



WHOLE BODY CRYOTHERAPY IN MODERN MEDICINE

Zastosowanie krioterapii ogólnoustrojowej
we współczesnej medycynie



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Abstract

20th century medicine saw the development of many physiotherapy fields. Among these, a new department called cryotherapy or cold treatment was created. This paper focuses on systemic cryotherapy, which is performed in a specially designed cryogenic chamber. Despite extensive literature on cryotherapy, the general indications mainly include pain and oedema reduction. Thus, they are often limited to rheumatologic diseases and osteoarthritis. Disability, joint pain and muscular atrophy, which occur at an increasingly young age, represent a civilization problem faced by societies suffering from physical activity deficit. Furthermore, disorders such as obesity and depression are on the rise. In both cases, the underlying cause can be traced to lifestyle changes. Inadequate diet and insufficient physical activity from an early age lead to the so-called lifestyle diseases at an increasingly early age. Whole body cryotherapy seems to be an ideal option for such patients as cold reduces pain that can occur even in fibromyalgia. This is confirmed by recent studies. Among other things, cryotherapy may be successfully used for chronic pain in patients with osteoarthritis, rheumatoid arthritis and other rheumatic diseases, as well as multiple sclerosis. In these patients, systemic cryotherapy may be the solution that not only reduces pain, but also has an anti-oedematous and anti-inflammatory effect.

Streszczenie

W medycynie XX w. nastąpił rozwój wielu dziedzin fizjoterapii. Powstał nowy dział o nazwie krioterapia, czyli leczenie zimnem. Praca dotyczy krioterapii ogólnoustrojowej, która przeprowadzana jest w specjalnej komorze kriogenicznej. Piśmiennictwo na temat krioterapii jest bardzo obszerne, jednak wskazania ogólne do zastosowania tej metody odnoszą się głównie do zmniejszenia dolegliwości bólowych i łagodzenia obrzęku, zatem często ograniczają się do chorób reumatologicznych i chorób zwyrodnieniowych stawów. Problemem cywilizacyjnym społeczeństwa cierpiącego na niedobór ruchu jest coraz wcześniej pojawiająca się niepełnosprawność, bóle stawów i zaniki mięśniowe. Mało tego, coraz częściej występują choroby takie jak otyłość i depresja. W obu przypadkach podłoża można doszukiwać się w zmianie stylu życia. Nieodpowiednia dieta i zbyt skąpa aktywność fizyczna już od najmłodszych lat są powodem występowania w coraz wcześniejszym wieku tzw. chorób cywilizacyjnych. Krioterapia ogólnoustrojowa wydaje się dla takich chorych idealną metodą terapii, gdyż zimno zmniejsza dolegliwości bólowe, które mogą występować nawet w fibromialgii, co potwierdzają najnowsze badania. Doskonale sprawdza się między innymi w chronicznych bólach, jakie towarzyszą pacjentom z chorobą zwyrodnieniową stawów, reumatoidalnym zapaleniem stawów i innymi chorobami reumatycznymi oraz stwardnieniem rozsianym. U tych chorych rozwiązaniem może stać się zastosowanie krioterapii ogólnoustrojowej, która nie tylko zmniejsza dolegliwości bólowe, ale również wykazuje działanie przeciwobrzękowe i przeciwzapalne.

Keywords: cryotherapy; whole body cryotherapy (WBC); cryochamber; cold therapy

Słowa kluczowe: krioterapia; krioterapia ogólnoustrojowa; kriokomora; terapia zimnem

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Introduction

20th century medicine witnessed the development of a new type of treatment called cryotherapy. The word is derived from Greek and means treatment with cold. Whole body cryotherapy (WBC) uses cold as a therapeutic agent. It causes constriction of blood vessels in the initial stage of cold exposure and their significant dilatation in the final stage of exposure. As a result, tissues are supplied with fresh blood. This is followed by an internal warming of the body, improved cell nutrition and oxygenation, as well as an acceleration of the metabolism. Cold has healing and rejuvenating properties.

The procedure, which involves whole-body exposure to very low temperatures ranging from -120°C to -180°C , is performed in a special cryogenic chamber and lasts approximately 2–3 minutes. The temperature of the skin and subcutaneous tissues drops in a controlled manner, producing a highly beneficial therapeutic effect. The treatment in the cryochamber is followed by systemic exercises under the guidance of a physiotherapist [1–3].

Historical background

Cold treatments were already used by the Egyptians about 2500 BC. It was in the 5th century BC that Hippocrates recommended hypothermia to reduce oedema, bleeding and pain. He also discovered the analgesic properties of cold [4]. Napoleonic surgeon Baron Dominique Jean Larrey observed during the Russian campaign that soldiers could have their limbs amputated with less pain and bleeding when previously placed in ice or snow.

The properties of ethylene chloride have been known since the first half of the 19th century. They were discovered in France in 1847 by Jean Pierre Florens, who applied the chemical compound topically. In 1866, ethylene chloride was used in aerosol form by Pierre Redard (Sweden) for general analgesia. To this day, it is still widely used in sports medicine as a pain reliever after injuries.

The beginning of modern cryogenics is marked by mastering gas liquefaction at the end of the 19th century. Physicists of that time, including Poles, liquefied oxygen, carbon dioxide, air and hydrogen. They also made it possible to produce these gas on an industrial scale and to utilise them to this day. These achievements contributed to the development of anaesthesiology and general cryotherapy.

In 1907, Whitehouse constructed a device to release liquid nitrogen vapour to treat superficial tumours and certain skin lesions.

The concept of cryotherapy as a stimulating application of cryogenic temperatures (below -100°C) over a short period of time (2–4 minutes) to elicit physiological systemic responses to cold, support primary treatment and aid kinesiotherapy was born in the 1970s. Cryogenic temperatures can be applied topically or systemically, using a cryochamber.

The introduction of cryotherapy in therapeutic practice is attributed to the Japanese prof. Toshiro Yamauchi and

his team from the Reiken Rheumatism Village Institute in Oita, where the first portable cryotherapy devices were constructed and, in 1978, the first cryogenic chamber was developed. Another chamber was developed at the St Joseph's Rheumatology Clinic in Sendenhorst (Germany). In 1983, a cryotherapy applicator was developed for use in volunteers with rheumatism and post-traumatic diseases in the Department of Physiotherapy at the University of Physical Education in Wrocław, headed by Prof. Zdzisław Zagrobelny. In 1989, the first cryochamber was built in Poland (the second in Europe and the third in the world). A group of students from the Academy of Physical Education in Wrocław volunteered to test the device [2, 3].

New directions of research on the use of whole-body cryotherapy

The safety of WBC has been proven in clinical trials for people of all ages, provided that they are correctly qualified and that certain principles are followed. No life-threatening symptoms have been reported so far. The benefit-risk ratio is clearly favourable, with the treatments shown to improve the patient's general condition and clearly facilitating further rehabilitation. Any adverse effects, e.g. frostbites or raised blood pressure, should be immediately managed [2–4].

There is extensive literature on cryotherapy, local cryotherapy in particular. General indications include rheumatological diseases, osteoarthritis (RA), injuries and their complications, oedema, and local pain. In rheumatoid arthritis (RA), WBC significantly reduces pain and disease activity, allowing for lower analgesic use. These effects are likely due to changes in cytokine levels [5]. However, more research is needed on the effects of WBC on the human body.

The natural strengthening of the body through exposure to cold has become a tradition in many parts of the world. It is a method used to prevent diseases and promote healing that has evolved from pure empiricism in places where the climate promotes body hardening. It has been observed that exposure to cold blocks pain receptors by reducing afferent spindle discharges and transiently weakening nerve conduction. Furthermore, exposure to low temperatures suppresses pain perception, as a result of reduced muscle tone, cooling of muscles and nerves, deactivation of skin receptors and slowing of sensory and vegetative neuromuscular conduction, as well as it affects the rate of chemical reactions. This results in reduced pain perception, supported by the release of higher levels of β -endorphins and an effect on 'pain control gates' at the level of spinal cord and brainstem [5].

Cryotherapy, as a type of physical therapy, aims to eliminate or reduce pain, maintain optimal musculoskeletal function and arrest or at least slow the progression of degenerative changes. The therapeutic effects of WBC used in medicine are mainly related to reducing inflammatory processes and skeletal muscle tone, relieving pain and oedema, increasing muscle strength and accelerating regenerative and reparative processes. Systemic exposure to extremely low temperatures also leads to an increase in exercise tolerance and immunity, and has a beneficial

effects on the mental state, reducing hyperactivity, anxiety and restlessness, as well as improving perception, concentration, CNS fatigue resistance and sleep quality. Many studies have shown that kinesitherapy should be an integral part of cold treatment protocols [6].

WBC may be effective in the augmentation of antidepressants (reduced antidepressant intake was noted). The rapid antidepressant effect results from the release of endorphins immediately after treatment. Although the outcomes of WBC combined with antidepressant therapy obtained so far are interesting, they need to be replicated in further studies. Once the high efficacy of WBC and its rapid therapeutic effect are confirmed, this therapy may become an attractive option of augmenting antidepressant treatment, possibly also in drug-resistant depression [7].

Research has shown that systematic exposure to extreme cold air reduces IL-1 α , increases IL-6 and IL-10 cytokines, and contributes to a reduction in total antioxidant status (TAS) (a measure of antioxidant capacity of biological substances, such as lipid proteins, which is used in research on oxidative stress and oxidant effects) and has an overall immunostimulatory effect [8–9]. To date, WBC has been proven to be effective in the treatment of somatic diseases such as RA, multiple sclerosis (MS), fibromyalgia, chronic back pain and ankylosing spondylitis [10–11]. It was shown in one study that cryotherapy reduced depressive symptoms in patients with mild cognitive impairment, as measured by a visual analogue

scale (10 sessions, study group $n = 33$, temperature from -110°C to -160°C), justifying an attempt to use WBC in the treatment of depression [12].

Few publications have reported the use of WBC to support pharmacotherapy in depressive patients. They indicate that this method can lead to improvement in individuals already receiving pharmacological treatment. The severity of depressive symptoms decreased by about 35% during this time in the study with 10 WBC sessions, and by up to 69% in another study with 15 sessions. This may indicate a rapid and possibly dose-dependent effect of the treatment. There was no significant effect of 20 WBC sessions on changes in blood cell count, rheology and biochemistry in women with MS. WBC significantly increases erythrocyte capacity and lowers haematocrit (within physiological norms) in healthy women, which has a beneficial effect on the rheological properties of the blood. Whole body cryotherapy is a safe method in MS patients as changes in blood rheology are not responsible for therapeutic efficacy and WBC does not adversely affect the deformability and aggregation of red blood cells [13].

Studies on the use of WBC in obesity and post-coronavirus disease 2019 (COVID-19) condition (PCC) have also shown promising results. They have demonstrated that WBC is a safe therapy leading to overall improvement. They also showed that multidisciplinary rehabilitation is effective in post-COVID-19 patients and suggested that WBC is safe and may aid rehabilitation programmes [14].



Fig. 1. Whole-body cryochamber



Fig. 2. Patients before treatment session

General construction and operation of the most common Wrocław-type cryochamber

- WBC is performed using a special kit including:
 - an assembly of devices producing a gas cloud of defined size and temperature;
 - treatment chamber;
 - control panel.

The gas cloud generating unit works by transferring vapour-free compressed air to a heat exchanger into which liquid nitrogen, used here as a source of cold, is fed from a special tank in a controlled manner via an adjusting valve. In the heat exchanger, the liquid nitrogen reduces the temperature of the compressed air stream, which is fed through insulated tubes to the set of nozzles located in the treatment chamber. Unlike those used previously, modern WBC chambers allow patients to be observed through the glass and on a monitor, as well as to be spoken to via an inbuilt system, enabling direct contact. It is also possible to control the size of the gas cloud and, most importantly, to exclude the patient's head from the low-temperature exposure zone. The incoming cold air is systematically fed to the outside by a vacuum-based system. In this way it is possible to maintain a stable size of the cold gas cloud and to eliminate its effect on the temperature of the room where the treatment chamber is located.

The regulation and control devices in the control panel allow for setting the main treatment parameters, such as

temperature (from -120°C to -180°C) and pressure of both the compressed air and the expanding liquid nitrogen. Individual treatment parameters are set on an electronic board with a set of sensors. The treatment time, when the patient stands in the cold gas cloud, ranges from 1 to 4 minutes (usually 3 minutes). First, 3–4 patients enter the atrium (about -100°C) for 30 seconds each. The patients walk in circles throughout the treatment.

Qualification for a cycle of 10–20 sessions is performed by a doctor, after considering indications and contraindications for WBC. Blood pressure must be measured before entering the chamber. Participants should remove any metal jewellery and dry their skin if necessary. Patients wear special personal protective clothing that consists of socks, gloves, headband and face mask, as the air heated in the airways doubles its volume and deep exhalations may lead to respiratory distress [1–3].

Therapeutic properties of WCB

The effects of cryotherapy on the human body include:

- reduction of pain – increased release of β -endorphins and functional deactivation of sensory receptors and their connections to proprioceptors, slowed conduction in sensory fibres and functional deactivation of pain by 'control gates' according to Melzack and Wall's gate control theory of pain [1];
- reduction of oedema – several-hour active congestion in the tissues exposed to cryotherapy improves



Fig. 3. Patients after treatment session

- metabolism and helps eliminate its products; improved blood flow as a result of cryotherapy combined with kinesitherapy has an oedema-reducing effect [1-3];
- relaxation of skeletal muscles and improvement of their strength – reduction of stimulus input to the medulla and segmental inhibition of gamma motor neuron stimulation and slowing down of conduction in motor neurons; analyses of EMG recordings after exposure to low temperatures and clinical observations confirmed that WBC significantly increases muscle strength [1-3];
- increased range of motion in the treated joints [1-3];
- increased serum adrenaline, noradrenaline, adrenocorticotrophic hormone, cortisol, and testosterone (in men). No increases in prolactin, follicle-stimulating hormone or 6-keto-PGF1 alpha have been reported [3];
- an increase in haemoglobin, leukocyte and platelet levels, as well as blood glucose and creatinine in blood cell count and biochemistry after 2 weeks compared to baseline; these values never exceeded the upper limit of normal [3].

The above data demonstrate an anti-inflammatory effect. The therapeutic effects persist for 2-4 hours, which are used for intensive kinesitherapy. Combining cryotherapy with kinesitherapy produces better outcomes [1-3].

The beneficial properties of WBC include:

- antioedematous, analgesic, anti-inflammatory effect, stimulating the body's natural regeneration processes;
- positive effect on well-being (helps relax);
- improving muscular, cardiovascular and lymphatic systems;
- improving the body's endurance by its hardening;
- regulation of blood flow and blood pressure as well as the cardiovascular system;
- rejuvenating effect on skin cells and stimulating other systems;
- reducing muscle spasticity while increasing muscle strength and flexibility;
- reducing stress symptoms.

Indications for use

Owing to its multiple properties, the cryochamber can be used to treat a wide range of diseases.

Indications for WBC [1-3]:

- treatment of rheumatic and degenerative diseases of the peripheral joints and spine;
- recovery from overload, post-traumatic muscle and joint disorders, discopathy and degenerative diseases;
- treatment of depressive syndromes and neuroses;
- physical rejuvenation for both amateur and professional athletes;
- auxiliary treatment of obesity and cellulite.

The following conditions are not contraindications to cryotherapy [1–3]:

- initial stage of systemic lupus erythematosus;
- early stage of systemic scleroderma;
- diabetes mellitus;
- varicose veins of the lower extremities;
- paroxysmal tachycardia;
- metal in deeper tissues;
- Raynaud's phenomenon;
- malignancies – local cryotherapy may be used in patients with no contraindications as confirmed by an oncologist.

Contraindications

Absolute contraindications to WBC [1–3]:

- severe heart disease and heart failure, post-MI syndrome, stage 3 hypertension, advanced atherosclerosis, thromboembolic and inflammatory venous changes;
- lung diseases – with the exception of asthma (cold reduces bronchial muscle tone);
- cold intolerance;
- paroxysmal haemoglobinuria;
- frostbites, cachexia, debilitation;
- active hyperthyroidism and hypothyroidism;
- skin sensory disturbances, open wounds and ulcers;
- febrile conditions;
- acute infections;
- kidney disease;
- claustrophobia, epilepsy, mental illness and excessive sweating;
- use of certain medications and stimulants such as antipsychotics, alcohol;
- advanced atherosclerosis.

Relative contraindications to WBC [1–3]:

- age > 65 years;
- heart valve defects;
- exertional and spontaneous angina pectoris;
- cardiac arrhythmias >100/min;
- history of venous thrombosis and peripheral arterial embolism;
- emotional lability, which may be expressed, among other things, by increased sweating of the skin.

Discussions on the effectiveness of cold therapy

Given that there are only 30,000 heat receptors and up to 250,000 cold receptors in the human body, and that the adaptation time to low temperature is many-fold shorter compared to high temperature, it could be expected that cold treatment should be more effective than heat treatment. In fact, this has been confirmed by research; however, there is no consensus at what temperature cryotherapy starts. For example, heat loss at the same temperature is approximately 250 times greater in water than in air. For this reason, immersion in icy water (winter swimming) has a greater effect on the body than a stay in a cryochamber, although a comparison of temperatures of 0°C and –180°C may lead to a dif-

ferent conclusion. Also for this reason, ice-water baths are much more challenging than cryochamber treatments and are therefore theoretically recommended mainly for healthy individuals, including athletes. Thus, it is not the temperature that determines the strength of a given treatment, but the intensity of the stimulus adequately selected for the purpose of treatment [15–17]. Winter swimming, which is a popular leisure activity, appears to be less safe than WBC. More research is clearly needed. However, there is a lot of research on the beneficial effects of cold exposure to reduce pain [18]. The authors of a four-week study on the effects of WBC and static stretching (SS) came to some interesting conclusions. The aforementioned studies showed that WBC reduces the severity of some symptoms of chronic fatigue syndrome. This is observed immediately after therapy. The authors of the four-week study on WBC and SS assessed the effects of these treatments on the autonomic nervous system and fatigue levels. They suggested the need to assess treatment outcomes, the duration of improvement and symptoms after a four-week follow-up. In this study, peripheral and aortic systolic blood pressure decreased one month after WBC combined with SS compared to before. The effects of WBC and SS on the reduction of fatigue, aortic stiffness indices and the severity of symptoms of autonomic nervous system disorders and improvement in cognitive function persisted for one month. However, improvements in all three fatigue measurement tools (Chalder Fatigue Questionnaire, Fatigue Impact Scale and Fatigue Severity Scale) were reported for 17 out of 22 patients [19].

Conclusions

The discussed form of modern therapy, stemming from the traditional use of cold in the treatment of pain, seems to offer hope to our society, which is increasingly affected by lifestyle changes (poor diet, lack of exercise) occurring at an increasingly earlier age, leading to early disability, joint pain, muscle atrophy and contractures that may contribute to greater susceptibility to injuries. Disorders such as obesity and depression are also becoming more common. In both cases, the cause can be traced to lifestyle changes.

Inadequate diet and poor physical activity from an early age give rise to so-called 'lifestyle diseases' at an increasingly early age. WBC appears to be an ideal therapeutic option for such patients as cold reduces pain that can occur even in fibromyalgia [19]. Among other things, it is an optimal approach for chronic pain in patients with osteoarthritis, RA and other rheumatic diseases, as well as MS. WBC can reduce the need for high doses of NSAIDs and opioids, as confirmed by recent studies. The use of WBC, which reduces pain, exhibits anti-oedematous and anti-inflammatory effects, could become a solution to many lifestyle diseases. Obesity and depression are also the consequences of a poor lifestyle [20]. Here, research into the use of WBC also seems to confirm the effectiveness of this form of treatment and offers some hope for the developing society.

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