REINHARD FRICKE

LOCAL CRYOTHERAPY AND WHOLE-BODY CRYOTHERAP AT –110°C

Cryotherapy with ice, cold gas or cold packs reduces or even eliminates pain, acts anti-inflammatory, decongesting and improves the function of the affected joints. Muscular hypertonicities will be reduced. Under cryotherapy, blood circulation will be maintained in the inflammatory region. Thus, the following indications result: inflammation, pain, swelling, impairment of function, muscular hypertonicity. Whole-body cryotherapy at –110°C results in a significant functional improvement. Oxygen concentration in the blood increases.

Since time immemorial, cold therapy in its various forms has been used for suppressing inflammations. The cold back of a knife to cure stye (hordeolum), aluminium acetate compresses against sprain, cold compresses against fever and local application of ice were elements of the general medical knowledge and were used to suppress inflammations.

However, as also local pain of the shoulder-hand syndrome, tennis elbow, sciatica, and pain in a tendon had been lumped together under the term “rheumatism”, heat therapy, which may be used to cure these non-inflammatory pain syndromes, had become of great importance to the treatment of rheumatic disorders over the millenniums. The „few“ inflammatory rheumatic illnesses, amounting to about three million in Germany alone, were thus included into heat therapy. If the inflammation had been fuelled by the heat and the symptoms worsened, this was credited to the so-called ‘cure reaction’. But in fact, it was a grave error in treatment.

More than 100 years ago, the ice bag had been described in Germany for treatment of inflammations. In the early 1960’s only a few studies about the therapeutic effect of intense local cold against inflammations were available. For more than 25 years, we have successfully been using cold therapy in the form of ice to cure inflammatory rheumatic disorders. After it had become evident that the therapeutic effect lasted only approx. three hours, we started to apply local ice treatment three to four times per day at intervals of three hours.

Today, several methods for use in local cryotherapy are available.

LOCAL CRYOTHERAPY

ICE TREATMENT

Ice in a closed plastic bag may be applied to hand and finger joints for 5 to 10 min, to shoulder and knee joints for 5 to 20 min.

COLD PACKS

In addition to the ice therapy, cold packs are used today which are supplemented with a cold storing agent, e.g. glycerol, and applied to the skin after being cooled down to –12°C to –14°C in the freezer.

COLD GAS

In 1979, Yamauchi introduced the nitrogen cold gas therapy with –180°C on the rheumatology congress in Wiesbaden/Germany. The intense local, dry cold is perceived as comfortable by most people. The –180°C cold air stream is blown onto the relevant body part by means of

compressed air and has to be moved over the skin. Joints or extremities are moved simultaneously. The application time is 0.5 to 1.5 minute.

In 1982, the first local cold gas instrument in Europe, which we developed in cooperation with the company Westfalen AG, was put into operation. Using a dry air pressure of two atmospheres above atmospheric pressure, the liquid nitrogen is transformed into nitrogen gas and blown onto the skin.

In recent years cold air instruments have been developed using a local cold air stream of –30°C (refrigerator principle) which is blown onto the skin. Due to the higher temperature, the application time is 2 to 3 minutes. The application period is determined by the initial temperatures of the different local cryotherapeutic methods. The application time, however, also depends on the patient's individual tolerance range.

1.1. Physiological Effect

Reduction of tissue temperature

According to Blair, the local tissue temperature is decreased 3.2 cm deep to a temperature of 22°C during ice application. The skin temperature is decreased to approx. 8°C and lower. The cryotherapeutic effect continues for about three hours [3].

As long as the ice melts, a temperature from 0°C to +2°C can be maintained for more than one hour.

Without lying on a hot joint, the cold pack becomes increasingly warmer and exceeds the 0°C limit after 30 minutes at the latest.

By means of ice bags and locally applied cold air stream applied by various methods, a large area of the joint and its narrow environment will be cooled. This therapeutic effect is desired as nociceptors (pain receptors) in the skin are linked to the connective tissue around the joints as Scheible and Mensing demonstrated in their studies around 1985. [16,18]. A therapeutic, analgesic effect is thus realized by cryotherapy also near the joints.

Tissue blood perfusion

Highly dosed cold causes vasoconstriction of the skin. In the muscle tissue underneath the skin, however, a reactive dilatation occurs.

In the case of chronic polyarthritis (rheumatoid arthritis) it was proved that the arterial blood flow in the knee joint can be maintained for more than 15 to 20 min after ice application [15]. This may be ascribed to the fact that in chronic polyarthritis no physiological vasoconstriction occurs due to a vasculitis and a strong formation of new capillaries in the granulation tissue as it is observed in healthy persons. Arteries and arterioles affected by vasculitis are no longer able to receive any physiological stimulation.

Lewis has observed that periodic vasodilatations occur during cooling of the skin. The constant succession of vasoconstriction and vasodilatation ensures a sufficient oxygen supply to the cells. In addition, excessive cooling of the body is prevented.

1.2 Therapeutic effect

Pain relieving effect

Cold has a pain relieving, analgesic effect. After decrease of the skin temperature, nociceptors are blocked thus creating a connection to the sensitive periarticular nerves. On the soccer field,

the therapeutic effect of extremely low temperatures is used by means of the cold air spray. This effect is verified by a diminishment of the pain area in shoulder pains (pain under the arch of the shoulder blade) upon ice or cold air therapy [7].

Pain induced by electrical stimulation is clearly blocked under the influence of ice, cold gas or cold air stream. The pain threshold is raised to a higher level for more than three hours after occurrence of a maximum pain relieving effect directly after therapy [14].

Functional improvement

As we have proved after local ice treatment and local nitrogen cold gas therapy, a limited range of motion is significantly improved in inflamed joint diseases.

Decongesting effect

Analog to bodies contracting under the influence of cold, a decongesting effect may be obtained simply by cooling in tissues which are swollen due to water retention (edema). At the same time, the edema which was caused by an inflammation is dissipated via the lymphatic system. In addition, it reduces edemas caused by traumatic lesions.

Increase in strength

In chronically inflamed joint diseases, the analgesic effect, decongesting effect, and the related functional improvements result in an increase of strength. In patients with polyarthritis significant increases in function, e.g. grasping, were observed [7].

Anti-inflammatory effect

Cooling of the tissue results in a significant reduction of temperature in deeper tissue regions [3]. As a result, the enzyme collagenase, which causes a degradation of tendinous tissue (collagen), is inactivated by a temperature decrease of only 6 K. [12]. This may be realized since a temperature reduction of 14 K already occurs in a depth of 3.2 cm after prolonged cooling with cold packs. A further evidence of the anti-inflammatory effect of cryotherapy was found in the observation that in crystal-induced arthritis created in the joints of dogs only a tenth of the usually observed 20,000 leuko/ml3 of white blood cells appear in the effusion after local cryotherapy. In contrast, leukocytes increased to 40,000 under heat application (thermotherapy).

LOCALLY APPLIED CRYOTHERAPY – THERAPEUTIC EFFECT		
Decrease of the tissue temperature		
Pain reduction	Anti-inflammatory effect	Tissue regeneration
Slow-down of reflexes	Metabolic slow-down	Functional improvement
Vasoconstriction	Increase in tonicity (short application)	
Periodic vasodilatation		
Reactive hyperemia	Decrease in tonicity (long application)	
FROM THE THERAPEUTIC EFFECTS THE FOLLOWING INDICATIONS FOR LOCALLY APPLIED CRYOTHERAPY RESULT:		
Inflammation	Functional limitations	
Pain	Muscle tension	
Tissue swellings	Muscle weakness (edema)	

Heat aggravates inflammations [4].

A third example of an anti-inflammatory effect of locally applied cryotherapy is the induced regeneration of inflamed tissue underneath the skin in hedgehogs after silicon implantation. While under normal ambient conditions a solid granuloma with dense macrophage accumulation develops, no cellular reaction is observed during winter sleep [13].

1.3 Change of the muscle condition

Relieving muscle spasms

Intense local cryotherapy may relieve excessive tonicity, i.e. muscle tensions. In the case of lumbago, i.e. pain in the lower region of the back, this is possible simply by local application of ice bags. An even faster effect can be obtained by a cold air stream applied locally for half a minute.

Muscle activation

In case of lack of muscle tone cooling may have a stimulating and activating effect. A temporary short-term cooling may result in a higher initial muscle tone which allows subsequent physiotherapeutic treatment thus strengthening the musculature with a greater stimulating effect.

As a result, the following therapeutic effects can be achieved:

1.4 Therapeutic procedure

The fact that cryotherapy lasts for about three hours until the tissue has re-warmed calls for a sensible strategy: To achieve a long-term treatment success, local cold treatments applied in intervals of three hours are required. A long-term treatment success can be achieved by application of four daily therapy sessions over a period of approx. 12 hours. As a result, this may lead to drug savings. In addition to its therapeutic effect, locally applied cryotherapy using ice or cold air stream in its various forms is also a reasonable preparation for subsequent physiotherapeutic treatments. Multiple daily cryotherapy and physiotherapy, when used in conjunction with medicamentous therapy, are important adjuvant therapy forms leading to a significant functional improvement within three to four weeks [8].

Whole-body Cryotherapy

The therapeutic effect of cryotherapy will even be considerably improved by whole-body cryotherapy. Since 1984, the first cold chamber outside Japan, built by the company Westfalen AG, has been in use in Germany after introduction of whole-body cryotherapy by Yamauchi in 1980 [21]. Each day, up to 40 to 60 patients are treated with a temperature of –110°C [9,10].

Using liquid nitrogen dry air is cooled down via heat exchanger in the cold chamber to a desired temperature of –110°C and –160°C. Yet another procedure of whole-body cold treatment is represented by the cold cabin where cold air is blown onto the body.

The latest development of a three-phase refrigerating system delivers a constant temperature of –110°C (Seus, Wilhelmshaven/Germany). This system runs at considerably lower operating costs as compared to cold chambers operated with nitrogen or cold air.

The patients enter he cold chamber wearing nose mask, head band and gloves as well as closed shoes. After the blood pressure has been checked and upon approval of the physician who stands at the control panel to supervise the application, patients enter the antechamber accompanied by a therapeutic assistant in winter clothes. After closing the door, the inner door is opened. Patients now enter the main chamber which has a temperature of –140°C to –110°C and walk around for 0.5 to 3 minutes in the chamber. Breathing out the inhaled air takes twice as

long because the cold air expands while being warmed in the patients' lungs. Due to the mist which forms in all cold chambers as a result of the warm, humid air flowing in patients walk along handrails for better orientation in the chamber. Patients may leave the chamber at any time. A member of the therapeutic team who is watching the patients from the antechamber may also assist them.

Within 0.25 to 1 minute after leaving the cold chamber, the blood flow in pale skin is strongly stimulated by vasoconstriction causing a pleasant, comforting sensation.

2.1 Physiological effects

Whole-body cryotherapy does not cause any stress to the organism. ACTH increases, cortisol is decreased. No change of the blood glucose occurs. Furthermore, no increases in adenohypophysial hormone, prolactin and STH were observed. Nor was an increase in adrenalin observed [5].

In comparison, a significant increase in noradrenalin was verified. This indicates an activation of synapses and nerve endings in the skin. This increase induces a kind of supply reaction. Minor increases in blood pressure are observed in patients with normal blood pressure. Hypertensive persons have to be treated with drugs.

An increase of the oxygen content was observed both in the blood of the sick and the control persons [19]. This increase can be traced back to a deeper respiration and inhalation of a larger number of oxygen molecules per liter air at –110°C. The increased oxygen content in the blood [19] produces an improved coronary blood flow. No angina pectoris has been observed although patients with coronary heart diseases entered the cold chamber. Moreover, extrasystolies were considerably reduced. These two observations indicate an improved oxygen supply in the coronary system.

2.2 Therapeutic effects

Analgesic effect

After approx. 30 seconds, children and adults (1/2 to 83 years of age) experience a pain blocking effect. It becomes easier to move the joints. The therapeutic effect lasts a minimum of three hours.

Functional improvement

Directly after treatment in the cold chamber a significant functional improvement in all joints affected by chronic polyarthritis or ankylosing spondylitis is evidenced. A significant functional improvement in some parameters [1] has also been observed following the three hours after cryotherapy in which physiotherapy had been performed.

Influencing immunocytes

Studies showed that in chronic polyarthrits, the number of lymphocytes is decreased for a minimum of three hours [2]. Further differentiation of lymphocyte population proved that T-helper lymphocytes decrease in chronic polyarthritis (rheumatoid arthritis) and ankylosing spondylitis (Morbus Bechterew) [17,11]. This results in an increase of the T-suppressor cells which control T-helper lymphocytes by inhibiting their tissue-destroying activity. The control mechanism probably works by means of Langhans' giant cells which express antigenes after cryotherapy in patients with chronic polyarthritis.

In further studies we observed a decrease of interleukine 1, 2 and 4. [22]. The results suggest an immunomodulating effect of whole-body cryotherapy.

Furthermore, we observed a bronchospasmolytic effect in emphysematous bronchitis and bronchial asthma.

2.3 Indications

Based on the current research results, whole-body cryotherapy may successfully be employed as part of a combination therapy in the following diseases:

Inflammatory joint diseases

Degenerative diseases with secondary inflamed components

Spine disorders – inflamed and degenerative

Soft-tissue rheumatic disorders

Collagenoses

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KEY WORDS:
Local cryotherapy
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Cold packs
Cold chamber
A 2-minute whole-body cryotherapy at –110°C increases muscle strength and performance
R. Fricke, G. Grappow, T. Nobbe, G. Gnauer

2-MINUTE WHOLE-BODY CRYOTHERAPY AT –110°C INCREASES MUSCLE STRENGTH AND PERFORMANCE

Whole-body cryotherapy at –110°C over 1, 2 and 3 minutes resulted in a maximum increase of muscle strength and performance of knee joints when applied over 2 min. To define optimal intervals for conditioning in sports, pause intervals of 5 instead of 2 min after cold chamber application have been used in this study.

METHOD:

After a 5-min warm-up phase on the ergometer, one healthy knee joint of each of 7 women and men was examined using a Cybex. After an interval of 5 min whole-body cold treatment over 2 min at –110°C was performed. After another pause interval of 5 min a retest on the Cybex was carried out.
Results: Examination of flexion 120°/s, flexion 60°/s, extension 120°/s, extension 60°/s showed an increase in peak strength between 2.83% and 3.76% – except for the 120°/s extension with a value of –3.35%. Performance examination showed an increase between 3.30% and 18.6%.

DISCUSSION:
Examination results suggest an additional increase of muscle strength and performance in the case of a 5-min pause interval as compared to the pre-tests with a 2-min pause interval.
Examination results of women and men have to be analyzed separately using larger test groups. Further investigations are necessary to determine optimal time intervals of cold chamber application for sports conditioning.

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Sprint after 2-min Whole-Body Exposure at –110°C

R. Fricke, K. Hoffmeister, Th. Nobbe, G. Knauer
Weserlandklinik Bad Seebruch, Vlotho/Germany

Kältetherapie –110°C über 1, 2 und 3 Minuten (*Cryotherapy at –110°C over 1, 2 and 3 minutes*) DRV-Schriften Band 12 (1999) 166-167

Prof. Reinhard Fricke (MD)
Weserlandklinik Bad Seebruch, D-32602 Vlotho

The realization that more red than white muscle fibers are activated during work under cool conditions (fast twitch = FT) strongly suggest further studies in which the influence of whole-body cold exposure on red muscle fibers is tested. In an initial study carried out during a sprint test after WBCE, Esslinger has measured an increase in sprint performance (using a stop watch).

To verify this observation we determined the sprint performance before and after 2-min cold chamber exposure at –110°C using an electronic measurement barrier. In two test groups, the sprint performance after 5m, 10m and 15m was measured. On the 1. day, the medical student group performed two sprint test to familiarize with the study conditions. On the following day, cold chamber exposure at –110°C was carried out. 5 minutes later, the sprint performance was tested again. The results were analyzed separately for men and women. An additional group of physiotherapeutic students (several female and 1 male) performed 3 sprints on the first day. On the 2. day, WBCE was carried out after 3 test runs. 5 min later, 2 additional test runs were measured with a 5-minute interval between tests, and the mean values were calculated.

The results of the sprint tests of untrained men and women showed an increase in sprint performance for both groups, though with different values.

While for the medical student group an increase in performance was measured only after 10m and 15m, the female physiotherapy students increased their sprint performance at all three measurement points. When dividing the medical students in men and women, a performance increase in all three parameters was observed in the men, in the women only for the 15m distance.

The differences between the two groups may probably be explained with a different training condition. It may be assumed that physiotherapy students are physically better trained than medical students.

The differences between men and women are caused by the fact that men have a relatively larger mass of red muscle fibers than women.

The study results suggest an improvement of sprint performance after 2-min whole-body cold exposure at –110°C.

To further verify the study results, an improved standardization of study conditions with respect to technical prerequisites and training condition is planned.

Improvement of Muscle Strength and Performance by means of Whole-body Cryotherapy at -110°C over 1, 2 and 3 Minutes

Fricke R., Grapow G., Knauer G.
Weserlandklinik Bad Seebruch, Vlotho/Germany

Test persons who exercised with decreased skin temperature showed a significant higher training effect than controls (Schuh, 1991). During work under cool temperature conditions relatively more red muscle fibers are activated (Brück, 1987). A muscle at rest is activated when rubbed with ice. Whole-body cryotherapy of –110°C over a period of 1 to 3 minutes offers these conditions for activation of the musculature. Therefore, studies to examine the influence of cold on strength and performance of healthy musculature in the lower extremities were carried out.

METHOD:

30 test persons were divided in 3 test groups of 10 persons each. After a warm-up phase, the test groups were treated separately in a cold chamber at –110°C over a period of 3, 2 and 1 minute respectively. Directly prior to therapy, peak strength and performance at flexion rates of 120°/s and 60°/s were tested on the Cybex. Two minutes after cold chamber treatment the same values were examined for each relevant group.

DISCUSSION:

Whole-body cryotherapy at –110°C results in an increase of the peak strength and performance. The best results were obtained after an application time of 2 minutes.

Optimum speeds obtained were flexion 120°/s and extension 60°/s. The rather negative results for flexion 60°/s and extension 120°/s suggest an unfavorable speed for the relevant function. On the other hand, this may also indicate a different distribution and activation of muscle fibers in untrained persons.

The therapeutic effect of whole-body cold therapy may be explained in part by the cool body shell and increase of the aerobic capacity of the muscular metabolism which facilitates the actual aerobic execution of the work. In further studies the impact of cold chamber treatment is examined with reference to intervals between warm-up phase and tests after therapy.

RESULTS:

		1 min	2 min	3 min
Peak strength	Flexion 120 °/s	- 18, 3 %	+ 27,6 %	+ 16,9 %
	Flexion 60°/s	+ 18,5 %	+ 36,1 %	- 27,8 %
	Extension 60°/s	+ 3,6 %	+ 84,7 %	+ 28,4 %
	Extension 120°/s	- 52,4 %	- 26,8 %	- 52,4 %
		1 min	2 min	3 min

Performance	Flexion 120°/s	- 16,6 %	+ 39,0 %	+ 49,7 %
	Flexion 60°/s	- 6,6 &	- 45,7 %	- 41,7 %
	Extension 110°/s	- 54,1 %	- 29,3 %	+ 51,8 %
	Extension 60°/s	+ 38,5 %	+ 100,1 %	+ 41,8 %

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