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The effects of cryotherapy on work-capacity during repeated sets of leg-extensions

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Abstract

Introduction Cryotherapy is traditionally used in a rehabilitation setting. Limited evidence points towards a possible performance enhancing effect during short high-intensity work from applying cooling. **Purpose** The aim of this study was to investigate if local cryotherapy between repeated sets of leg-extension exercise could influence total number of repetitions completed, total working volume, power output, core temperature, subjective perceptions of pain and exertion. **Method** A total of 17 subjects participated in this study. The subjects were all used to strength training and had been exercising regularly for the past three months. The subjects performed three sets at 85 % of their individual 1-RM to failure on a leg-extension device during two trials separated with at least 48 hours. The order of the trials was counterbalanced. During cooling trials (CT), local cryotherapy using plastic bags of ice was applied during rest intervals for a total of two and a half minute. During active trials (AT), subjects were to slowly walk around the facility. **Results** The number of repetitions was higher during CT (7.6 ± 1.9) compared to AT (6.7 ± 1.7). The total amount of weight lifted was also higher during CT (430 ± 194 kg) compared to AT (384 ± 169 kg). Subjective perceptions of pain were lower during CT (4.5 ± 1.9) compared to AT (5.4 ± 1.9). **Conclusion** Cryotherapy, when applied between repeated sets of leg-extension to failure, can increase the total amount of repetitions completed and weight lifted and lower perceptions of pain.

Keywords: ice, performance enhancement, strength training

Abstrakt

Introduktion Kylterapi används traditionellt för rehabilitering. Viss evidens pekar mot en möjlig prestations-höjande effekt under kort hög-intensiv arbete när kylning är applicerad. **Syfte** Syftet med denna studie var att undersöka om lokal kylterapi mellan upprepade sets av bensträckar-träning kunde påverka det totala antalet genomförda repetitoner samt arbetsvolym, effekt-utveckling, kropps-temperatur, subjektiv upplevelse av smärta och utmattning. **Metod** Totalt 17 försökspersoner deltog i studien. Alla försökspersoner var vana vid styrketräning och hade tränat regelbundet de senaste 3 månaderna. Försökspersonerna utförde 3 set på 85 % av deras individuella 1-RM till utmattning på en bensträckar-maskin under två tillfällen separerade med 48 timmar. Ordningen på försöken var viktad. Under kylningsförsöken (CT) så var kylterapi applicerad på deltagarna med hjälp av påsar fyllda med is under viloperioderna under totalt två och en halv minut. Under de aktiva försöken (AT) gick deltagarna långsamt runt i lokalen. **Resultat** Antalet repetitioner var högre under CT (7.6 ± 1.9) jämfört med AT (6.7 ± 1.7). Den totala mängden vikt som lyftes var högre under CT (430 ± 194 kg) jämfört med AT (384 ± 169 kg). Subjektiva upplevelser av smärta var lägre under CT (4.5 ± 1.9) jämfört med AT (5.4 ± 1.9). **Slutsats** Cryotherapy, när den är applicerad mellan upprepade sets av ben-sträckar träning till utmattning, kan öka den totala mängd repetitioner som blir utförda och den totala mängd vikt som blir lyft samt sänka den subjektiva upplevelsen av smärta.

Nyckelord: Is, prestationshöjare, styrketräning

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Introduction

Cryotherapy involves applying cold, via bags of ice or other tools, to a certain area. Cold water immersion (CWI) is one form of cryotherapy that usually involves immerging, with partial immerging or whole body immerging, into a cold water bath (Swenson, Swärd, Karlsson, 1996; Kennet, Hardaker, Hobbs, Selfe, 2007). Another way of applying cryotherapy is by cooling the palms using a rapid thermal exchanger (RTX). The most commonly used RTX consists of a metal cone heat-exchanger surface with water circulating inside of it with a temperature of 10-11° C. The palm of the hand is placed on the cone and a plastic chamber encloses the hand and a seal above the wrist maintain a vacuum around the hand. Negative pressure can be controlled and maintained in the plastic chamber surrounding the hand (Grahn, Dillon, Heller, 2009). In this article, peripheral cooling is defined as cooling when cooling is applied distant from the working muscle and local cooling is defined when cooling is applied directly on top of the skin of the working muscle.

Cryotherapy is traditionally used in a rehabilitation setting to reduce inflammation and to control pain (Furmanek, Słomka, Juras, 2014). Some sports traditionally use cryotherapy between training sessions or games to enhance recovery, the literature on this topic are however not consistent (Poppendieck, Faude, Wegmann, Meyer, 2013). A number of studies have documented positive effects of cryotherapy in acute measures and performance. In a study by Palmieri-Smith and collagues (2007), cold application to the ankle stimulated a sympathetic response from the central nervous system which enhanced the muscle fibers ability to contract. Burke and colleagues (2000) showed that local cryotherapy applied immediately before isometric strength training of the hip extensor muscles improves strength gains over an extended period of time. Another study by Grose (1958) suggests that local CWI for eight minutes applied immediately before repeated maximal isometric contractions of the fore-arm can decrease overall fatigue by increasing work during the last repetitions. Moreover, Grahn and colleagues (2012) manipulated core temperature by having subjects exercising on a treadmill with or without the RTX device and the total amount of repetitions was increased with two repetitions when peripheral palm-cooling was applied.

Strength training is a widely used tool by athletes and sedentary individuals to

improve the size of the skeletal muscle and to increase power and strength, but also to shorten recovery time after injury (Wernbom, Augustsson, Thomeé, 2007). Two important contributors for gaining strength and increasing the size of the skeletal muscle, are volume and intensity. In strength training, volume is commonly described as weight used times repetitions times the number of sets completed. Intensity is commonly described as the weight used, usually presented as percentage of one repetition maximum (1-RM). Athletes and coaches constantly search for methods to improve the ability maintain a high intensity throughout the training session and delay the onset of fatigue. Based upon previous research, cryotherapy might be one of these methods. Verducci (2000) applied local cooling between repeated sets of arm-pulling and found that cryotherapy, when compared to control, increased the total amount of work completed, increased the velocity of the movement and increased the average power output when measured in the four initial sets. In another study by Verducci (2001), local cryotherapy was applied between repeated baseball innings which delayed the onset of fatigue and increased the velocity and power of the pitching's. Kwon and colleagues (2010, 2015) conducted two studies where they applied peripheral cooling using the RTX between repeated sets of bench-press. Total work-volume and repetitions were increased with the application of cooling compared to control and heating in both men and women.

Furthermore, Bacon and colleagues (2012) applied local cooling using bags filled with ice on certain muscle groups involved in the pull-up exercise. Two variants of the pull-up exercises were performed, the closed-handed and the open-handed pull-up. The total number of repetitions completed was higher during cooling trials compared to control for the open-handed pull-up exercise, but not for the closed-handed. The authors suggest that this is because the open-handed pull-up variation involves the muscle groups that the cooling was applied upon, while the closed-handed involves other muscle groups which was not as exposed to the cooling. Thus, peripheral cooling distant from the working muscles had no positive effect on the number of repetitions completed. However, these results do not agree with the previous mentioned studies by Kwon and colleagues (2010, 2015) which saw an increase in total working volume during bench-press exercise during cooling trials when cryotherapy was applied to the palms, i.e. peripheral cooling. The latter mentioned studies used the RTX to apply cryotherapy to the

palms. The RTX is designed after the premise that heat is generated from the metabolism of the muscle, this induces vasodilation to facilitate heat loss by increasing blood flow to the skin. This increase in blood flow is not uniform, since, according to Grahn and colleagues (2009), only the glabrous skin, like the palm, is capable of accommodating large increases in blood flow. Douris and colleagues (2003) conducted a study where they investigated the effects of local cold-water immersion (CWI) on recovery between repeated tests of maximal grip strength. Maximal isometric grip strength was decreased when CWI was applied for between five and 20 minutes, and that it was not recovered fifteen minutes' post CWI. In addition, Ruiz and colleagues (1993) suggested that local cryotherapy on top of the thigh 25 minutes before testing decreases isokinetic strength immediately after treatment, but that the suppressed strength is back to normal 20 minutes' post-treatment.

The different findings in the previously mentioned studies are most likely linked to the duration of cryotherapy or CWI and the different locations of application of the cold. The work of Burke and colleagues (2001) showed that women experience less increases in strength, and the authors speculate that this is due to a higher percent of body-fat in the females. Although body-fat was not measured in the latter study, mid-thigh skinfold thickness showed a significantly higher percent of body-fat in the female subjects. Thus, this could explain the differences between genders. According to Slosman et al. (1992), females have a higher percent of body-fat compared to males, which is associated to a better thermal insulation. Trained individuals do usually have a lower percent of body fat compared to sedentary individuals (Nudri, Wan Abdul Manan, Mohamed Rusli, 2009). Therefore, another aspect that might have affected the findings is the amount of body fat-percentage in the subjects.

One theory that could explain the above mentioned effects of cryotherapy is that the skeletal muscle seems to have an optimal temperature for accomplishing the most amount of total work (Clarke, Hellon, Lind, 1958). With blood constantly circulating through the muscle, the heat from the skeletal muscle can be extracted and transported through the body. This transportation from the muscle to other tissues will raise the core temperature. Since the transfer of heat is limited by the difference in circulating blood flow and muscle temperature, the raised core

temperature will result in making it less effective at transferring heat. Therefore, during training, when the muscle temperature rises with the increase of metabolism, it would seem beneficial to cool down the muscle to be within the optimal temperature zone or to cool down the core to become more effective at extracting heat. This excessive heat is then transported via the circulating blood to the skin, where it is lost to the environment. Cryotherapy as a cooling method results in a conductive heat loss, which during normal conditions is relatively small, but for people that has a skin contact with cold surfaces, conductive heat losses might be of considerable significance to their total heat loss (Knight, 1985) and might assist in reducing muscle temperature closer the optimal zone. Two of the previously mentioned studies has measured core temperature when applying cryotherapy. Kwon and colleagues (2010) measured esophageal temperature in six of the total 16 subjects, a significant reduction of 0.02° C was seen when peripheral palm-cooling was applied between sets. In a study by Grahn and his colleagues (2012) peripheral palm-cooling was applied and lowered core temperature with 0.6° C compared to control. This reduction was associated with a higher number of repetitions completed.

Another theory to explain the effects of cryotherapy could be an impaired sensory perception. Some of the local effects of applying cold involves decreased nerve conduction velocity. According to a study by Edwards (1978), this seems to be directly linked to temperature and cooling seems to reduce the velocity of both motor and sensory signals. However, the sensory neurons seem to be influenced by more modest changes due to their superficial anatomic location (Merrick, Knight, Ingersoll, Potteiger JA., 1993), which could mean that modest cooling could have an analgesic or pain-killing effect without impairing the motor neurons.

The diverse study designs and findings in the currently available literature makes it hard to draw conclusions. Previous studies that have been applying cryotherapy on an interval basis have 1) been using a too low percentage of 1RM which would not represent commonly prescribed training schemes for increasing strength or size of the skeletal muscle 2) been using a commercial cooling device, which may be inconvenient and too expensive for some strength coaches and athletes 3) not been measuring if local cryotherapy with ice has any effect on core temperature.

Purpose

The purpose of this study was to further investigate if local cryotherapy with ice can influence the total repetitions completed, the total amount of weight lifted, power output, core temperature, perceived exertion and pain during repeated sets of leg-extension at 85 % of the subjects individual 1-RM. As control, active rest was chosen between sets.

Method

Subjects

The subjects (Table 1) were recruited at the Mid Sweden university and local gyms. All of the subjects were informed about the purpose of the study and any possible risks. Before participation, the participants filled out an information sheet (Appendix 1) to make sure that they met the following inclusion criteria's; an age of 18-45, at least one healthy/non-injured knee, were familiar with strength training and had been engaged in strength training for at least three times/week the last three months. Before day one, participants filled out a health form to make sure that there were no contraindications in exercise (Appendix 2) and a written consent form (Appendix 3).

	Men	**Women**
Number of participants	**12**	**5**
Age (yrs)	**27 ± 6**	**28 ± 6**
Height (cm)	**181 ± 5**	**163 ± 5**
Weight (kg)	**88 ± 14**	**57 ± 3**
Body fat (%)	**15 ± 5**	**14 ± 3**

Table 1, Subjects' characteristics. *(mean, ± SD)*

Testing procedures

The study involved three experimental trials, separated by 48-72 hours. Each trial was conducted at the same time each day to achieve the same training environment. All of the trials were concluded in the month of March in 2016.

Day 1: Body composition and 1-RM testing

During the first testing day, the participants performed an estimated one repetition maximum (1-RM) test on the leg-extension device and body composition was measured. The participants were on forehand asked to arrive to the laboratory in a fasted state during the first testing day and to have the same intake of caffeine and

nutrition before each remaining trial. The body-composition testing was conducted on a bio-impedance device (In-body 720, Inbody™, Seoul, Korea).

After the body composition analysis, the subjects had the opportunity to consume a small snack before the 1-RM testing. All of the trials were performed on a leg-extension device (Leg-ext/curl c-240, Atlantis™, Laval, Canada). Before the warm-up, the participants were asked to estimate their 1-RM capability. Based on the predicted 1-RM, the warm-up consisted of a total of three unilateral sets, one leg at the time; ten repetitions at 50 %, eight repetitions at 60 % and six repetitions at 70 %. During the 1-RM testing, the participants were asked to complete the exercise through the full range of motion (ROM). The rest between each warm-up set was one minute. If participants were struggling to complete the first set at 50 %, the increase to the second set were lower than the initial increase of 10%. The participants then proceeded to the 1-RM test. Subjects performed three unilateral sets for both legs with three minutes between each set, one leg at a time, until failure but no more than six repetitions. If a participant completed any lower than six repetitions with a certain weight, that weight was used to determine their 1-RM. The leg that completed the highest amount of repetitions, the dominant leg, were used in the following trials. The estimation was based on the formula introduced by Brzycki (1993).

Day 2 and 3: Experimental trials

During day two and three the warm-up procedure was the same as it was during the first trial, although now the weights were based on the true estimated 1-RM and the participants only used their dominant leg. The participants then rested for three minutes before their first working set. During the experimental trials the participants performed three sets until failure at 85% of their estimated 1-RM. Between each set, the participants rested for three and a half minute. The order of the trials was randomly assigned, subjects started with either the cooling trials (CT) or active trials (AT). During the cooling trials, the participants were asked to sit down on a bench next to the training device and plastic bags of ice was applied on the thigh, between trochanter major and the superior angle of the patella, of the working leg for two and a half minute. The size of the bags used were five litre and each bag were half-filled with ice cubes to create a flat surface. New ice was used for each participant. During the active trials, the participants were asked

to slowly walk around in the gym, similar as they would during their normal training sessions.

Measurements

Core temperature
Core temperature was measured using an ear thermometer (ThermoScan©, BRAUN™, Lausanne, Switzerland). Measurements were taken three times at each measure point and a mean value of those three measurements were used. Measurements were undertaken as expressed in Figure 1.

Subjective perceived exertion and pain
To measure subjective perceptions of exertion, the 15-graded ratings of perceived exertion(RPE)-scale (Appendix 4) were used (Borg, 1982). To measure the subjective perceptions of pain, a visual analog scale (VAS) (Appendix 5) was used (Kersten, White, Tennant, 2014). The subjects were shown the printed versions of these scales and were asked to pick a number. Measurements were undertaken as expressed in Figure 1.

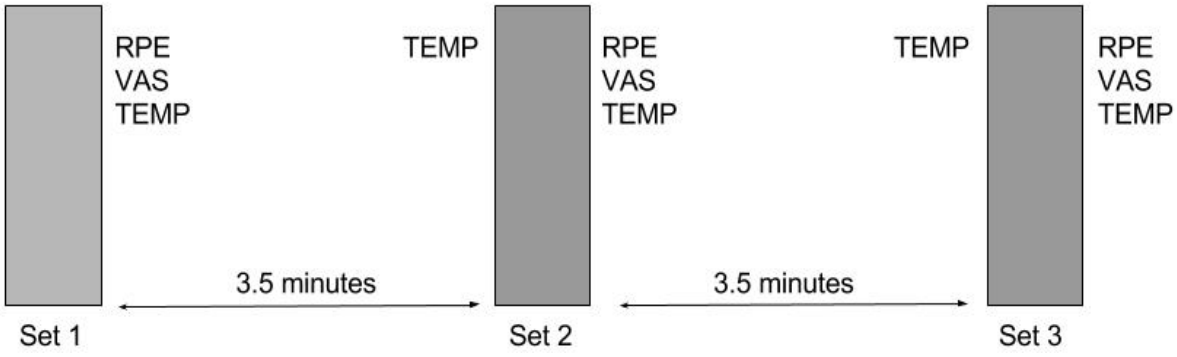

Figure 1, Measurements during day 2 and 3. *RPE = rating of perceived exertion, VAS = visual analog scale, TEMP = core temperature*

Total repetitions
The total number of repetitions was counted manually and automatically using a Linear encoder during set one, two and three (MuscleLab 6000 Ergotest Innovation A.S, Porsgrunn, Norge) The encoder was attached to the pin of the rack and the spool was placed directly beneath. Each repetition that differed 10 cm or more from the longest repetition in a given set were excluded from the data analysis, as expressed by the MuscleLab V.10 software.

Total amount of weight lifted
Total amount of weight lifted was calculated using each individual working weight (kg) during set one, two and three during the AT and CT, respectively, times the number of repetitions.

Power output
Matched power output was calculated by taking the mean of the average power of the first four repetitions in each set (automatically calculated with the linear encoder).

Statistical analysis
The statistical computations were made in SPSS (IBM Statistics 22). A paired sampled t-test were used to quantify differences in number of repetitions, core temperature, RPE, VAS, power output and total work volume between the two conditions; AR and CR. Only measurements and results from set two and three from the experimental trials were used in the computations. A one-way anova test were used to quantify differences between set one, two and three in the trials in the number of repetitions, work volume, power output and total work. Statistical difference was accepted if $P \leq 0.05$.

Results

Repetitions and total amount of weight lifted
The number of repetitions in CT and AT were 7.6 ± 1.9 and 6.7 ± 1.6, respectively ($p < 0.01$) (Figure 2). The number of repetitions during set two in CT and AT were 7.8 ± 1.9 and 6.7 ± 1.7, respectively ($p < 0.05$). The number of repetitions during set three in CT and AT were 7.4 ± 2 and 6.7 ± 1.6, respectively. The total amount of weight lifted in CT and AT were 430 ± 194 kg and 384 ± 169 kg, respectively ($p < 0.05$) (Figure 3). The total amount of weight lifted during set two in CT and AT were 438 ± 187 kg and 383 ± 168 kg, respectively ($p < 0.05$).

The total amount of weight lifted during set three in CT and AT were 422 ± 205 and 385 ± 174, respectively. The total amount of weight lifted in CT were 420 ± 193 kg, 438 ± 187 kg and 422 ± 205 kg during set one, two and three, respectively. The total amount of weight lifted in AT were 415 ± 205 kg, 383 ± 168 kg, 385 ± 174 kg during set one, two and three, respectively

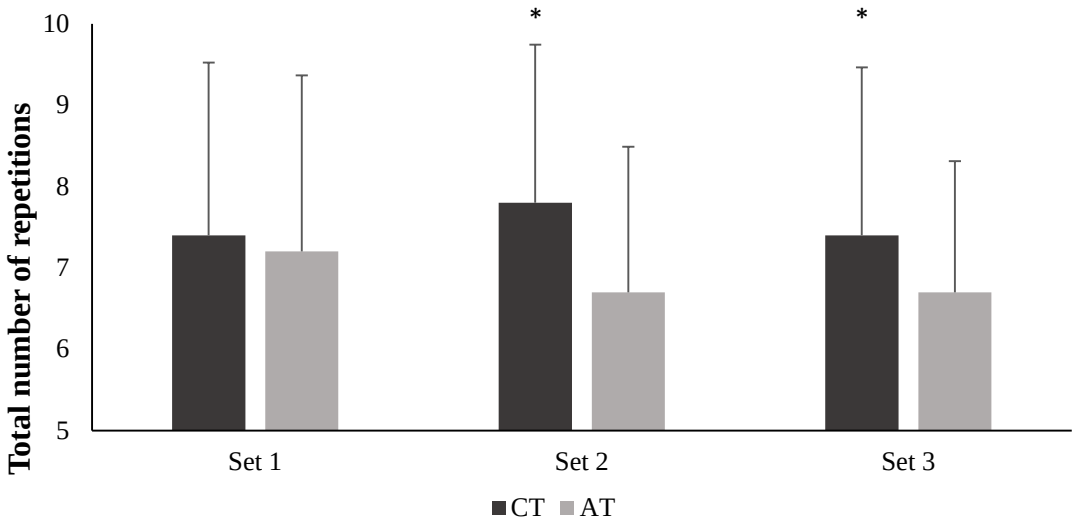

Figure 2, Total amount of repetitions. Each value represents the mean repetitions completed during the leg extension exercise. Error bars indicates SD

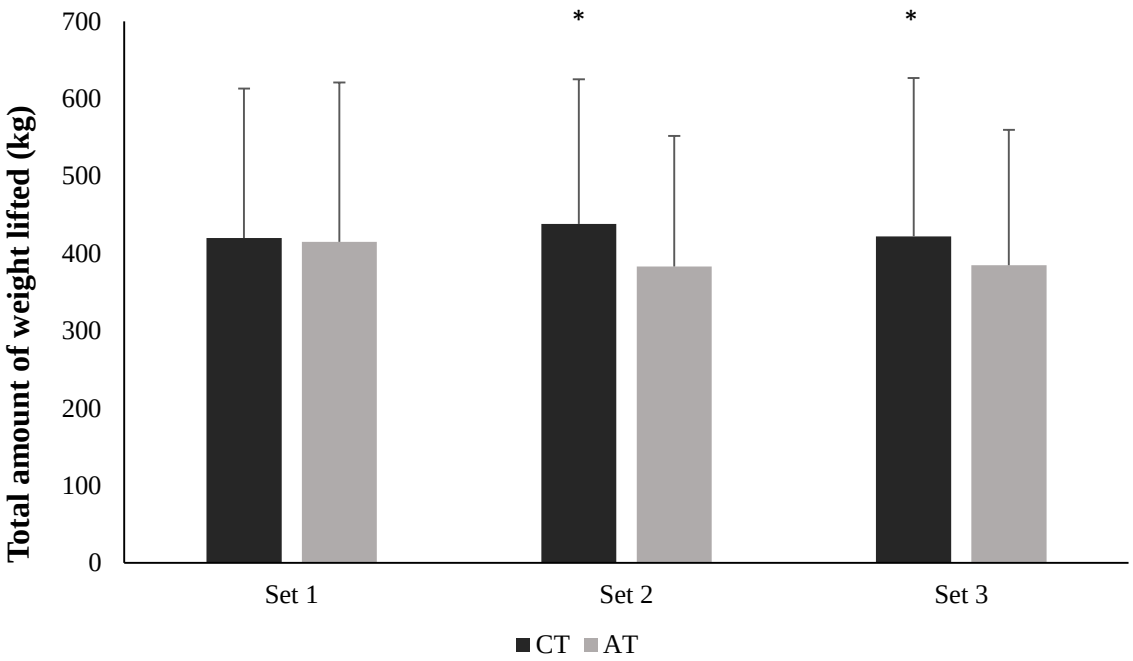

Figure 3, Total amount of weight lifted. Each value represents the mean amount of weight lifted during leg-extension exercise. Error bars indicates SD.

VAS and RPE

The ratings in VAS in CT and AT were 4.5 ± 1.9 and 5.4 ± 1.9, respectively ($p <$ 0.001) (Figure 4). The ratings during set two in CT and AT were 4.6 ± 2 and 5.3 ± 1.9, respectively ($p < 0.05$). The ratings during set three in CT and AT were 4.4 ± 1.9 and 5.5 ± 2, respectively ($p < 0.0$

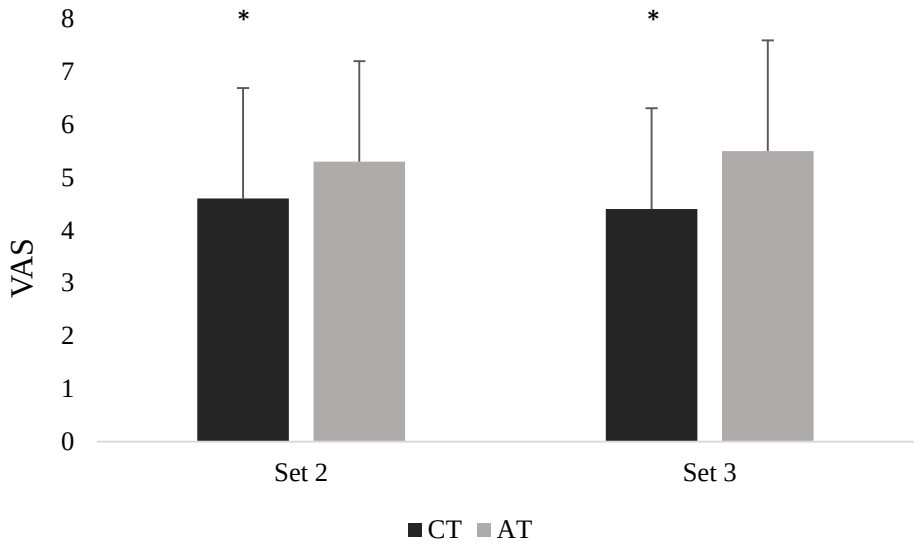

Figure 4, VAS**.** Each value represents the mean of the subjective perceptions of pain after leg-extension exercise. Error bars indicates SD.

The ratings in RPE in CT and AT were 17.1 and 17.1 respectively. The ratings in RPE after set two in CT and AT were 16.9 ± 1.9 and 17 ± 1.7, respectively. The ratings in RPE after set three in CT and AT were 17.4 ± 2 and 17.4 ± 1.58, respectively.

Core temperature

The core temperature in CT and AT were 37.05 ± 0.32° C and 36.92 ± 0.40° C, respectively. The core temperature in CT and AT after set one were 37.03 ± 0.29° C and 36.96 ± 0.33° C, respectively. The core temperature in CT and AT before set two were 36.98 ± 0.33° C and 36.88 ± 0.45° C, respectively. The core temperature in CT and AT after set two were 37.06 ± 0.37° C and 36.91 ± 0.35° C, respectively. The core in temperature in CT and AT before set three were 37.11 ± 0.31° C and 36.90 ± 0.35° C, respectively ($p < 0.05$).

Power output

The average power output in the first four repetitions during CT and AT were 243 ± 98 W and 236 ± 97 W, respectively. The power output during set two in CT and AT were 246 ± 101 W and 238 ± 97 W, respectively. The power output during set three in CT and AT were 239 ± 97 W and 233 ± 101 W, respectively.

Discussion

The purpose of this study was to investigate whether the total amount of repetitions and working volume could be influenced by applying cryotherapy

between repeated sets of leg-extensions to failure at 85 % of the individuals 1-RM. The main findings of this study shows that the total amount of weight lifted increased by 12 % and the number of repetitions increased with 13 % when cryotherapy was applied on an interval basis compared to the active trials. No difference was seen in average power during the first 4 repetitions. Subjects also rated their pain perception lower during the cooling trials compared to the active trials. No differences were seen in RPE. Before set three during active trials, subjects had a lower core temperature compared to cooling trials.

The results of the current study are in line with those of Verducci (2000), that showed an increase of 14.1 % in total work performed and 14.5 % more repetitions in an arm-pulling test. Results from Kwon et al. (2010, 2015) indicates that interval cryotherapy led to an increase of 30 % in total amount of weight lifted. In the current study, there were no differences between cooling and active trials in regards to average power production during the first four repetitions. However, there was a small not significant increase of 3 % in power production during cooling compared to active trials, which agrees with the work of Verducci (2000) that had an increase of 3.4 % in power production when cryotherapy was applied. These results does not agree with the work of Grose (1958) that suggested that cryotherapy lowered the initial strength a grip dynamometer test.

It is well known that cryotherapy reduces pain perception amongst injured individuals (Furmanek et al., 2014). However, previous studies that have been applying cryotherapy on an interval basis have all been using the RPE-scale and not a more specific scale, like the VAS used in the current study, to measure pain. No significant differences was found in RPE in this study, which is in line with previous research (Bacon et al., 2012, Kwon et al., 2010). A lower core temperature was seen in set three during active trials, which does not agree with earlier studies that suggests that core temperature decreased during cooling trials compared to control (Grahn et al., 2012, Kwon et al., 2010).

In the present study, there are some methodological differences compared to previous research. Verducci (2000) and Bacon et al. (2012) used an intensity corresponding to 20-RM or 60 % of the individual 1-RM which is lower then

what was used in this study. Kwon et al. (2010, 2015) used the same percentage of 1-RM as this study, but peripheral cryotherapy was applied used the RTX device. In this study, 2.5 minutes of local cryotherapy was applied, in the work of Grose (1958) subjects immersed their fore-arm in a cold-water bath of 10 ° C for eight minutes before testing. The lowered core temperature during the active trials in the current study is probably due to an unreliable measuring instrument to measure the core temperature. It is also possible that the cryotherapy was too short or did not cover enough surface to affect the core temperature. Alternatively, a mix of both. None of the previous studies that had applied local cryotherapy with ice have measured the core temperature. Kwon and collaegues (2010) suggests that there was a decrease in core temperature in subjects during cooling trials compared to control trials, but core temperature was only measured in six of the total 16 subjects. The results of Grahn and collaegues (2012) also suggests a decrease in core temperature during cooling trials compared to control, although heat stress was induced on purpose and thus the core temperature might have been higher during these trials compared to other more standard conditions. Both of the latter mentioned studies used the RTX.

Due to the unreliable measuring instrument in this particular study and some weaknesses of previous research such as abnormal core temperatures and measurements only in some of the subjects, no conclusion between core temperature and an improved work capacity can be drawn. The subjects did rate their perceived pain lower during cooling trials compared to the active trials, which may support the theory that there is a reduction in sensory input when the skin temperature is lowered. Females and males experience cold in different ways. Females have, according to earlier studies, a lower threshold for pain (Fillingim et al., 2009). This might be due to a higher density of nerve fibers in their skin (Mowlavi et al., 2005). Thus, during high-intensity training, the pain might be of a bigger concern to women compared to men. In this particular study, all female subjects but one, who rated her pain perception equally, rated their pain perceptions lower during the cooling compared to active trials, although this was not directly related to an increase in performance variables. Although, only six out of the total 17 subjects in this study were females, therefore any differences between genders is hard to draw any conclusions from.

Kwon and research group (2015) applied cryotherapy between repeated sets of bench-press exercise and found a 30 % increase in working volume during cryotherapy trials compared to control in well-train women, but with no difference compared to what has been shown in well-trained men (Kwon et al., 2010). Athletes of any gender is known to have a higher pain tolerance compared to sedentary individuals (Tesarz, Schuster, Hartmann, Gerhardt, Eich, 2012). Cryotherapy might then be more effective at lowering pain perception in sedentary women compared to well-trained men.

Study limitations

One of the limitations of this study were the unreliable instrument to measure core temperature. Since the change is of most interest in this particular matter, an instrument with a higher reliability would tell us about the effects of local cryotherapy on core temperature. Even though there were attempts to standardize each test as much as possible like having each participant at the same time of the day and having the same volume of surrounding music, another limitation is the environment in which the tests were performed in. All of the tests were completed in an open gym, in which the amount of surrounding sound and people greatly varied. This could have a positive effect on some people's performance because the feel like they have people watching them (Rhea, Landers, Alvar, Arent 2003). If these people are present during one of the trials but not the other, this might affect the results. According to Bartolomei et al. (2015) music has proven to enhance strength endurance, thus if one type of music was present at one of the trials but not the other, this might affect the results.

Practical applications

Since working volume is an important contributing factor to long-term strength and hypertrophy gains, the results from this study suggests that trained individuals who seek to improve their strength and hypertrophy could do so by implementing local cryotherapy with ice on an interval basis. The training regimen used in this study, three working sets at 85 % of 1RM and three and a half minute of rest between sets, is a common regimen used by individuals who aim to increase strength and hypertrophy. Athletes are usually involved in strenuous exercise, which could be associated with pain, cryotherapy could be used as a method to lower the pain. These results go in line with previous studies, but also further

suggests that local cryotherapy with ice can improve the total amount of weight lifted and total amount of repetitions at higher percentages of 1-RM, and that these results are not exclusive to palm-cooling with the RTX device.

Conclusion

The results of this suggests that local cryotherapy with ice can lower subjective perceptions of pain, enhance the number of repetitions completed and the total amount of weight lifted during repeated sets of leg-extension exercise at 85 % of 1-RM to failure.

Future research

There was a significant reduction in core temperature before the third set, this was however most likely due to an unreliable measuring instrument. Future research should conduct studies with a more reliable method of measuring the effects of local cryotherapy on the core- and muscle temperature. Furthermore, a study with an even distribution of men and women would help us to evaluate if there is any potential gender effect. Also, comparing an athlete population to a non-athlete population would perhaps tell us more about for which populations cryotherapy might prove to be effective on.

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Appendix

Appendix 1. Information sheet (Swedish)

Mittuniversitetet
MID SWEDEN UNIVERSITY

Avdelningen för hälsovetenskap

Hej! Denna enkät fyller du endast för att jag ska kunna se att du kvalificerar för att vara med i mitt arbete. Den är inte bindande på något sätt och du kan avvika ifrån studien när du vill. Informationen kommer behandlas konfidentiellt och kommer endast läsas utav mig personligen.

Vad heter du?

Hur gammal är du?

Äter du några mediciner, om ja, vilka?

Vad har du för träningsbakgrund?

Hur många gånger i veckan tränar du styrketräning?

Hur många gånger i veckan tränar du övrig träning?

Har du några knä-problem eller andra skador som kan påverka testerna?

Appendix 2. Health form (Swedish)

Nationellt vintersport-centrum
MITTUNIVERSITETET

Hälsoformulär

Datum: _____ **Personnummer (12 siffror):** _____

Namn: _____ **E-postadress:** _____

Mobiltel: _____ **Tel anhörig (ICE):** _____

1. Har du någon skada som du upplever kan påverka din prestationsförmåga? Ja Nej
   Om ja, vilken/vilka: _____
2. Har du/har haft någon känd lung- eller hjärt/kärlsjukdom? Ja Nej
   Om ja, vilken/vilka: _____
3. Har du någon annan känd sjukdom? Ja Nej
   Om ja, vilken/vilka: _____
4. Använder du någon/några mediciner? Ja Nej
   Om ja, ange vilken/vilka: _____
5. Om du röker/snusar, när rökte/snusade du senast? _____
6. När drack du senast någon koffeinhaltig dryck? _____
7. När var du senast förkyld? _____
8. Känner du dig fullt frisk idag? _____
   Om nej, varför? _____
9. Hur många träningstimmar har du haft det senaste året? _____
10. Hur många timmar och på vilken intensitet har du tränat de senaste:
    (Skatta intensiteten mellan 1-10; 1=Mycket lätt, 10=Mycket ansträngande)

    24 timmarna: _____ Intensitet: _____

    3 dagarna: _____ Intensitet: _____

Jag genomför dagens test på egen risk:

Datum: _____ Underskrift: _____

Målsmans underskrift (<18 år): _____

Testledare: _____

Appendix 3. Written consent form (Swedish)

Information till försökspersoner

Bakgrund och syfte
Styrketräning är idag en vida använd träningsmetod för att minska skaderisk samt öka styrka. Många olika typer av återhämtningsmetoder finns att tillgå idag. Syftet med denna studie är att jämföra två olika typer av återhämtningsmetoder mellan upprepade sets av benspark.

Förfrågan om deltagande
Du har frivilligt visat intresse för att medverka i studien ”Olika återhämtningsmetoders påverkan på arbets-kapacitet på benspark”. Härmed tillfrågas du att delta i studien som försöksperson.

Hur går studien till?
Studien sträcker sig över tre test-tillfällen. Varje testtillfälle beräknas ha en tidsåtgång på cirka 45 minuter. Vid det första testtillfället kommer ett test göras för att estimera 1-RM i benspark samt kroppssammansättning. Vid nästkommande två tillfällen kommer du att göra totalt 3 sets av benspark. Under dessa två tester kommer ett antal olika parametrar att mätas (kraft, antal repetitioner, kroppstemperatur), du kommer även få uppskatta på en skala hur ansträngd samt gradera smärtupplevelse efter varje set. Mellan/innan test-tillfällena ska ingen ovanligt tung träning göras, helst skall träning för underkroppen undvikas helt.

Praktisk information
Testerna kommer utföras i vår träningslokal som ligger högst upp i hus D på campus Östersund.

Hantering av data och sekretess
De uppgifter som avses att samlas in och behandlas är namn, ålder, vikt, längd, födelseår och träningshistorik. Utöver detta kommer data samlas in enligt ovanstående beskrivning av studien. Du avgör själv om du vill lämna några övriga uppgifter. Uppgifterna kommer endast att behandlas av mig inom projektet och behandlas så att inte obehöriga kan ta del av dem.

Du har enligt 26 § personuppgiftslagen (1998:204) rätt att få besked om vilka personuppgifter om dig som behandlas och hur behandlingen går till. Det är du själv som lämnar personuppgifterna. Personuppgifter hämtas inte från någon övrig källa. Du har rätt att enligt 28 § personuppgiftslagen begära rättelse i fråga om personuppgifter som behandlas om dig.

Risker
Riskerna med testerna är väldigt små. Riskerna kan likställas med de risker du utsätts för när du själv tränar.

Hur får jag information om studiens resultat?
Efter att studien är färdig och alla resultat sammanställda kommer du få den tilldelad till dig via mail.

Frivillighet
Deltagandet i studien är helt frivilligt och du kan när som helst avbryta studien utan att motivera varför.

Kontakt
Om det skulle uppstå några problem eller frågor ta kontakt med ansvarig student:

Björn Hansson
Tel: 073 020 00 32
E-mail: bjha1301@student.miun.se

Samtycke

Undertecknad har tagit del av ovan information och också av den information som jag meddelats muntligen genom ansvarig student. Jag har beretts tillfälle att ställa frågor om experimenten och jag är medveten om att närhelst jag önskar och utan att behöva meddela orsak därtill kan avbryta experimenten.

Jag tackar **JA** till medverkan i studie och samtycker till att projektansvariga behandlar personuppgifter om mig i enlighet med ovanstående. _____

Jag tackar **NEJ** till deltagande i studien. _____

Östersund den…….
den……...

Östersund

…….
Underskrift försöksperson

…….
Björn Hansson, ansvarig student

…….
Namnförtydligande

Appendix 4. RPE-scale (Swedish)

6 Ingen ansträngning alls
7 Extremt lätt
8
9 Mycket lätt
10
11 Lätt
12
13 Något ansträngande
14
15 Ansträngande
16
17 Mycket ansträngande
18
19 Extremt ansträngande
20 Maximal ansträngning

Appendix 5. VAS (Swedish)