38°C. However in the cryogenic chamber with lingering cold the reached temperature is generally lower of about 20°C and the temperature fluctuations in time are markedly smaller. It is clearly seen from the Fig. 3 and 4 and Table 1 that more stabilized temperature is in the chamber with lingering cold.

Fig. 5 additionally presents temperature plots during two full cryotherapy session (480 sec.) including patients entering. Entering the patients into chamber can causes some temporary temperature increase but generally the temperature is kept nearly constant. One can see periodically increasing of temperature connected with patients entering and going out from the chamber. Patients entering into the chamber caused increase of temperature of about several degrees that was dependent on the height of chamber. The changes of temperature were mainly observed at height more than 100 cm.

It is also interesting to compare temperature condition outside the chambers. Opening the door of the two-stepped cryogenic chamber influence markedly on the temperature of the room where it is installed. In the case of the chamber with lingering cold the temperature changes overlap in the basin while the room temperature is negligible influenced. It follows that temperature stabilization is better in chamber with lingering cold than in two-stepped cryogenic chamber.

Moreover it is important to note that application of physical phenomenon of lingering cold in the basin in technology of cryogenic chamber lead to decrease of thermal isolation and eliminate the preliminary chamber (two-stepped

cryogenic chamber was changed to one main chamber and the vestibule) what can reduce production costs. However there are many factors that could have an influence on cryogenic chamber efficiency: the tank coolant distance from chamber, pipes isolation and its length as well as capacity of the chamber.

The other difference between cryogenic chambers is the maximal patient number that could stay inside during the cryotherapy at the same time: 5 in the GCR and 3 - 4 in the WORR.

On the other hand there are no cryotherapy facilities for patients on the wheel chairs in cryogenic chamber with lingering cold in opposite to two-stepped one where preliminary and the main chamber are at the same level.

It is difficult unambiguously to point out the superiority of one type of the studied cryogenic chambers.

Whole body cryotherapy effects in patient's opinion - polls

It was interesting to know the patients view on cryotherapy for the sake of reduction of pain level.

It is thought that one of the main effect of cold treatment is pain level decrease as result of increased excretion of b-endorphins, the switching off the feeling receptors nonactive due to cold and their connection with proprioreceptors and slower conduction in feeling fibres [5, 6].

The second aspect of cryotherapy is the improvement of physical fitness what is using in sport medicine.

Therefore an influence of the cryotherapy on reduction of the level of pain and improvement of patient's health condition (physical fitness) was analysed.

Two groups of patients were taking into consideration:

- after 1 cryotherapy cycle (1 - 10 cryotherapy sessions) - 28 patients
- after 2 cryotherapy cycles (11 - 20 cryotherapy sessions) - 12 patients

The scale of evaluation of effects of whole body cryotherapy was following:

0 - no improvement
1 - weak improvement
2 - significant improvement

Results of analysis of polls are presented on wheel percentage diagrams (Fig. 6 - 9). And collected in Table 2.

It follows from Figure 6 that cryotherapy involving 10 sessions caused decrease of pain level in about 90% patients (53% - significant improvement and 39% - weak improvement). Only 7% of patients did not feel any improvement. Similar proportions were obtained regarding to improvement of the physical fitness.

Additionally 10 sessions of whole body cryotherapy caused that all patients reported the improvement of physical fitness and decrease of pain (~83% significant and ~17% weak) what is presented in Fig. 7.

Table 1. The mean temperature at different heights in both cryogenic chambers types.

Height [cm]	Mean temperature inside empty cryogenic chamber		Real mean temperature inside cryogenic chamber during the therapy	
	Main chamber ("wrocławski" type)	Chamber with lingering cold	Main chamber ("wrocławski" type)	Chamber with lingering cold
180	-70,7 ± 1,3° C	-69,3 ± 0,3° C	-68,0 ± 1,6° C	-67,3 ± 1,3° C
145	-75,1 ± 1,7° C	-94,3 ± 0,2° C	-67,1 ± 5,6° C	-91,2 ± 1,3° C
110	-91,1 ± 1,7° C	-97,4 ± 0,6° C	-88,8 ± 3,0° C	-94,3 ± 1,3° C
60	-108,6 ± 1,5° C	-131,6 ± 0,3° C	-107,3 ± 2,9° C	-125,3 ± 0,3° C

Moreover it followed from medical history of patients that cryotherapy is beneficial and after each session patients felt of well being and relaxed. Thus patients took willingly the next cryotherapy sessions (some patients even several times during few years). However there were rare cases when patients couldn't overcome the fear against the cold (only one in our experiment).

There were following age criterion:

- 20 to 50 years old
- above 50 years old

One can see from Fig. 8 that cryotherapy has similar positive influence on decrease of the pain level regardless of age. The situation is different as we analyse the cold treatment influence on physical fitness. In this case the effects are better seen for younger patients than older. In the group of 20 - 50 age, 40% of patients reported weak while the others - significant improvement of physical fitness.

The cryotherapy effects for older patients were also beneficial however there were some patients (13%) that did not reported any physical fitness improvement (see Fig. 9).

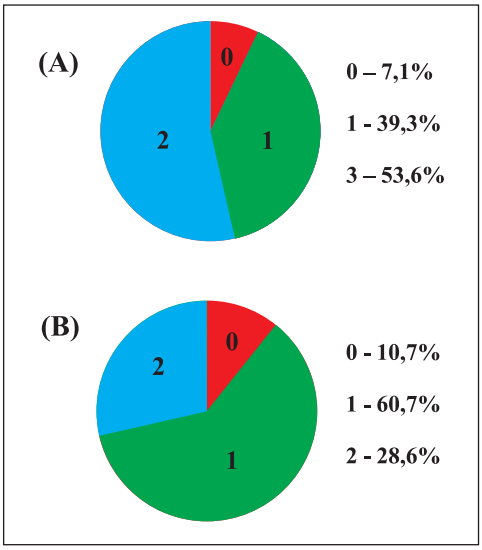

Fig. 6. Wheel percentage diagram presented influence of whole body cryotherapy on pain level (A) and on physical fitness (B) for patients after 1 - 10 cryotherapy sessions.

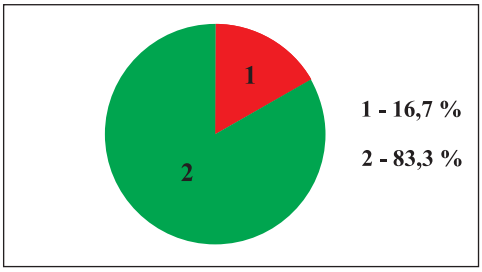

Fig. 7. Wheel percentage diagram presented influence of whole body cryotherapy on pain level as well as on physical fitness (the same percent values) for patients after 11 - 20 cryotherapy sessions.

Conclusions

Low temperature (about -120°C) advisable for whole body cryotherapy could be reached by using LN2 pumped through the pipes into the heat exchangers inside the cryogenic chamber (two-stepped cryogenic chamber) as well as due to physical phenomenon of lingering cold in the basin where the cryogenic chamber cooled by liquid air sprayed through the nozzles is placed.

It follows from our measurements that the low temperature is more stabilized in the chamber with lingering cold than in two-stepped cryogenic chamber. However the two-stepped cryogenic chamber is convenient for patients on the wheel chairs in cryogenic.

Moreover the studies indicate that the whole body cryotherapy conditions are similar regardless of cryogenic chamber type.

Table 2. Summary effects of whole body cryotherapy influence on physical fitness and pain level.

Sessions number	Improvement of physical fitness	No improvement of physical fitness	Decrease of pain level	No decrease of pain level
0 - 10	89,3%	10,7%	92,9%	7,1%
11 - 20	100%	0%	100%	0%

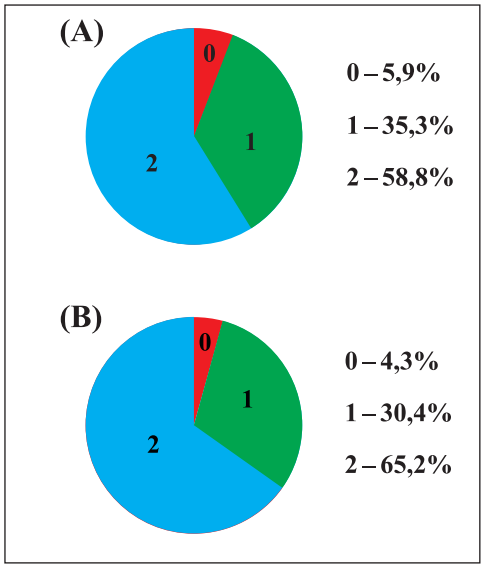

Fig. 8. Wheel percentage diagram presented influence of whole body cryotherapy on pain level for patients in age 20 - 50 (A) and above 50 (B). It was interesting to check the whole body cryotherapy reception with patient's age.

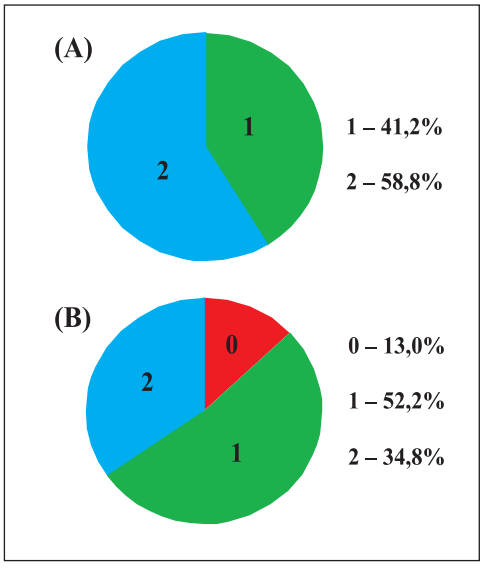

Fig. 9. Wheel percentage diagram presented influence of whole body cryotherapy on physical fitness for patients in age 20 - 50 (A) and above 50 (B).

From patient's point of view and medical history of patients suffered from back pain the cryotherapy leads to improvement of health state increasing with the number of sessions. It manifested by the reduction of the level of pain, improvement of physical fitness and the feeling of well-being.

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