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original research

Skinfold Thickness at 8 Common Cryotherapy Sites in Various Athletic Populations

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Context: Researchers have observed slower cooling rates in thigh muscle with greater overlying adipose tissue, suggesting that cryotherapy duration should be based on the adipose thickness of the treatment site. Skinfold data do not exist for other common cryotherapy sites, and no one has reported how those skinfolds might vary because of physical activity level or sex.

Objective: To determine the variability in skinfold thickness among common cryotherapy sites relative to sex and activity level (National Collegiate Athletic Association Division I athletes, recreationally active college athletes).

Design: Descriptive laboratory study.

Setting: Field.

Patients or Other Participants: Three hundred eighty-nine college students participated; 196 Division I athletes (157 men, 39 women) were recruited during preseason physicals, and 193 recreationally active college athletes (108 men, 85 women) were recruited from physical education classes.

Intervention(s): Three skinfold measurements to within 1 mm were taken at 8 sites (inferior angle of the scapula, middle deltoid, ulnar groove, midforearm, midthigh, medial collateral ligament, midcalf, and anterior talofibular ligament [ATF]) using Lange skinfold calipers.

Main Outcome Measure(s): Skinfold thickness in millimeters.

Results: We noted interactions among sex, activity level, and skinfold site. Male athletes had smaller skinfold measurements than female athletes at all sites except the ATF, scapula, and ulnar groove ($F_{7,2702} = 69.85$, $P < .001$). Skinfold measurements were greater for recreationally active athletes than their Division I counterparts at all sites except the ATF, deltoid, and ulnar groove ($F_{7,2702} = 30.79$, $P < .001$). Thigh skinfold measurements of recreationally active female athletes were the largest, and their ATF skinfolds were the smallest.

Conclusions: Skinfold thickness at common cryotherapy treatment sites varied based on level of physical activity and sex. Therefore, clinicians should measure skinfold thickness to determine an appropriate cryotherapy duration.

Key Words: adipose tissue, cold therapy, treatment settings

Key Points

- Skinfold thickness varied by sex, activity level, and site.
- Variations in skinfold thickness should be considered when determining cryotherapy durations.

Cryotherapy, which most often involves the application of a cold pack or ice bag, is the most common therapeutic modality for orthopaedic injuries. The optimal amount of tissue cooling needed to prevent secondary injury or facilitate healing of orthopaedic injury is unknown.[1] Authors of therapeutic modality textbooks have recommended various durations of ice-pack application with little definitive explanation. Recommendations have varied from 20 minutes[2] to 30 to 45 minutes,[3] whereas some[4,5] do not recommend durations. Given the inconsistencies in durations of application, clinicians might question how long they should apply cryotherapy.

Intramuscular tissue temperature data have suggested that adipose tissue thickness affects the cooling of underlying tissue.[1,6–8] Therefore, adipose thickness, which commonly is measured by skinfold, should be considered when determining cryotherapy duration. Evidence supports increasing the duration of cryotherapy when skinfold measurements are larger to achieve an amount of tissue cooling equivalent to that achieved in people with smaller skinfold measurements.[1] After measuring temperature decreases 1 cm subadipose in the thighs of people with a variety of skinfold thicknesses, Otte et al[1] made recommendations for cryotherapy durations based on skinfold thickness that theoretically would produce a 7°C decrease in the targeted tissue. Otte et al[1] recommended cryotherapy duration times of 15, 25, 40, and 60 minutes for people with thigh skinfolds of less than 10 mm, 11 to 20 mm, 21 to 30 mm, and more than 30 mm, respectively. Thus, previously recommended cryotherapy duration times[1] are useful only if clinicians determine the skinfold measurement before cryotherapy application in the thigh, and the targeted tissue is 1 cm subadipose. We are unaware of any published skinfold data for other common cryotherapy treatment sites in any population.

Extremities often are injured in sports. National Collegiate Athletic Association (NCAA) injury-surveillance data have indicated that the ankle and knee are injured most commonly in multiple sports.[9–14] In addition, the elbow and shoulder also are injured frequently.[14,15] The increased injury rates for the ankle, knee, elbow, and shoulder likely result in treating these body sites more often with cryotherapy for acute injuries. Therefore, knowing how skinfold thickness varies for the ankle, knee, elbow, and shoulder would help clinicians.

We assert that overall body composition can help predict skinfold thickness at common cryotherapy treatment sites. Body composition is influenced by several factors, including sex and level of physical activity.[16] Sex might influence some treatment sites more than others because men (males older than 17 years of age) and women (females older than 17 years of age) have different patterns of adipose distribution. Women are more likely than men to have adipose deposits around their hips and thighs.[16] Other treatment sites, such as over the anterior talofibular ligament, would be influenced less by sex-related adipose distribution and more by overall body composition. Activity level also would influence skinfold thicknesses.[16] Therefore, when comparing male and female elite and recreational athletes, we would expect skinfold measurements for most treatment sites to increase in the following order: elite male collegiate athletes, recreationally active collegiate men, elite female collegiate athletes, and recreationally active collegiate women.[17,18]

Our experience has been that most clinicians do not assess skinfold measurements before cryotherapy application regardless of the treatment site. Understanding how adipose tissue thicknesses of populations differ at common application sites could provide clinicians with more specific guidelines for cryotherapy application durations, resulting in more standardized and therefore more effective cryotherapy treatments for all patients with orthopaedic injuries. The purpose of our study was to compare skinfold thicknesses at several common cryotherapy application sites in both male and female Division I student-athletes and recreationally active college athletes. We hypothesized that sex, activity level, and treatment site would influence skinfold measurements.

METHODS

Experimental Design

A 2 × 2 × 8 factorial, controlled cohort design was used to guide data collection. The independent variables were sex (male, female), activity level (Division I athletes, recreationally active collegiate athletes), and skinfold site (inferior angle of scapula [scapula], middle deltoid [deltoid], ulnar groove, midforearm [forearm], midthigh [thigh], medial collateral ligament of the knee [MCL], midcalf [calf], and anterior talofibular ligament [ATF]). The dependent variable was the average of 3 skinfold measurements in millimeters at each site.

Participants

Three hundred eighty-nine college students participated in this study. Of these, 196 Division I athletes (157 men: age = 21.7 ± 2.0 years, height = 185.3 ± 8.4 cm, mass = 90.4 ± 21.2 kg; 39 women: age = 19.4 ± 1.5 years, height = 171.1 ± 7.4 cm, mass = 62.9 ± 8.6 kg) were recruited during preseason physicals, and 193 recreationally active collegiate athletes (108 men: age = 23.4 ± 4.2 years, height = 181.6 ± 7.4 cm, mass = 77.6 ± 11.9 kg; 85 women: age = 21.1 ± 2.6 years, height = 168.0 ± 7.8 cm, mass = 64.4 ± 10.0 kg) were recruited from physical education classes that met twice each week. *Recreationally active* was defined as participation in these classes. All participants gave written informed consent, and the Institutional Review Board of Brigham Young University approved the study.

Procedures

Skinfold thickness was measured at the right scapula, deltoid, ulnar groove, forearm, thigh, MCL, calf, and ATF using Lange skinfold calipers (Beta Technology Incorporated, Cambridge, MD) (Figures 1–8). Participants stood and were instructed to relax their right limbs during all measurements. For all lower extremity measures, they were instructed to shift their weight to their left legs. Standardized skinfold measurement techniques were used for traditional skinfold measurement sites.[19,20] Unconventional skinfold measurements were taken directly over the MCL and ATF and over the deltoid muscle half the distance between the deltoid tubercle and the acromioclavicular joint. Investigators took 3 consecutive measurements within 1 mm of each other at each site by grasping the skin of the participant between the thumb and the forefinger and placing the skinfold caliper approximately 1 cm from the thumb and forefinger.[19,20] Vertical folds were used for the deltoid, forearm, thigh, MCL, and calf, and oblique folds were used for the scapula, ulnar groove, and ATF.

Two trained investigators, who were not authors, worked together to perform the measurements. One investigator obtained the measurements using the skinfold caliper, while the other read the gauge within 4 seconds of contact and recorded each measurement to the nearest millimeter. The investigator performing the measurements was blinded to the data. In the event that the first 3 measurements of a site were not within 1 mm, the investigators moved on to a different site or waited approximately 5 minutes before obtaining the measurement again.[21] The average of the 3 site measurements within 1 mm of each other was used as the participant's skinfold measurement for the treatment site.

Statistical Analysis

Means and standard deviations (SDs) were computed for each skinfold site. A 2 × 2 × 8 repeated-measures analysis of variance (ANOVA) in which skinfold site was the repeated variable was used to assess differences in skinfold thickness by sex, activity level, and skinfold sites, including interactions. Two-way ANOVAs followed by Tukey-Kramer post hoc analyses were used to locate group differences when appropriate. The α level was set at .05. An intraclass correlation (ICC [2,1])

Figure 1. Inferior angle of scapula skinfold measurement.

Figure 3. Ulnar groove skinfold measurement.

Figure 2. Middle deltoid skinfold measurement.

Figure 4. Midforearm skinfold measurement.


Figure 5. Midthigh skinfold measurement.


Figure 6. Medial collateral ligament skinfold measurement.


Figure 7. Midcalf skinfold measurement.


Figure 8. Anterior talofibular ligament skinfold measurement.

was used to calculate reliability.[22,23] All statistical analyses were performed using NCSS (version 2007; NCSS, Kaysville, UT).

RESULTS

The reliability of our skinfold measurements (Table 1) was excellent (ICC [2,1] = 0.98). We found a 3-way interaction among sex, activity level, and skinfold site ($F_{7,2688} = 2.56$, $P = .01$). Two-way ANOVAs followed by Tukey-Kramer post hoc tests for interaction terms revealed that female athletes had larger skinfold measurements than their male counterparts for all skinfold sites except the ATF, scapula, and ulnar groove ($F_{7,2702} = 69.85$, $P < .001$; Table 2). In addition, skinfold measurements were greater for recreationally active collegiate athletes than for their Division I counterparts at all skinfold sites except the ATF, deltoid, and ulnar groove ($F_{7,2702} = 30.79$, $P < .001$; Table 3). Additional relationships are reported in Tables 2 and 3.

DISCUSSION

Our data confirmed our hypothesis that skinfold measurements were larger for female athletes than male athletes for most treatment sites when elite and recreationally active athletes were combined. In addition, the thigh skinfold measurements of the female athletes were the largest skinfold measurements. These athletes also had greater variability in skinfold measurements as indicated by skinfold site SDs. Their deltoid skinfold measurements had greater variability. The data also supported our hypothesis that skinfold measurements would be larger in recreationally active athletes than in Division I athletes. When we compared treatment sites between activity levels, recreationally active athletes had greater measurements at all but 3 skinfold sites (ie, the deltoid, ulnar groove, and ATF), and those sites were not different from each other. Recreationally active athletes had larger skinfold measurements for the scapula (20.1 ± 9.2 mm) and thigh (20.2 ± 9.2 mm) than did the Division I athletes. In addition, recreationally active participants also had greater variability as indicated by the treatment site SDs.

Although we categorized skinfold measures based on sex, activity level, and body part, these characteristics do not appear to account for all of the variability in our participants' skinfold measurements. For most body parts, the SDs were between 40% and 50% of the average skinfold measurements. Additional population characteristics must be considered if clinicians want to more accurately generalize skinfold thickness of individual body parts. Examples of additional characteristics that could be taken into consideration include age, somatotype, height, and body mass.[24]

Clinical Implications

Researchers[1,6–8] have evaluated the relationship between adipose thickness and intramuscular temperatures, yet we are the first to examine the differences in skinfold measurements at common cryotherapy treatment sites based on sex and level of physical activity. Because sex and activity level affect skinfold measurements and adipose thickness affects the cooling of underlying tissue during cryotherapy, clinicians should consider these factors when determining cryotherapy duration for their

Table 1. Skinfold Measurements by Sex, Activity Level, and Skinfold Site, mm (Mean ± SD)

	Male Athletes		Female Athletes	
Treatment Site	National Collegiate Athletic Association Division I Athletes (n = 157)	Recreationally Active Collegiate Athletes (n = 108)	National Collegiate Athletic Association Division I Athletes (n = 39)	Recreationally Active Collegiate Athletes (n = 85)
Scapula	13.4 ± 6.0	14.4 ± 5.4	11.6 ± 4.0	15.6 ± 5.8
Deltoid	16.2 ± 2.4	15.0 ± 5.8	18.8 ± 5.6	21.6 ± 13.1
Ulnar groove	5.3 ± 1.9	5.3 ± 1.5	5.4 ± 1.8	5.8 ± 2.6
Forearm	4.9 ± 2.4	6.0 ± 2.7	6.5 ± 2.7	9.3 ± 4.0
Thigh	13.0 ± 5.4	15.8 ± 7.2	19.5 ± 4.7	25.7 ± 8.5
Medial collateral ligament	11.0 ± 4.4	13.1 ± 5.6	17.3 ± 4.6	22.0 ± 7.7
Calf	8.2 ± 4.1	13.0 ± 5.7	14.9 ± 5.1	19.0 ± 7.2
Anterior talofibular ligament	3.5 ± 1.6	2.4 ± 1.1	2.6 ± 0.6	2.8 ± 3.8

Table 2. Skinfold Measurements by Sex and Treatment Site, mm (Mean ± SD)

Skinfold Site	Male Athletes (n = 265)	Female Athletes (n = 124)
Scapula	13.8 ± 5.8[a]	14.3 ± 5.6[a]
Deltoid	15.7 ± 6.7[a]	20.7 ± 11.4[a]
Ulnar groove	5.3 ± 1.7[a]	5.7 ± 2.4[a]
Forearm	5.4 ± 2.6[a]	8.44 ± 3.82[a]
Thigh	14.2 ± 6.3[a]	23.8 ± 8.0[a]
Medial collateral ligament	11.8 ± 5.0[a]	14.3 ± 5.6[a]
Calf	10.2 ± 5.3[a]	17.7 ± 6.87[a]
Anterior talofibular ligament	3.0 ± 1.5[a]	2.7 ± 3.1[a]

[a] Indicates female and male anterior talofibular ligaments < male ulnar groove, male forearm, and female ulnar groove < female forearm < male calf < male medial collateral ligament < male scapula, male thigh, female scapula, and male deltoid < female calf < female medial collateral ligament and female deltoid < female thigh (Tukey-Kramer $P < .05$).

Table 3. Skinfold Measurements by Activity Level, mm (Mean ± SD)

Skinfold Site	National Collegiate Athletic Association Division I Athletes (n = 196)	Recreationally Active Collegiate Athletes (n = 193)
Scapula	13.0 ± 5.7[a,b]	20.1 ± 9.2[a,b,c]
Deltoid	16.7 ± 7.1[c]	17.9 ± 10.3[a,c]
Ulnar groove	5.3 ± 1.9[b]	5.5 ± 2.1[c]
Forearm	5.3 ± 2.5[c]	7.5 ± 3.7[b]
Thigh	14.3 ± 5.8[c]	20.2 ± 9.2[a,b,c]
Medial collateral ligament	12.2 ± 5.1[c]	17.0 ± 8.0[b,c]
Calf	9.6 ± 5.1[a,b,c]	15.6 ± 7.1[a]
Anterior talofibular ligament	3.3 ± 1.5[c]	2.6 ± 2.6[c]

[a] Indicates skinfold measurements of Division I calf < Division I scapula < recreationally active calf < recreationally active deltoid < recreationally active thigh (Tukey-Kramer $P < .05$).
[b] Indicates skinfold measurements of Division I calf < Division I scapula < recreationally active scapula < recreationally active medial collateral ligament < recreationally active thigh (Tukey-Kramer $P < .05$).
[c] Indicates skinfold measurements of recreationally active anterior talofibular ligament and Division I anterior talofibular ligament < Division I forearm, Division I ulnar groove, and recreationally active ulnar groove < recreationally active forearm and Division I calf < Division I medial collateral ligament < Division I thigh and recreationally active scapula < Division I deltoid, recreationally active medial collateral ligament, and recreationally active deltoid < recreationally active thigh (Tukey-Kramer $P < .05$).

patients. Because female and recreationally active athletes appear to have more variability in their skinfolds, clinicians might need to measure their skinfolds before cryotherapy application to ensure consistent and appropriate cooling. Failure to account for the larger skinfolds could compromise the effectiveness of the cryotherapy for both female and recreationally active athletes.

The differences in skinfold measurements in our populations indicate that a standardized cryotherapy duration would not produce the same physiologic results in all patients. According to data from Myrer et al,[8] a 20-minute ice-pack application to the ATF in a recreationally active male athlete (skinfold = 2.4 ± 1.1 mm) would result in an approximately 14.4 ± 4.5°C decrease in tissue temperature 1 cm below the adipose tissue, whereas a 20-minute ice-pack application to the thigh of a recreationally active female athlete (25.7 ± 8.5 mm skinfold) would result only in an approximately 5.0 ± 2.1°C decrease in tissue temperature.[8] In this case, the treatment settings are standardized, yet the amount of cooling is approximately 3 times as great for the ATF ligament. Failure to select treatment settings that generate a standard physiologic effect could explain why cryotherapy has demonstrated inconsistent treatment outcomes.[25,26]

Currently, using meta-analysis, systematic reviews, and randomized controlled trials to select treatments with better treatment outcomes is emphasized. We applaud these efforts, yet if the treatment settings, such as mode and duration, do not produce a standard physiologic effect in all patients in a treatment group, we question the value of these comparisons. Overlying adipose tissue clearly will affect the amount of tissue cooling during cryotherapy.[1,6,8] Therefore, researchers conducting clinical trials should consider treatment settings that standardize the physiologic effect.

To provide examples of how skinfold measurements could affect cryotherapy duration for all the skinfold sites we measured, we have provided estimated treatment durations that account for sex, activity level, and treatment site using our skinfold data and the observations of Otte et al[1] (Table 4). These examples are intended to demonstrate how a clinician could provide more uniform cooling across a patient population rather than an optimal treatment.[1] Clinicians might find it beneficial for researchers to develop treatment guidelines for situations when measuring skinfolds before applying cryotherapy (eg, an acute injury on the sideline of a field or court) is impractical.

Our examples of how adipose could affect cryotherapy durations across the body are not without limitations. The examples of durations for the deltoid, forearm, and calf of recreationally active female athletes might need to be adjusted for some of our participants. When both the skinfold mean and the large standard deviations for our groups are considered, the participant's skinfold measurement could fall slightly outside the Otte et al[1] skinfold grouping, thus underestimating cryotherapy application times. In addition, we did not assess all populations treated with cryotherapy; therefore, our examples of durations are not appropriate for all populations (eg, adolescent athletes). Finally, our duration examples do not take into account other variables that would influence heat removal, such as differences in circulation or metabolism. We recommend that in future research, investigators use indwelling catheters, such as those that Otte et al[1] used, at other commonly injured sites. Moreover, these researchers should use a controlled injury model to examine the possibility of creating cryotherapy guidelines based on patient demographics. Even with these limitations, the duration examples we presented demonstrated how the physiologic effects of cryotherapy could be more standardized.

CONCLUSIONS

Skinfold thickness varies by sex, activity level, and treatment site; therefore, clinicians should use skinfold measurements when determining a person's cryotherapy duration. Future research in which investigators assess the effect of adipose thickness on tissue cooling at common cryotherapy application sites across the body is warranted.

Table 4. Examples of How Skinfold Thickness Could Be Used to Standardize Cryotherapy Effects Based on Data of Otte et al[1]

Treatment Site	Activity Level	Sex	Otte et al[1] Skinfold Thickness Group, mm	Recommended Treatment Duration, min
Scapula	Collegiate varsity	Male	11–20	25
		Female	11–20	25
	Recreational	Male	11–20	25
		Female	11–20	25
Deltoid	Collegiate varsity	Male	11–20	25
		Female	11–20	25
	Recreational	Male	11–20	25
		Female	21–30	40[a]
Ulnar groove	Collegiate varsity	Male	0–10	15
		Female	0–10	15
	Recreational	Male	0–10	15
		Female	0–10	15
Forearm	Collegiate varsity	Male	0–10	15
		Female	0–10	15
	Recreational	Male	0–10	15
		Female	0–10	15[a]
Thigh	Collegiate varsity	Male	11–20	25
		Female	11–20	25
	Recreational	Male	11–20	25
		Female	21–30	40
Medial collateral ligament	Collegiate varsity	Male	11–20	25
		Female	11–20	25
	Recreational	Male	11–20	25
		Female	21–30	40
Calf	Collegiate varsity	Male	0–10	15
		Female	11–20	25
	Recreational	Male	11–20	25
		Female	11–20	25[a]
Anterior talofibular ligament	Collegiate varsity	Male	0–10	15
		Female	0–10	15
	Recreational	Male	0–10	15
		Female	0–10	15

[a] When both the mean and SD are considered, a population's skinfold thickness might extend outside the Otte et al[1] skinfold thickness group, so a longer treatment duration might be needed for a standard physiologic effect.

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