Effects of Cold Application on Pressure Sensation, Two-Point Discrimination and Maximal Isometric Muscle Strength

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Abstract

This study was conducted to ascertain the effect of cryotherapy on sensation of pressure, two-point discrimination (2PD) and maximal muscle isometric force production, and how these effects varied with time. Fifty apparently healthy individuals were recruited, in a quasi-experiment, using consecutive sampling. Participants' age, height and weight were recorded while pressure sensation was determined using a 5 g monofilament while muscle strength was measured using a hand dynamometer. Ten minutes of cooling of the right forearm and hand at 10˚C was administered with 2PD ability measured pre-cooling, immediate post-cooling, as well as 5 and 10 minutes post-cooling using an adapted discriminator. Pre-cooling pressure sensation, 2PD and maximal isometric hand grip strength were found to be 0.96±1.67 g, 1.67±0.67 mm and 35.3±10.2 N respectively. Immediate post-cooling isometric hand grip strength (38.7±8.37 N), pressure sensation (1.00±0.00 g) and 2PD threshold (1.59±0.86 mm) were recorded. Muscle strength was also obtained 5 and 10 minutes post-cooling as 37.3±9.96 N and 38.8±10.8 N respectively. No significant changes were observed in pressure sensation ($p = 0.159$) and 2PD ability ($p = 0.508$), and between maximal isometric muscle strength pre- and immediately post-cooling ($p = 0.685$), and between pre- and 5 minutes post-cooling ($p = 0.079$). A significant difference, however, was observed between maximal isometric strength pre-cooling and 10 minutes post-cooling ($p = 0.008$), with muscles showing greater isometric strength post-cooling (38.8±10.8 N). It was concluded that cryotherapy at 10˚C did not have deleterious effects on sensation and muscle strength but can significantly improve the latter, and therefore can be employed preceding rehabilitation, strength training to improve athletic performance.

Keywords: *Cryotherapy; Two-point discrimination; Isometric muscle strength*

Introduction

Pressure sensation results from the deformation of deeper tissues by touch stimuli (Guyton & Hall, 2000) and is described as a sustained touch (Ganong, 2003) that is elicited by any object of adequate weight being held against the skin for a period of

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time or intermittently (Rubley, Denegar, Bukley & Newell, 2003). Touch and pressure perception are mediated by mechanoreceptors in the skin and can be assessed using the two-point discrimination (2PD) test (Kaneko, 2005) which examines the ability to perceive that two nearby objects touching the skin simultaneously are truly two distinct points and not one (Guyton & Hall, 2009). Thus, the minimal distance by which two touch stimuli must be separated to be perceived as separate is the two-point threshold (Ganong, 2003) and can be assessed using a discriminator. The application of heat and cold treatments known as thermotherapy and cryotherapy respectively has a long history. As treatment modalities, these have been established to be associated with a wide range of therapeutic benefits. The use of temperature (heat or cold) can also impact pressure sensation and 2PD and has in fact been shown to sharpen tactile acuity (Stevens, 1982).

Cryotherapy is the use of ice or cold in reducing the symptoms of inflammation associated with blood flow such as swelling, and also decreases pain by its inhibitory effect on spinal neurons (Porter, 2005). The therapeutic effects of cryotherapy are well documented (Rubley *et al.*, 2003; Mitra, 2006; Chao *et al.*, 2008). However, while some researchers have found that cryotherapy has beneficial effects, others reported no changes. Consequently, the effect of cryotherapy on treatment outcome is somewhat controversial. Also, the post-cooling character of an area to which cryotherapy has been applied, in terms of sensation and muscle strength, has yet to be fully understood (Grabois *et al.*, 2000). Therefore, this study aimed to ascertain the effect of the application of cold on sensation of pressure, two-point discrimination and maximal muscle isometric force production, and how these effects vary with time.

Methods

This study was conducted using a quasi-experimental design with fifty participants (25 males and 25 females) recruited. They were apparently healthy male and female undergraduate students who volunteered to participate, being satisfied with the criteria involved. The participants had no history of neurological defects, no history of musculoskeletal impairments or any wounds or infections. Ethical approval was sought and obtained from the Ethical Review Committee of the Nnamdi Azikiwe University Teaching Hospital, Nnewi, South-eastern Nigeria. All measurements were taken at the same time of the day to eliminate the possible influence of diurnal variation in temperature and activity levels on the results obtained from the study. The procedure was explained to the participants and informed consent was obtained before the commencement of the study. Their biodata were also obtained and recorded.

Preparation of the participants pre-cooling

a. Each participant was comfortably positioned on a chair with the dominant arm placed on a table and any obstructive clothing was removed, from the hand to the mid arm. A monofilament was used to assess pressure perception. The participant was instructed to close their eyes and to respond ‘yes’ or ‘no’ to indicate feeling or not feeling the monofilament respectively. The mounted monofilament was then pressed to the participant’s skin until it bent. Participants were first asked if they felt the monofilament on touching it against the skin and secondly when the

monofilament had bent. This was done three times and their answer, yes or no, was recorded.

b. The two-point discrimination test was carried out by asking participants to close their eyes, placing the two monofilament points of the adapted discriminator on the participant at the same time and asking them to respond 'one' or 'two', depending on the number of points felt. The distance between the arms of the divider was set at 50 mm. This was then progressively decreased by 5 mm. At 5 mm, it was progressively decreased by 0.5 mm until only one point was felt. That distance was then recorded as the two-point threshold.
c. The isometric grip strength of the participants was measured by placing the dominant hand with the elbow fixed on the table at an angle between 100 and 110 degrees. They were then asked to tightly grip the hand bar of the hand-held dynamometer, squeeze maximally and maintain maximum contraction for 30 seconds. The maximum force produced and sustained for 30 seconds was read off the dynamometer and recorded.

Cooling

An ice bath was prepared using ice and water of sufficient depth to totally submerge the forearm in 90 degrees of flexion. The temperature of the bath was lowered to 10^{o}C and monitored with a thermometer. All bony prominences in the forearm and hand were coated with a thin layer of petroleum jelly to avoid cold burns. The participant's forearm and hand were immersed into the ice bath from 5 cm above the medial epicondyle to cover the finger tips. After 10 minutes, the participant's limb was withdrawn from the bath. The dominant upper limb was used to ensure uniformity.

Post Cooling

Immediately after cooling, the participant's maximal isometric force production was first measured as described above, and then the pressure perception and two-point discrimination threshold were assessed using the procedures described above. The maximal isometric contraction of the subject was measured again 5 minutes and 10 minutes post-cooling.

Results

Fifty individuals (25 males and 25 females) served as participants in this study. They were all apparently healthy, young individuals aged between 19 and 28 years with a mean age of 22.7±2.00. The demographic characteristics of the participants are presented in Table 1.

Table 2 shows that pre-cooling pressure sensation tended to be lower in females than in males but that pre-cooling maximum strength was greater in males than in females. The two-point discrimination threshold tended to be lower in males than in females. Table 3 shows no significant difference between pre-cooling and post-cooling pressure sensation in each of the groups (males versus females).

Table 4 shows that the male values for two-point discrimination decreased following cooling while those for females increased post cooling. There was no significant

difference between pre-cooling and post-cooling two-point discrimination in either group (gender) ($p > 0.05$).

Table 5 shows that the mean maximum isometric strength for males decreased from 42.08 N to 41.0 N while mean maximum isometric strength for females increased from 28.5 N to 30.4 N immediate post-cooling. The paired samples t test was used to analyse these values and revealed no significant difference between pre- and immediate post-cooling muscle strength for the groups ($p > 0.685$). Table 5 also displays comparison between pre-cooling and 5 min post-cooling isometric strength of the groups and found no significant differences although an increase in strength was generally observed. Strength was observed to increase in females more than in males ($p = 0.014$). A significant difference was also noted between pre-cooling maximum strength and maximum strength 10 minutes post-cooling overall. Strength was observed to increase in both males (45.4±8.57 N) and females (32.4±8.65 N) compared to the pre-cooling values for males (42.08±8.534 N) and for females (28.5±6.94 N). There was, however, a statistically significant increase in muscle strength in females compared to the males.

Table 1: *Physical characteristics of the participants*

Gender	N	Mean Age (yrs)	Mean Height (cm)	Mean Weight (kg)
Total	50	22.7±2.00	110.1±7.66	67.3±11.5
Male	25	23.6±1.94	174.9±6.95	71.0±10.5
Female	25	21.8±1.68	165.3±5.57	63.5±11.3

Table 2: *Pre-cooling values based on gender*

Group	N	Pressure Sensation (g)	2 Point Threshold (mm)	Maximum Strength (N)
Total	50	0.96±1.67	1.67±0.77	35.3±0.19
Male	25	1.00±0.00	1.60±0.75	42.1±8.53
Female	25	0.92±0.28	1.74±0.81	28.5±6.54

Table 3: *Comparison of pre- and post-cooling pressure sensation*

Group	N	Pre cooling	Post cooling	t	*p*
Total	50	0.96±1.67 g	1.00±0.00 g	- 1.429	0.159
Male	25	1.00±0.00 g	1.00±0.00 g	-	-
Female	25	0.92±0.28 g	1.00±0.00 g	-1.445	0.161

Table 4: *Comparison of pre- and post-cooling two-point discrimination*

Group	N	Pre cooling	Post cooling	t	*p*
Total	50	1.07±0.77 mm	1.59±0.86 mm	0.665	0.508
Male	25	1.60±0.75 mm	1.54±0.87 mm	0.377	0.709
Female	25	1.24±0.81 mm	1.64±0.86 mm	0.548	0.589

Table 5: *Comparison of pre- and immediate post-cooling, 5 minutes and 10 minutes post-cooling maximum strength*

	Total	Male	Female
N	50	25	25
Pre cooling	35.3±10.19 N	42.08±2.534 N	28.5±6.94 N
Immediate post cooling	35.7±8.37 N	41.0±2.44 N	30.4±5.35 N
t	- 0.808	0.576	-1.688
p	0.685	0.570	0.104
5 min post cooling	37.3±9.96 N	43.2±8.62 N	36.3±7.36 N
t	1.791	-0.589	-2.646
p	0.79	0.561	0.014
10 min post cooling	38.8±10.8 N	45.4±8.57 N	32.2±8.65 N
t	-2.755	-1.532	-2.656
p	0.008	0.139	0.014

Discussion

Cryotherapy is a simple, portable and inexpensive means of managing acute inflammation and pain. It has found extensive use in both clinical and sports physiotherapy in the management and rehabilitation of patients. Several authors have investigated the post-cooling properties of muscles and other tissues in patients treated with cryotherapy. While some studies reported that cryotherapy has no significant effect on muscle strength (Marino, 2008), others found a decrease in muscle strength and peak torque (Chao *et al.*, 2008). A third group has observed an increase in muscle strength and endurance (Sanya & Bello, 1999; Mermier, Schneider, Gurney, Weijart & Wilmerding, 2008). These variations in reportage may have been due to different protocols employed by the researchers.

The current study employed a protocol that was not previously used and made similar observations with findings from the earlier studies. It was observed that the pressure sensation of the participants did not significantly change even 10 minutes post-cooling in an ice bath at 10^{o}C. This observation supports the findings of Rubley *et al.* (2003) and Knight (1995) who reported that cooling decreased the sensation of pressure although not significantly.

The effect of cooling on the two-point discrimination of participants was also assessed. Comparison of participants' pre- and post- treatment values for two-point discrimination revealed that there was no change in two-point discrimination following 10 minutes of cooling in a bath at 10^{o}C. This is in agreement with the results of previous research which revealed that cooling did not have any effect on two-point discrimination (Rubley, 2003; Knight, 1995). Two-point discrimination ability has been reported to be the true test of sensation and has been employed as a quantitative method of testing for loss of nerve function (Periyasamy, Manivannan & Narayanamurthy, 2008). Our results have confirmed that the application of cryotherapy for 10 minutes at 10^{o}C does significantly impair nerve function and tactile skin sensation.

The third property studied was the post-cooling maximal isometric grip strength as compared to participants' pre-cooling values. Several studies have been carried out on this subject with varying results due to variation in temperature, cooling media,

temperature assessment methods, muscle fibre type and contraction type (Drinkwater, 2008) as well as duration of cooling, and surface area cooled (Marino, 2008). It is generally accepted that these variations will introduce differences in results obtained.

Sanya and Bello (1999) observed a rise in isometric strength and endurance of the quadriceps following 5 minutes of cooling with ice towels at 6˚C while Chao *et al.* (2006) reported a decrease in concentric peak torque and velocity of the quadriceps following cooling with ice pack and towels for 20 minutes. Marino (2008) did not observe any significant difference post-cooling either. The differences in the results of these studies may be accounted for by the time frame of application and the types of muscle fibre recruited. However, it is widely accepted that cooling the muscles to any temperature below 27˚C will not inhibit maximal force though the temperature at which cooling starts to impair maximal voluntary force is not exact. We observed that cooling the forearm and hand for 10 minutes in an ice bath at 10˚C did not significantly alter the maximal isometric strength of grip muscles immediately following cryotherapy. This may be because the cooling did not last long enough (25 minutes) to lower the muscle temperature adequately (≥27˚C) to produce a decrease in muscle strength as suggested by Grabois *et al.* (2006).

After 5 minutes post-cooling, muscle strength was observed to increase but not enough to produce a significant difference. At this point, a reflex dilatation of blood vessels is expected to occur in the cooled part to restore local temperature to baseline (Foster & Palastanga, 1981) improving muscle nutrition which may elicit an increase in muscle strength. The significant increase we observed in maximal isometric strength 10 minutes post cooling in comparison to pre-cooling values and immediate post-cooling values may be due to the increase in blood flow and consequently improved nutrition and removal of metabolic waste products that accompany cryotherapy. It could also be as a result of decreased fatigue of the muscles associated with improved circulation.

Finally, our results are in line with previous research and suggest that cryotherapy is not contraindicated in exercise, sports or neuromuscular rehabilitation as it was applied using the duration and temperature range commonly employed in clinical practice.

Conclusion

Based on the findings of this research, we concluded that cryotherapy can be safely used in neuro-rehabilitation and musculoskeletal reconditioning and that cooling at 10˚C for 10 minutes has no negative effects on muscle strength and nerve conduction. Therefore, cryotherapy may be used to improve muscle performance in athletes.

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