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Research Article

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The Importance of Target Tissue Depth in Cryotherapy Application

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Abstract

Background: Subcutaneous adipose tissue thickness has been demonstrated to alter intramuscular cooling time. This demonstration was based on a relative depth, half skin fold thickness +10 mm. As such, one cannot determine whether the measured differences related to temperature transmitting more slowly through adipose tissue or because of the absolute difference in the depth of measurement. Additionally, previous research has not evaluated the role that gender may play, since females commonly have thicker skinfolds.

Hypothesis: Our purpose was to determine what had a greater influence on cooling time, adipose tissue or muscle thickness, and what role gender plays in those cooling times. We believed that adipose tissue would more greatly affect the cooling time, irrespective of gender.

Study design: Cross-sectional group comparison.

Methods: Three anterior thigh (½ the distance between ASIS and base of the patella) skinfold measurements were averaged for each participant. Subjects lay supine while a multi-probe was inserted into the thigh at the skinfold measurement site. The multi-probe measured intramuscular temperature at 25 mm, 32.5 mm, and 40 mm below the skin surface. Temperatures were recorded at each depth every 10 min during a 10 min baseline, 60 min ice bag (1 kg) application, and 30 min after icing (10 time points). Temperature recordings served as the dependent variable.

Results: At the 32.5 and 40 mm depths, subjects with a thicker skinfold cooled less than those with a thinner skinfold, but these differences were not significant until at least 60 min of cooling. Males cooled to a greater extent than females at the 40 mm depth (32.0 ± 0.7°C vs. 33.3 ± 1.2°C), but this difference did not persist when skinfold thickness was added as a covariate.

Conclusions and clinical relevance: Treatment times associated with cryotherapy use may not be as dependent on skinfold thickness as it is on depth of the target tissue being treated.

Keywords: Acute care; Treatment; Skinfold; Rehabilitation

Introduction

Cryotherapy is commonly used for the immediate care of musculoskeletal injuries [1]. Cold application following injury is theorized to decrease the metabolic demand of the injured tissues. As a result, the tissues require less oxygen and secondary injury (i.e., tissue death due to lack of oxygen) is reduced. In doing so, cryotherapy reduces the deleterious effects of the injury potentially improving recovery time [2,3].

Tissue cooling is mitigated by a variety of factors including, the type of cryotherapy applied (e.g., ice massage, ice bags), length of application [4-7], and the physical characteristics of the person (e.g., skinfold thickness) and body part on which it is applied [8-10]. Otte et al. [10] observed thicker adipose tissue on the anterior thigh corresponded with longer cooling times. Based on these observations, they recommended measuring skinfold thickness prior to cryotherapy application and tailoring the duration of cryotherapy based on the skinfold thickness of the patient. Specifically, sites with skinfolds of less than 10 mm, 11-20 mm, 21-30 mm, and greater than 30 mm of skinfold thickness should be iced for 15, 25, 40, and 60 mins respectively.

The recommendations from the Otte et al. [10] research left two questions unanswered. First, because the measurements were taken at a relative depth, half skinfold plus 10 mm (Figures 1A and 1B), what role does adipose tissue play in delayed cooling? The increased cooling times may merely be due to the fact that the cold had to penetrate deeper to reach the thermocouple tip, not the amount of overlying adipose tissue. Second, what role does gender play in cooling time? Otte et al. reported that 62% participants were females, but did not report how many females were in each skinfold category [10]. Females on average have a larger thigh skinfold [11]. Based on these observations, we can assume that the thicker skinfold pairings

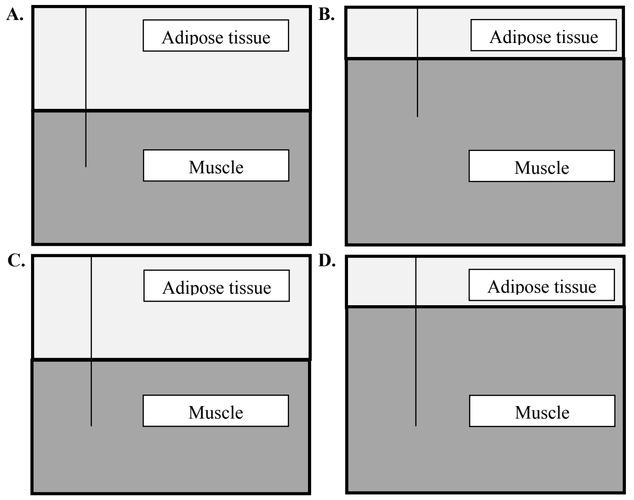

Figure 1: Depiction of the comparison of thermocouple insertion differences. Otte et al. inserted thermocouples to the depth of ½ skinfold plus 10 mm. In this manner, the thermocouples were inserted to a depth relative to the amount of adipose tissue – the thermocouple is deeper in (A) than in (B) due to the larger skinfold in (A). In the present study, we inserted thermocouples in the thigh to an absolute depth. Thus, even though (C) has a larger skinfold than (D), temperatures for both were measured at an absolute depth (40 mm, 32.5 mm, and 25 mm). By using the absolute depth procedures when measuring temperatures in the thigh, we were able to determine if the differences in cooling time were a function of adipose tissue or muscle, male vs. female, or a combination of both.

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in the Otte et al. study were predominantly female. Inserting a thermocouple to an absolute depth (Figures 1C and 1D) allows for a comparison between the cooling characteristics of adipose tissue and muscle and between males and females to be made.

There were two purposes for this study. First, to determine what had a greater influence on cooling time, subcutaneous adipose tissue thickness or muscle thickness. Second, to determine what role gender plays in cooling times. We hypothesized that subcutaneous adipose tissue would more greatly affect the cooling time of underlying muscle tissue, irrespective of gender.

Methods

This study obtained Institution Review Board approval (IRB Protocol 2010-0416) and all subjects provided informed consent. Fifteen recreationally active males (age=26 ± 4 y, ht=180.7 ± 11.9 cm, mass=80.7 ± 12.2 kg) and 15 recreationally active females (age=21 ± 2 y, ht=166.6 ± 8.4 cm, mass=64.5 ± 7.9 kg) reported to an Athletic Training Laboratory on one occasion. Skinfold thicknesses were measured on the anterior thigh, half the distance between the anterior superior iliac spine and the superior border of the patella, with Lange skinfold calipers (Beta Technology Incorporated, Cambridge, MD) using standard techniques [12]. The same clinician, who was trained and experienced in skinfold measurement procedures, measured each subject three times and calculated the average skinfold thickness for the thigh. All measurements were within 1 mm of each other.

Following the skinfold measurements, subjects lay supine on a treatment table. The anterior thigh was shaved (if necessary) and cleaned for 30 seconds using single use, disposable povidone-iodine swabs. A 16-gauge, 45 mm Teflon single use, disposable catheter was inserted 40 mm into the same site where the skinfold measurement was taken. Each catheter was marked to ensure depth of insertion. This technique was consistent with the research conducted by Otte et al. [10], except at an absolute depth. A multi-probe thermocouple, which consists of three thermocouples with 7.5 mm spacing between thermocouples within the same sheath, was threaded through the catheter until it reached the end. The catheter was then removed leaving the multi-probe in place. Using this approach enabled us to measure temperature at 3 different depths (40 mm, 32.5 mm, and 25 mm beneath the skin surface) with only one insertion. An additional thermocouple was taped to the skin within 5 mm of the insertion site to measure skin surface temperature. The thermocouples were attached to a 16-channel Iso-Thermex electrothermometer interfaced with a personal computer. The subject remained supine throughout the experiment.

Following thermocouple insertion, we measured tissue and skin temperatures every 30 seconds for 10 mins to establish a baseline. We continued to measure temperature every 30 seconds while we applied a crushed 1 kg ice bag to the area for 60 mins. We selected 60 mins as the treatment time because of the Otte et al. [10] recommendations. We shook the ice bags every 5 mins during the ice bag application to remove any thermal gradients that may have formed. Additionally, after 30 mins of icing, we replaced the ice bag with a new, 1 kg ice bag. Temperatures were recorded, at each depth, every 10 mins during the 60 min ice bag application and 30 min rewarming period.

After 60 mins, we removed the ice and continued to measure tissue and skin temperature for an additional 30 mins to determine if additional cooling took place. Following the 30 mins, we detached the thermocouples from the Iso-thermex and removed them from the leg. We cleaned the thermocouple insertion site with soap and water and applied an adhesive bandage with antibiotic ointment over the insertion site. Subjects were also instructed on how to properly care for the wound (i.e., removal and replacement of bandages and cleaning the wound).

Statistical analysis

To compare adipose tissue and muscle thickness, we separated subjects into two equal groups by average skinfold thickness (≤ 20 mm or >20 mm skinfold thickness) and analyzed the data using three (one for each thermocouple depth) 2×10 repeated measures ANOVAs with Greenhouse-Geisser corrections. Multiple independent sample *t*-tests were performed to determine where differences occurred.

To compare males and females, we separated subjects by gender and analyzed the data using three (one for each thermocouple depth) 2×10 repeated measures ANOVAs with Greenhouse-Geisser corrections. This analysis was repeated with skinfold thickness as a covariate. As with the first analyses, multiple independent sample *t*-tests were performed to determine where differences occurred. Significance was accepted when $p \leq 0.05$ for all calculations. Data were analyzed using PASW Statistics 18.0 (SPSS Ltd, Hong Kong).

Results

For the first analysis, the ≤ 20 mm skinfold grouping was predominantly male (14 males, 1 female) while the >20 mm skinfold group was predominantly female (14 females, 1 male). The average skinfold thickness between the two groups was statistically different (≤ 20 mm skinfold thickness=12.5 ± 4.6 mm, >20 mm skinfold thickness=25.9 ± 5.6 mm; $p<0.001$). Temperature differences between the groupings were not significant until 60 mins of ice application and/or after the ice was removed, dependent upon thermocouple depth (Table 1). Using the arbitrary 7°C decrease in temperature proposed by Otte et al. [10] subjects with ≤ 20 mm average skinfold reached this target in approximately 40 mins at the 25 mm depth and in approximately 60 mins at the 32.5 mm depth. Subjects with >20 mm average skinfold reached the 7°C decrease in temperature in approximately 50 mins at the 25 mm depth and 70 mins, or 10 mins after the ice was removed, at the 32.5 mm depth. Neither group reached the target temperature at the 40 mm depth (Table 1).

The male to female comparison did not differ greatly from the skinfold groupings comparison. Males differed statistically from females with respect to average skinfold thickness (males=13.0 ± 5.3 mm, females=25.4 ± 6.1 mm; $p<0.001$). Temperature differences were not significant between males and females until 60 mins of ice application, 40 mm deep. Differences were also present 20 and 30 mins after the ice was removed (time points 80 and 90 respectively) at the same depth (Table 2). When adding skinfold thickness as a covariate, the gender differences were no longer present. As with the skinfold grouping comparison, the males reached a 7°C decrease in temperature quicker than the females did (25 mm: 40 mins vs. 50 mins; 32.5 mm: 60 mins vs. 70 mins, or10 mins after the ice was removed; neither males or females reached at 40 mm; Table 2).

Discussion

We question whether the contribution of skinfold thickness is as important as the depth of the target tissue being treated. To best compare our data to that of Otte et al. [10], we must view their

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Table 1: Differences in intramuscular temperature (°C ± SD), across the 10 times points, between individuals with ≤20 mm skinfold thickness and those with >20 mm skinfold thickness. The average depth (mm ± SD) of the thermocouple (TC) tip in to the muscle is also reported for clarity. This depth was determined by dividing the skinfold by 2 and subtracting this value from the total thermocouple depth. Shading indicates when ice is applied.

	TC Depth in Muscle	Time (min)									
	(mm)	0	10	20	30	40	50	60	70	80	90
25 mm										a	a
≤20 mm	18.7 ± 2.3	36.2 ± 0.6	35.4 ± 1.0	33.4 ± 1.2	31.2 ± 1.7	29.4 ± 1.6	28.1 ± 1.9	27.0 ± 1.7	26.0 ± 1.3	26.3 ± 1.8	27.3 ± 1.2
>20 mm	12.1 ± 2.8	36.6 ± 0.9	35.8 ± 1.2	34.1 ± 1.5	32.1 ± 1.9	30.5 ± 2.1	29.4 ± 2.5	28.4 ± 2.3	27.7 ± 2.2	28.4 ± 2.0	29.3 ± 1.9
32.5 mm									b	b	b
≤20 mm	26.2 ± 2.3	36.3 ± 0.5	36.0 ± 0.6	34.7 ± 0.7	33.1 ± 1.1	31.6 ± 1.1	30.5 ± 1.2	29.5 ± 1.2	28.5 ± 1.1	28.4 ± 1.0	29.0 ± 1.0
>20 mm	19.6 ± 2.8	36.7 ± 0.6	36.3 ± 0.8	35.3 ± 1.0	33.9 ± 1.3	32.6 ± 1.4	31.7 ± 1.8	30.9 ± 1.7	30.1 ± 1.8	30.3 ± 1.6	30.8 ± 1.6
40 mm								c		c	c
≤20 mm	33.7 ± 2.3	36.7 ± 0.4	36.5 ± 0.4	35.9 ± 0.5	34.8 ± 0.7	33.7 ± 0.7	32.7 ± 0.8	31.9 ± 0.7	31.1 ± 0.8	30.7 ± 0.8	30.9 ± 0.8
>20 mm	27.1 ± 2.8	37.0 ± 0.4	36.8 ± 0.5	36.3 ± 0.6	35.5 ± 0.8	34.7 ± 0.8	34.0 ± 1.1	33.4 ± 1.0	32.5 ± 1.3	32.4 ± 1.2	32.5 ± 1.2

[a] $p = 0.03$
[b] $p = 0.007$
[c] $p < 0.001$

Table 2: Differences in intramuscular temperature (°C ± SD), across the 10 times points, between males and females. The average depth (mm ± SD) of the thermocouple (TC) tip in to the muscle is also reported for clarity. This depth was determined by dividing the skinfold by 2 and subtracting this value from the total thermocouple depth. Shading indicates when ice is applied.

	TC Depth in Muscle	Time (min)									
	(mm)	0	10	20	30	40	50	60	70	80	90
25 mm											
M	18.5 ± 2.7	36.2 ± 0.5	35.5 ± 1.0	33.6 ± 1.2	31.5 ± 1.7	29.7 ± 1.5	28.3 ± 1.9	27.2 ± 1.7	26.3 ± 1.3	26.6 ± 1.2	27.6 ± 1.4
F	12.3 ± 3.0	36.6 ± 1.0	35.7 ± 1.2	33.9 ± 1.5	31.8 ± 2.0	30.2 ± 2.2	29.3 ± 2.6	28.2 ± 2.5	27.4 ± 2.4	28.1 ± 2.2	29.0 ± 2.1
32.5 mm											
M	26.0 ± 2.7	36.4 ± 0.4	36.1 ± 0.6	34.9 ± 0.7	33.4 ± 1.0	31.9 ± 1.0	30.6 ± 1.3	29.6 ± 1.1	28.7 ± 1.1	28.6 ± 1.1	29.2 ± 1.1
F	19.8 ± 3.0	36.6 ± 0.7	36.2 ± 0.8	35.1 ± 1.1	33.6 ± 1.4	32.4 ± 1.6	31.6 ± 1.9	30.8 ± 1.8	29.9 ± 1.9	30.1 ± 1.8	30.6 ± 1.7
40 mm								a		a	a
M	33.5 ± 2.7	36.8 ± 0.4	36.6 ± 0.4	36.1 ± 0.4	35.0 ± 0.6	33.9 ± 0.6	32.9 ± 0.8	32.0 ± 0.7	31.2 ± 0.8	30.8 ± 0.7	31.1 ± 0.8
F	27.3 ± 3.0	36.9 ± 0.5	36.7 ± 0.5	36.2 ± 0.7	35.4 ± 1.0	34.6 ± 1.0	33.8 ± 1.2	33.3 ± 1.2	32.4 ± 1.5	32.2 ± 1.4	32.4 ± 1.4

[a] Males differed from females at 60 minutes of cooling and 20 and 30 minutes after the ice was removed ($p<0.001$); when using skinfold thickness as a covariate, subjects no longer differed by sex ($p=0.056$)

data as if it was taken at an absolute depth. The most appropriate comparable data points are the temperature changes they reported for the 21 – 30 mm and 31 – 40 mm skinfold thicknesses (the 21 – 30 mm skinfold thickness subjects would equate to a thermocouple 20 – 25 mm deep; 31 – 40 mm skinfold thickness subjects would equate to a thermocouple 25 – 30 mm deep). Using the 25 mm depth thermocouple from our study as the comparison, our ≤ 20 mm average skinfold thickness group reached the arbitrary 7°C decrease in temperature in approximately 40 mins, whereas the >20 mm average skinfold thickness group took approximately 10 mins longer. Otte et al. recommended a 40 min treatment for a skinfold thickness of 21 – 30 mm (target tissue depth of 20 – 25 mm deep) and 60 mins for a skinfold thickness of 31 – 40 mm (target tissue 25 – 30 mm deep) [10]. These recommended times do not differ greatly from our observations, even though their recommendations were based on skinfold thickness. Because of this, we concur that skinfold appears to be a contributing factor in temperature decrease, but does not appear to be the major factor it is been thought to be.

In 2001 Jutte et al. [13], reported that skinfold thickness accounted for "14% of the intramuscular temperature variance" in individuals whose anterior thigh was treated with cryotherapy for 30 mins. Our observations are consistent with this observation; we did not observe statistical significance based on skinfold thickness until after 60 mins of treatment, at the 40 mm depth. However, the direct comparison between our study and the Jutte et al. study is problematic. The Jutte et al. temperature measurements were taken at half skinfold thickness +20 mm. Based on their reported anterior thigh skinfold thickness (21.2 ± 8.6 mm), their thermocouples would have been inserted approximately 26 – 35 mm deep [13], yielding a natural comparison with our 32.5 mm deep thermocouple. Interestingly, there is a large difference between their reported values and ours. After 30 minutes of cryotherapy application our intramuscular temperatures decreased approximately 3°C, whereas they reported a "just over 8°C" decline. This value is similar with what Otte et al. [10] reported for an 11 – 20 mm skinfold (thermocouple 15 – 20 mm deep). If their reported level of cooling was truly that great, skinfold thickness could not have played much of a role in slowing temperature decrease.

Clinical Implications and Conclusions

Our data suggest that treatment times associated with cryotherapy use may not be as dependent on skinfold thickness as it is on depth of the target tissue we are trying to treat. From that standpoint, the recommendations presented by Otte et al. may still have relevance. Whereas their recommendations were based on skinfold thickness, we recommend the following treatment times based on target tissue depth:

- 0 – 10 mm skinfold thickness=0 – 15 mm target tissue depth=15 min treatment
- 11 – 20 mm skinfold thickness=15 – 20 mm target tissue

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depth=30 min treatment

- 21 – 30 mm skinfold thickness=20 – 25 mm target tissue depth=40 min treatment
- 31 – 40 mm skinfold thickness=25 – 30 mm target tissue depth=60 min treatment

In presenting these recommendations we are not suggesting that this level of cooling is optimal; an optimal tissue temperature for healing has not been determined. However cryotherapy times should be modified based on the suspected depth of the injury.

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