The Effects of Three Different Cold Therapy Methods After Arthroscopic Knee Surgery

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Abstract

Background: Cold therapy is commonly used after arthroscopic surgery. **Objectives:** The aim in this study was to compare the effects of cold therapy methods after arthroscopic knee surgery. **Methods:** This study was quasi-experimental study. The study sample comprised 60 patients; 20 patients each were included in three different cold therapy method groups (combined cold and compression system, ice pack, and cold pack groups). First, a standard protocol for cold application was established. Thereafter, the effects of the cold therapy methods on skin temperature, knee circumference, range of motion, and patient satisfaction were examined. Data were collected from the records of the patients' descriptive characteristics, observation and evaluation forms, and patient satisfaction questionnaires. **Results:** The ice packs were the most effective method for reducing skin temperature after 15 min. Cold packs were ineffective at lowering skin temperature after 10 min. The patients were most satisfied with the combined cold and compression therapy. However, the knee circumference and range of motion did not differ among the groups. **Conclusion:** This study indicates that ice packs are an effective method for reducing skin temperature; however, the nurses should also consider the advantages of other methods.

Anahtar Kelimeler: Arthroscopy, Cold Therapy, Skin Temperature, Patient Satisfaction.

Öz

Artroskopik Diz Ameliyatı Sonrası Kullanılan Üç Farklı Soğuk Uygulama Yönteminin Etkileri

Giriş: Soğuk uygulama artroskopik cerrahi sonrası yaygın olarak kullanılmaktadır. **Amaç:** Araştırma, artroskopik diz ameliyatından sonra kullanılan soğuk uygulama yöntemlerinin etkilerini belirlemek amacıyla yapılmıştır. **Yöntem:** Araştırma yarı deneysel olarak yapılmıştır. Araştırmanın örneklemini 60 hasta oluşturmuştur. Hastalar her grupta 20 hasta olacak şekilde üç gruba (buz paketi, soğuk paket ve kombine soğuk kompresyon yöntemi) ayrılmıştır. Araştırmada ilk olarak soğuk uygulama yöntemlerine ilişkin standart işlem basamakları geliştirilmiştir. Daha sonra soğuk uygulama yöntemlerinin deri sıcaklığı, diz çevresi, eklem hareket açıklığı ve hasta memnuniyetine etkisi değerlendirilmiştir. Veriler, hastaları tanıtıcı özelliklere ilişkin anket formu, gözlem ve değerlendirme formları ve hasta memnuniyeti anket formu ile toplanmıştır. **Bulgular:** Araştırmada buz paketinin 15. dakikadan sonra deri sıcaklığını düşürmede en etkili yöntem olduğu, soğuk paketin 10. dakikadan sonra deri sıcaklığını düşürmede etkili olmadığı, hastaların en çok kombine soğuk kompresyon sistemi uygulamasından memnun oldukları ancak diz çevresi ve eklem hareket açıklığı değerleri açısından gruplar arasında fark olmadığı belirlenmiştir. **Sonuç:** Araştırmada deri sıcaklığını azaltmada buz paketinin etkili bir yöntem olduğu ancak hemşirelerin diğer uygulama yöntemlerinin avantajlarını da göz önüne almaları önerilmektedir.

Key Words: Artroskopi, Soğuk Uygulama, Deri Sıcaklığı, Hasta Memnuniyeti.

Geliş tarihi:02.08.2016 Kabul tarihi: 05.01.2017

Cold therapy has been used to treat soft tissue injuries since ancient times (Mac Auley, 2001). Cold application decreases bleeding and edema by causing vasoconstriction, reduces muscle tone via inhibition of gamma fibers, and alleviates pain and muscle spasms by altering the conduction properties of peripheral nerves. The use of cold therapy is based on this basic physiological effects (Berman, Snyder and Frandsen, 2015; Kazan, 2011; O'Young, Young and Stiens, 2002; Oguz, Dursun and Dursun, 2004; On, 2006).

The field where in cold application is most frequently used is orthopedic surgery. Arthroscopic procedures are frequently performed for orthopedic surgical intervention. Although the complication rate of arthroscopic surgery is low, problems such as postoperative hemarthrosis, thromboembolism, and infection may occur. These postoperative complications can be prevented by immobilization and elevation of the extremity, monitoring of bleeding and circulation, and cold application. The main purpose of cold application after arthroscopy is to improve the range of motion by reducing pain, swelling, and bleeding (Erdil and Elbas, 2008; Miller, 2012; Oguz et al., 2004).

It is recommended that cold application should start immediately after surgery and it should be applied at intervals in first 72 hours (Oguz et al., 2004; Tandoğan and Alparslan, 1999). However, providing useful of cold application, it should be known that which cold application method is more effective and true. Otherwise, cold application made unconsciously does not achieve its purpose and it may bring about disappointing results (Oguz et al. 2004). For instance, cold compression in extended period of time causes deterioration of circulation and ultimately because of deficiency of oxygen and nutrient it induces tissue injury. By the reason of tissue injury, in beginning, it is observed that redness in skin, afterwards, bluish purple spotted view, apathy and pain (Berman et al., 2015; DeLaune and Ladner, 2011; Potter and Perry, 2009; Taylor, Lillis, LeMone and Lynn, 2010). For this reason, understanding physiological basis of cold application is extremely important for nurses and the duration of cold application should not be exceeded 30 minutes (min) (Berman et al., 2015).

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On the other hand, ineffective cold application causes to length of patients' recovery period and feelings of more pain and discomfort, accordingly, it can cause increase of hospital stay and health care cost. There are various methods for administering cold therapy—the most frequently used methods include cold packs, ice packs, cold compresses, ice bags, and combined cold and compression systems (such as the Cryo Cuff) (Berman et al., 2015; DeLisa, Gans and Walsh, 2005; Kazan, 2011; On, 2006). The decrease in skin temperature in response to cold therapy is a well-known major determinant of the effectiveness of cold application. Maximum venous vasoconstriction occurs when cold application reduces the skin temperature to 15°C (Berman et al., 2015; O'Young et al., 2002; Taylor et al., 2010). However, in literature, it is indicated that analgesic effect in cold compression starts when skin temperature goes down below 13.6°C, when the temperature is 12.5°C, the nerve conduction velocity decreases at the rate of 10% and when the temperature is between 10°C-11°C, metabolic enzyme activity decreases at the rate of 50% approximately (Bleakley, McDonough and MacAuley, 2004; Chesterton, Foster and Ross, 2002; Kanlayanaphotporn and Janwantanakul, 2005). Literature reviews have not identified any information regarding the optimal target skin temperature in patients who have undergone arthroscopic surgery. However, given that the analgesic effect is noted only when the skin temperature falls below 13.6°C (Bleakley et al., 2004; Chesterton et al., 2002; Kanlayanaphotporn and Janwantanakul, 2005), it seems reasonable that cold application should be used to decrease the skin temperature to 13.6°C or lower.

Applying compression to the area enhances the reduction of skin temperature by cold therapy. The benefits of simultaneous application of cold and compression have been demonstrated in some studies (Holmstrom and Harding, 2005; Janwantanakul, 2006; Kullenberg, Ylipaa, Soderlund and Resch, 2006; Levy and Marmar, 1993). Compression ensures full contact between the ice and skin and increases conduction, thus enhancing the effect of cold application on tissue temperature, reducing blood flow to the tissue, and avoiding consequent edema. Therefore some studies have been suggested that the combined application of cold and compression to reduce tissue temperature more effectively than ice application alone (Janwantanakul, 2006; Mac Auley, 2001).

In our country orthopedics clinics, after arthroscopy surgery, on the purpose of cold application, ice packs and cold packs are most frequently used. Besides, combined cold compression system which is an alternative method of technological developments presented to health care services is used rarely. Ice packs are frequently used, easy to implement and low cost tools. However, during the application of ice packs, nurses encounter some difficulties. Ice packs are rigid plastic structured and it cannot take the form of apply to area. For this reason, when ice pack is placed on knee, it can slip easily and nurses have to apply various methods to immobilize ice packs into application area (for instance, attaching ice pack to knee). Difficulties related ice packs are acceptable for cold packs partially. In both methods, difficulties during the application period can cause disruptions in the monitoring of the application period and bring additional workload to nurses. Besides, due to ice packs cool only contacting area on knee is wrapped with bandage, whether this method of cold application reach the aim or not is controversial topic.

Determination of whether cold therapy, applied over the bandage, serves the intended purpose is critical for the objectives of post-arthroscopic medical care, as the expected result of the application cannot be achieved unless the skin temperature is reduced to a therapeutic level. Hence, the present study compared the efficacies of these three cold application methods for reducing skin temperature in patients who had just undergone arthroscopic surgery.

The field of medicine is particularly open to technological advances and the technological products developed are rapidly transitioned into application. However, the satisfactions of the patients with these products are usually not considered. In fact, the consideration of the satisfaction of the patient with the use of the equipment will help improving the quality of patient care.

Aim

This study was carried out to compare the effects of three modalities used for cold therapy after arthroscopic knee surgery—a combined cold and compression system, ice packs, and cold packs—on skin temperature, range of motion, knee circumference and patient satisfaction.

Hypotheses

$H_{0:}$

1. The methods used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—do not differ in their effects on skin temperature.
2. The methods used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—do not differ in their effects on the range of motion.
3. The methods used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—do not differ in their effects on knee circumference.
4. The methods used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—do not differ in their effects on patient satisfaction.

H_1:
1. The agents used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—differ in their effects on skin temperature.
2. The agents used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—differ in their effects on the range of motion.
3. The agents used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—differ in their effects on knee circumference.
4. The methods used for cold application after arthroscopic knee surgery—namely, combined cold and compression systems, ice packs, and cold packs—differ in their effects on patient satisfaction.

Methods

Study Design

This quasi-experimental study was performed to compare the effects of three different cold application methods on the skin temperature of the knee area, range of motion, knee circumference, and patient satisfaction.

Sample

The research was conducted from November 2008, to August 2009. The study population comprised patients who underwent knee surgery for anterior cruciate ligament reconstruction and meniscus repair in the orthopedic clinic of a university hospital in Ankara/Turkey. In total, 107 patients underwent arthroscopic knee surgery during that period. In this clinic, ice packs are the most frequently used post-operative knee surgery.

The necessary size of the study sample was determined using the Number Cruncher Statistical System (NCSS) – Statistical and Power Analysis Software – Power Analysis and Sample Size (PASS) program. However, it is necessary to identify the incidence rate in order to use the program (Ozdamar, 2013). Because the study results related to the skin temperature change caused by each cold application method were controversial, these results could not be used. Therefore, to determine the sample size, the skin temperature data obtained during the preliminary stage of the study were used. In the preliminary application, the mean values of the skin temperatures at the beginning and after 20 min of cold application were 3.03 in the ice pack group, 2.18 in the cold pack group, and 3.13 in the combined cold and compression group. The calculation based on these values and other parameters (Alpha = .05, standard deviation = 1.0, and power = .80) yielded a necessary sample size of 60 patients, and 20 patients in each cold application group, namely, the ice pack group/Group 1, cold pack group/Group 2, and combined cold and compression system (Cryo Cuff) group/Group 3.

Patients aged ≥ 18 years who did not have diabetes mellitus or peripheral vascular disease; who could communicate; and who had undergone arthroscopic surgery for meniscectomy, meniscus repair, and anterior cruciate ligament (ACL) reconstruction were included in the sample.

Data collection instruments

The skin temperature was measured using a graphing data logger (Xplorer GLX). The data logger calibration was made by the company official. The measurement was obtained by connecting the temperature probe to the port, and the stored data were transferred to the computer via a USB flash card.

The range of knee motion was measured using a goniometer and the knee circumference was measured using a non-flexible tape measure that was 1.5 cm in width, 1 m in length, and marked in 1-mm increments.

The data obtained in the study were recorded in the following documents that were previously developed by the researcher: Patients' Characteristics Form, Patient Progress Report (the knee skin temperature, circumference, and range of motion values were recorded), Patient Satisfaction Questionnaire (this form consists of 5 questions, which includes satisfaction of the patients in cold application methods and their experienced difficulties in addition to the positive effects of the application).

Intervention

In the research, firstly, the standard application guideline related three different cold therapy methods were developed for enabling nurses realize three cold application methods in compliance with process steps located in standard application guide and training sessions concerning this topic was made and each nurse was observed in three times for every cold application method.

The physicians at the clinic where the research was performed generally recommend cold application after arthroscopic surgery for 12 × 20 min, such that the cold therapy is administered at 2-hour intervals over a 24-hour period. The cold applications included in the study were administered every 2 hours according to the standard protocol by the researchers and the clinic nurses. The cryotherapy was continued until the patient was discharged (a maximum of 3 days).

The patients who were eligible for inclusion according to the sampling criteria were identified preoperatively and informed about the aim and method of the research at that time. Written documentation of consent was obtained from all patients who agreed to participate in the research, and their personal information was recorded in the "Patient's Characteristics Form." Assignment of the patient to a specific group (Group 1, Group 2 and Group 3) was by the researcher to be homogeneous according to gender, age, and surgery type and the nurses were informed about the group assignment.

Measurement of skin temperature

For all groups, the researcher started administering cold application 4 hours after each patient returned from surgery, because it takes 4 hours after surgery for cardiovascular function to return to normal (Berman et al., 2015). In the fourth postoperative hour, the patient's vital signs and blood circulation in the lower extremities were assessed. When this examination determined that the patient's vital signs had returned to normal, the first cold application was started and the knee skin temperature was measured. Furthermore, the knee skin temperature was measured during the first cold application after wound dressing every morning until the patient was discharged. The measured time was totally 40 min, including 20 min during application and also immediately 20 min post treatment. Post treatment duration was the same with cold application duration.

Before the start of the cold application, the bandage over the knee was partially removed and the skin temperature probe was placed on the skin over the lateral epicondyle of the femur; thereafter, the device was connected to the computer.

Cold therapy was conducted according to the protocol in each research group as per the type of treatment assigned. Skin temperature was measured at the beginning of the cold application and again after 5, 10, 15, and 20 min of treatment. The cold therapy ended after 20 min in order to determine how soon the skin temperature returned to the baseline value after the cold source was removed, the skin temperature was measured again immediately (1 min) and 5, 10, 15, and 20 min after the treatment. After the skin temperature measurements were completed, the patient's vital signs were assessed again and all of the data were recorded.

Measurement of the circumference of the knee

First, on the morning of the surgery, the researcher used a tape measure to measure the circumference of the knee at the mid-patella level with the knee in maximum extension. Thereafter, the circumference of the knee was measured every morning after wound dressing until the patient was discharged. The measurement was repeated at the postoperative follow-up examination and the results were recorded.

Measurement of the range of motion

Range of motion was measured by assessing the full active and passive ranges of knee flexion and extension with the patient in the prone and supine positions, with his or her legs hanging over the edge of the bed. Thereafter, the difference between the two measures was estimated and the normal range of motion was calculated (Otman, Demirel and Sade, 2003). The measurement was repeated on the day of the follow-up examination.

Patient satisfaction related to the cold application method

Each patient was administered a questionnaire on the day of discharge to ascertain his or her satisfaction with the cold application method with which he or she was treated.

Data analysis

The data coding and evaluation were performed by the researcher using a computer. Statistical analyses were performed using IBM SPSS Statistics 15.0 (Chicago, ILL, USA) software. A p value less than .05 was considered as statistically significant. The temperature values measured at the beginning and after 5, 10, 15, and 20 min of during the cold application, as well as those measured immediately (1 min) and 5, 10, 15, and 20 min of post treatment, were considered point values, and the means of these values were assessed. Repeated-measures analysis of variance was used to assess the differences in the knee circumference, range of motion, and skin temperature. When this test indicated a difference among the groups, the Bonferroni test was used to determine which group caused the difference (Alpar, 2011; Sumbuloglu and Sumbuloglu, 2014).

Ethical Approval

The researchers obtained written permission to conduct the study from the ethics committee of the Hacettepe University Medical, Surgical and Pharmaceutical Research Ethics Board, Ankara/Turkey. The nurses and patients involved in the research were informed about the study and provided written consent to participate in the study.

Limitations

The major limitation of this study is that the skin temperature of the knee was measured only at the location at which the temperature probe was placed and could not be measured at other areas of the knee.

Results

The descriptive data are shown in Table 1. The patients who participated in the study comprised 21 women and 39 men, 38% (23 patients) were aged 30–51 years, and the mean age was 38.2 years (standard deviation [SD] = 13.98 years). Among them, 35 had lateral /medial meniscus tear recovery and 25 had anterior cruciate ligament

(ACL) reconstruction. According to the statistically test, the groups data were homogeneous in the study (Table 1).

Table 1. Description Data of All Patients According to the Cold Application Method (N = 60)

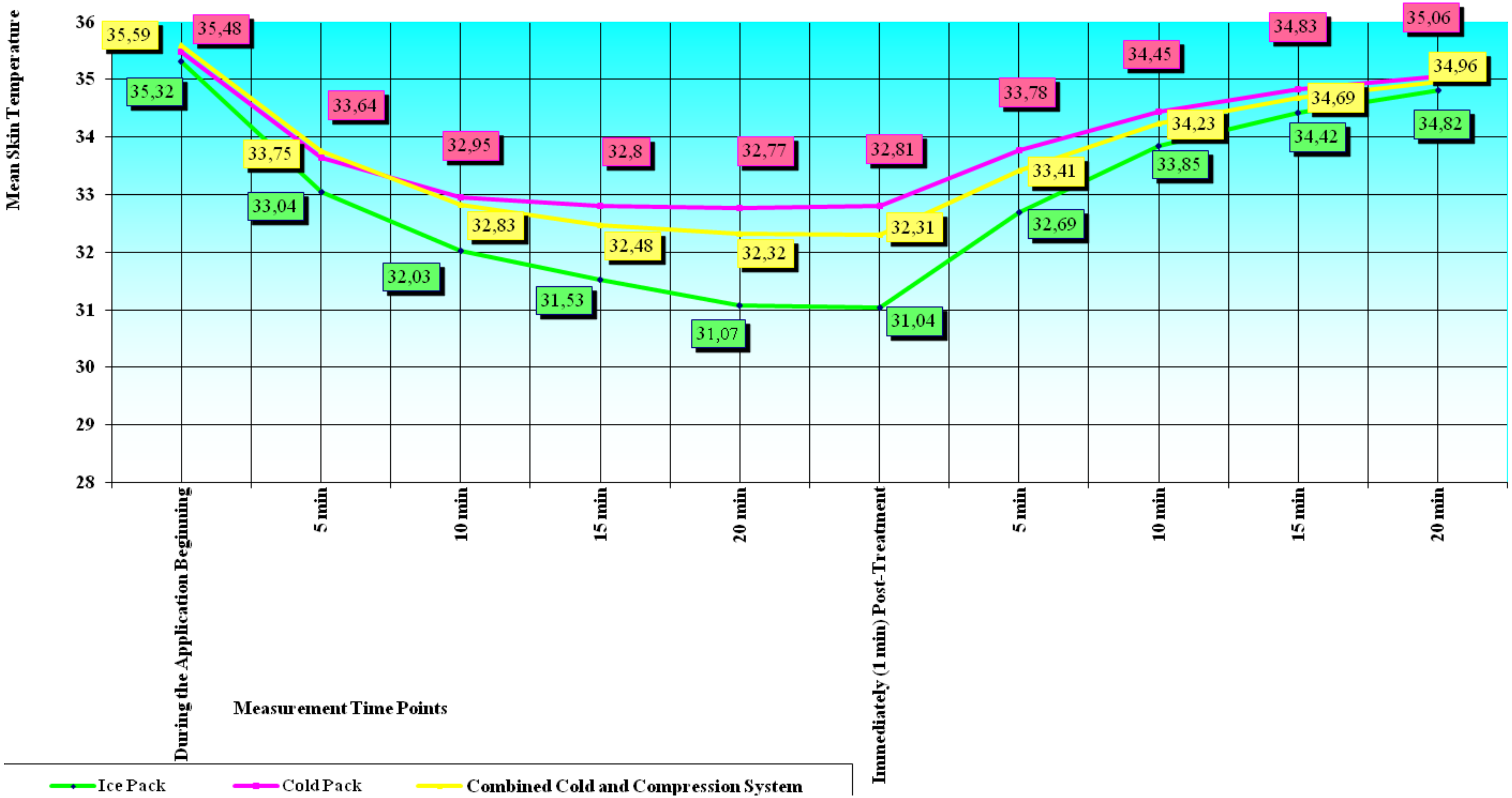
	Cold Application Method			**Total**
	Ice pack (n = 20)	**Cold pack (n = 20)**	**Combined Cold and Compression System (n = 20)**	
Gender				
Female	7	8	6	21
Male	13	12	14	39
Age				
19-29	6	8	7	21
30-40	6	3	5	14
41-51	4	2	3	9
52-62	4	7	5	16
Surgery Type				
Lateral /Medial Meniscus Tear Recovery	10	12	13	35
Anterior Cruciate Ligament (ACL) Reconstruction	10	8	7	25

The mean values of the patients' vital signs, which were assessed before and after the cold therapy, were estimated for each cold application method group, and no statistically significant difference within or across the groups was detected (all p > .05).

The mean beginning skin temperatures during the application were very similar among the three groups (ice pack = 35.32°C; cold pack = 35.48°C; combined cold and compression system = 35.59°C). The mean decreases in skin temperature after 5, 10, 15, and 20 min of during cold application were highest in the ice pack group (5 min = 33.04°C; 10 min = 32.03°C; 15 min = 31.53°C; 20 min = 31.07°C) (Graphic 1).

The mean skin temperature 1 min post treatment was lowest (31.04°C) in the ice pack group and highest (32.81°C) in the cold pack group. In contrast, the skin temperature 5, 10, 15, and 20 min post treatment was lowest in the cold pack group at all time points (5 min = 33.78°C; 10 min = 34.45°C; 15 min = 34.83°C; 20 min = 35.06°C) (Graphic 1).

In the study, 20 min post treatment temperature value was closest to the beginning temperature in the cold pack group (beginning value = 35.48°C; 20 min post treatment = 35.06°C) (Graphic 1).



Graphic 1. Mean Skin Temperature Values During and After Cold Therapy According to the Application Method

The difference between the mean temperatures measured at the beginning (0 min) and after 5, 10, 15, and 20 min of during treatment was highest in the ice pack group for all time points. In this group, the difference between the beginning value and the temperature after 5 min was 2.28°C (SD = 0.73°C) and the difference between the beginning value and the temperature after 20 min was 4.24°C (SD = 1.10°C) ($p < .001$ for all measurement time points during the application). The combined cold and compression group exhibited the second-highest differences between the beginning value and those obtained from the subsequent measurements (Table 2).

In the cold pack group, the difference between the temperatures at the beginning and after 20-min time points was only 2.71°C (SD = 0.97°C) ($p < .01$ for all measurement time points during the application relative to the beginning value). Furthermore, in the cold pack group, there was no significant difference between the measurements made after 10 and 20 min ($p = .512$) or those made after 15 and 20 min ($p = 1.000$) of cold application (Table 2).

Comparison of the skin temperatures at the beginning and after 5, 10, 15, and 20 min of cold application among the groups revealed a statistically meaningful difference among the means. Advanced statistical analyses showed that the differences between the ice pack and cold pack groups after 15 min ($p = .013$) and 20 min ($p = .001$) and between the ice pack and combined cold and compression groups after 20 min ($p = .022$) of cold application were significant. It is determined that the major contributor to this difference was the value of the ice pack group (Table 2).

Table 2. Differences in the Mean Temperature of Measurement Time Points During the Application According to the Cold Application Method

Measurement Time Points During the Application	**Differences in the Mean Skin Temperature During the Application**										
	Ice Pack $\bar{X} \pm S$	**p value**	**Cold Pack** $\bar{X} \pm S$	**p value**	**Combined Cold and Compression System** $\bar{X} \pm S$	**p value**	**p value: Ice pack vs. Cold Pack**	**p value: Ice pack vs. Combined Cold and Compression System**	**p value: Cold Pack vs. Combined Cold and Compression System**	**Statistical Evaluation: Within group**	**Statistical Evaluation: Between groups**
0 min - 5 min	2.28 ± 0.73	**p < .001**	1.83 ± 0.70	**p < .001**	1.83 ± 0.89	**p < .001**	p = 1.000	p = .482	p = 1.000	**p < .001** **F = 456.039**	**p = .018** **F = 4.301**
0 min - 10 min	3.28 ± 0.86	**p < .001**	2.53 ± 0.85	**p < .001**	2.76 ± 1.16	**p < .001**					
0 min - 15 min	3.78 ± 0.96	**p < .001**	2.68 ± 0.90	**p < .001**	3.10 ± 1.30	**p < .001**					
0 min - 20 min	4.24 ± 1.10	**p < .001**	2.71 ± 0.97	**p < .001**	3.26 ± 1.35	**p < .001**					
5 min - 10 min	1.00 ± 0.29	**p < .001**	0.69 ± 0.30	**p < .001**	0.92 ± 0.33	**p < .001**	p = .235	p = .118	p = 1.000		
5 min - 15 min	1.50 ± 0.52	**p < .001**	0.84 ± 0.46	**p < .001**	1.26 ± 0.52	**p < .001**					
5 min - 20 min	1.96 ± 0.70	**p < .001**	0.87 ± 0.61	**p < .001**	1.42 ± 0.62	**p < .001**					
10 min - 15 min	0.50 ± 0.25	**p < .001**	0.15 ± 0.19	**p = .045**	0.34 ± 0.22	**p < .001**	p = .072	p = .148	p = 1.000		
10 min - 20 min	0.96 ± 0.48	**p < .001**	0.18 ± 0.37	p = .512	0.50 ± 0.34	**p < .001**					
15 min - 20 min	0.45 ± 0.27	**p < .001**	0.03 ± 0.22	p =1.000	0.16 ± 1.14	**p = .015**	**p = .013**	p = .086	p = 1.000		
20 min							**p = .001**	**p = .022**	p = .969		

The differences in the mean skin temperatures between the immediately (1 min) and the 5, 10, 15, and 20 min post-treatment measurements were smallest in the cold pack group; this difference was 0.97°C (SD = 0.47°C) between the 1 min and 5 min measurements and 2.24°C (SD = 0.62°C) between the 1 min and 20 min measurements ($p < .001$ for all post-treatment measurement time points) (Table 3).

In the ice pack group, a large difference was noted between the measurements immediately (1 min) and 5 min post-treatment (1.64°C; SD = 0.68) and the greatest difference was noted between the 1 min and 20 min measurements (3.77°C; SD = 1.07°C) ($p < .001$ for all post- treatment measurement time points) (Table 3).

Comparison among all the cold therapy groups revealed a statistically significant difference ($p < .05$) among the mean values immediately (1 min) and 5, 10, 15, and 20 min post-treatment. Advanced statistical evaluation showed that the differences between the ice pack and cold pack groups immediately (1 min) and 5 min ($p = .016$) post-treatment and between the ice pack and combined cold and compression groups immediately (1 min) post-treatment ($p = .021$) were significant. It is determined that the major contributor to this difference was the value of the ice pack group (Table 3).

Table 3. Differences in the Mean Temperature of Measurement Time Points Immediately Post-Treatment According to the Cold Application Method

Post-Treatment Measurement Time Points	**Post-Treatment Differences in the Mean Skin Temperature**										
							p value			**Statistical Evaluation**	
	Ice pack $\bar{X}$ ± S	**p value**	**Cold Pack $\bar{X}$ ± S**	**p value**	**Combined Cold and Compression System $\bar{X}$ ± S**	**p value**	**Ice pack vs. Cold Pack**	**Ice pack vs. Combined Cold and Compression System**	**Cold Pack vs. Combined Cold and Compression System**	**Within group**	**Between groups**
1 min - 5 min	1.64 ± 0.68	**p < .001**	0.97 ± 0.47	**p < .001**	1.10 ± 0.75	**p < .001**				**p < .001**	**p = .051**
1 min - 10 min	2.80 ± 0.92	**p < .001**	1.64 ± 0.52	**p < .001**	1.92 ± 1.00	**p < .001**	**p = .001**	**p = .021**	p = .807		
1 min - 15 min	3.38 ± 1.02	**p < .001**	2.02 ± 0.59	**p < .001**	2.38 ± 1.13	**p < .001**					
1 min - 20 min	3.77 ± 1.07	**p < .001**	2.24 ± 0.62	**p < .001**	2.65 ± 1.20	**p < .001**					
5 min - 10 min	1.15 ± 0.32	**p < .001**	0.66 ± 0.18	**p < .001**	0.81 ± 0.31	**p < .001**					
5 min - 15 min	1.73 ± 0.48	**p < .001**	1.05 ± 0.32	**p < .001**	1.28 ± 0.49	**p < .001**	**p = .016**	p = .179	p = .987		
5 min - 20 min	2.12 ± 0.57	**p < .001**	1.27 ± 0.41	**p < .001**	1.54 ± 0.60	**p < .001**					
10 min - 15 min	0.57 ± 0.19	**p < .001**	0.38 ± 0.16	**p < .001**	0.46 ± 0.19	**p < .001**	p = .240	p = .794	p = 1.000	**F = 439.686**	**F = 3.145**
10 min - 20 min	0.96 ± 0.31	**p < .001**	0.60 ± 0.26	**p < .001**	0.73 ± 0.31	**p < .001**					
15 min - 20 min	0.39 ± 0.13	**p < .001**	0.22 ± 0.12	**p < .001**	0.26 ± 0.13	**p < .001**	p = .564	p = 1.000	p = 1.000		
20 min							p = 1.000	p = 1.000	p =1.000		

The preoperatively measured knee circumference values were similar among the groups (ice pack = 39.77 ± 4.06 cm; cold pack = 39.64 ± 2.68 cm; combined cold and compression system = 39.73 ± 3.38 cm). The measurements performed in the postoperative period showed increases in all groups (ice pack = 41.63 ± 3.34 cm; cold pack = 41.15 ± 2.34 cm; combined cold and compression system = 40.79 ± 2.92 cm). Slight but measureable decreases were observed at the follow-up examination (ice pack = 41.10 ± 4.09 cm; cold pack = 41.02 ± 3.03 cm; combined cold and compression system = 40.38 ± 2.79 cm) (Table 4).

Advanced statistical analysis of the knee circumference values obtained during the preoperative, postoperative, and follow-up examinations showed significant ($p < .001$) within group differences but no significant between group difference ($p = .886$). Moreover, advanced statistical evaluation showed that the difference between the preoperative and postoperative values was significant ($p < .05$) for all groups. Significant differences were also detected between the values measured during the preoperative and follow-up examinations in the ice pack and cold pack groups ($p < .05$), although the difference between these values was not significant ($p > .05$) in the combined cold and compression group. No significant difference ($p > .05$) was detected between the values measured during the postoperative and follow-up examinations in any of the therapy groups ($p > .05$) (Table 4).

The values of the knee range of motion in the prone position for each of the three cold application groups are shown in Table 5. In all groups, the mean postoperative normal range of motion in the prone position was quite low relative to the preoperative value. Advanced statistical analysis of the range of motion values indicated a significant ($p < .001$) within group difference, but no significant ($p = .442$) between group difference (Table 5).

In the study, only 2 patients in the ice pack group, compared to 5 in the cold pack group and 12 in the combined cold and compression group, said that they were "very satisfied" for the application. While the number of "satisfied" patients was equal (n = 14) between the ice pack and cold pack groups, there were no "dissatisfied" patients in the combined cold and compression group.

Table 4. Knee Circumference Values According to the Cold Application Method

Cold Application Method (n = 49*)		**Circumference of the Knee (cm)**	**p value**			**Statistical Evaluation**	
		$\bar{X}$ ± S	**Preop. vs. Postop.**	**Preop. vs. Follow-up**	**Postop. vs. Follow-up**	**Within group**	**Between groups**
Ice Pack (n = 14)	**Preop.**	39.77 ± 4.06	**p < .001**	**p = .002**	p = .573	**F = 28.146 p < .001**	F = .121 p = .886
	Postop.	41.63 ± 3.34					
	Follow-up	41.10 ± 4.09					
Cold Pack (n = 17)	**Preop.**	39.64 ± 2.68	**p < .001**	**p < .001**	p = 1.000		
	Postop.	41.15 ± 2.34					
	Follow-up	41.02 ± 3.03					
Combined Cold and Compression System (n = 18)	**Preop.**	39.73 ± 3.38	**p = .011**	p = .141	p = .731		
	Postop.	40.79 ± 2.92					
	Follow-up	40.38 ± 2.79					

* 11 patients did not return for a follow-up examination after discharge.

Table 5. Knee Range of Motion in the Prone Position According to the Cold Application Method

Cold Application Method (n = 49*)		Mean Knee Range of Motion in the Prone Position: Flexion (°) $\bar{X} \pm S$	p value	Extension (°) $\bar{X} \pm S$	p value	Normal Range of Motion (°) $\bar{X} \pm S$	p value	Statistical Evaluation: Within group	Statistical Evaluation: Between groups
Ice Pack (n = 14)	Preop.	104.43 ± 15.05	**p < .001**	14.00 ± 4.83	p = .535	90.43 ± 15.29	**p < .001**	**F = 65.142 p < .001**	F = .832 p = .442
	Follow-up	73.57 ± 19.91		15.00 ± 3.48		58.27 ± 20.93			
Cold Pack (n = 17)	Preop.	111.65 ± 13.00	**p < .001**	15.65 ± 3.75	p = .202	96.24 ± 12.34	**p < .001**		
	Follow-up	78.24 ± 18.45		17.53 ± 5.12		60.71 ± 21.55			
Combined Cold and Compression System (n = 18)	Preop.	102.33 ± 23.60	**p = .004**	15.44 ± 6.09	p = .105	86.89 ± 24.20	**p = .002**		
	Follow-up	85.56 ± 14.96		17.78 ± 6.17		67.89 ± 17.50			

* 11 patients did not return for a follow-up examination after discharge.

Discussion

This study demonstrated that the mean temperature during cold application was initially similar among the three tested methods; however, the decreases in temperature after 5, 10, 15, and 20 min of treatment were largest in the ice pack group and smallest in the cold pack group. Calculation of the mean increases in temperature 5, 10, 15, and 20 min after the treatment showed the smallest increase in the cold pack group and the largest in the ice pack group (Graphic 1, Table 2, and Table 3). These findings indicate that ice packs markedly reduce skin temperature, although their post-treatment effect is shorter and the skin temperature returns to baseline more quickly, than after treatment with cold packs or the combined cold and compression system. A study supporting our findings was conducted by McMeeken et al. (McMeeken, Lewis and Cocks, 1984). The researchers observed the effects of cold application for 20 min using 3 different methods (ice cubes wrapped in a dry towel, a cold pack wrapped in a dry towel and a cold pack in a wet towel) on skin temperature and nerve conduction velocity. The results demonstrated that the application of ice was more effective at reducing skin temperature and conduction velocity compared to cold pack application; however, after the removal of the ice, the skin temperature increased more rapidly, and returned to normal within 15 min.

Comparison of the mean skin temperature at various time points among the three methods of cold therapy showed a significant difference ($p < .05$). Advanced statistical analysis confirmed that the difference originated from the ice pack method, which reduced the skin temperature more dramatically after 15 min of application (Table 2). These findings suggest that ice packs are more effective than the other cold application methods at reducing skin temperature. Kanlayanaphotporn and Janwantanakul (2005) compared the effects of cold application for 20 min using 4 different application methods—ice packs, gel packs, frozen peas, and an ethanol-water mixture—on skin temperature, and found that the ice pack and ethanol-water mixture were more effective at lowering skin temperature. These results are consistent with the findings of our study.

In the present study, comparison of the changes in the mean skin temperature between various time points during cold application using each method showed that the differences between 10 and 20 min and between 15 and 20 min of cold application were not statistically significant only in the cold pack group ($p > .05$) (Table 2). This finding indicates that the cold pack does not further decrease the skin temperature after 10 min, suggesting that cold packs are more susceptible to the ambient temperature and their cooling power diminishes accordingly, relative to the other methods.

The effects of cold therapy using frozen peas and gel packs on skin temperature were compared by Chesterton, Foster and Ross (2002), who reported that frozen peas reduced the skin temperature after 10 and 20 min of treatment, whereas a cold gel pack reduced the skin temperature by only 0.1°C after application for 10 min. The influence of the degree of compression on the effectiveness of a combined cold and compression system in decreasing skin surface temperature was examined by Janwantanakul (2006), who bandaged the cuff of a sphygmomanometer over the cold pack and thus administered 5 different degrees of compression. The initial skin temperature was similar among all levels of compression, and cold application without compression actually achieved the lowest skin temperature, which stabilized after 9 min. The results of these two studies support the findings of our present study.

The mean skin temperature after the end of cold application differed significantly among the three methods at only 1 min and 5 min after treatment ($p < .05$), and these differences were primarily due to the values of ice pack group. The differences among the mean skin temperatures 10, 15, and 20 min after treatment, on the other hand, were not significant ($p > .05$) (Table 3). These results demonstrate that the skin temperature increases more rapidly after ice pack removal than after the removal of the other cold sources, but only within the first 5 min. Thereafter, there is no difference among the groups in terms of the return of skin temperature to baseline.

Comparison of the mean preoperative and postoperative knee circumference values showed no significant difference ($p > .05$) among the treatment groups. Advanced statistical analysis showed that, only in the patients who received combined cold and compression therapy, the circumference of the knee measured at the follow-up visit was similar to the preoperative value, with no statistically significant difference between the measurements ($p > .05$) (Table 4). This finding of our study indicates that although cold and compression therapy is less effective than ice pack application at lowering the skin temperature, it is the most effective of the three methods at reducing the late postoperative circumference of the knee.

The range of motion of the knee with the patient in a prone position was measured before and after surgery. Statistical analysis demonstrated no effect of the cold application method on the knee range of motion in the prone position ($p > .05$) (Table 5). Studies concerning this issue have obtained various results. The postoperative therapeutic effect of cold application in patients with total knee arthroplasty was evaluated by Levy and Marmar (1993), who applied cold compression to 40 knees and standard compression bandages alone to another 40 knees. In that study, cold compression reduced blood loss, swelling, and pain, and enabled more rapid return of range of motion. However, another study of the application of cold compression on healing after total knee arthroplasty, by Healy, Seidman, Pfeifer and Brown (1994), compared the effects of cold compression and ice pack application on the bandage in terms of range of motion, narcotic drug consumption, swelling, and wound drainage. None of these parameters differed significantly between the groups, and cold compression was concluded to provide no objective benefit. The meta-analysis of the effects of cold application on healing after orthopedic surgery by Adie, Naylor and Harris (2010) and Block (2010) were found cold application to be slightly effective at increasing the range of motion in the early postoperative period.

Conclusions

This study was conducted to compare the effects of the use of three different cold application methods after arthroscopic knee surgery on skin temperature and patient satisfaction and found that among the three methods, ice packs not only lowered the skin temperature to the greatest extent but also allowed the fastest return of the skin temperature to its baseline level after removal, the effect of cold packs was no longer present 10 min after the beginning of the cold application. In accordance with these findings, H_{1-1} has been accepted.

The combined cold and compression system reduced the circumference of the knee at the follow-up examination, but the knee circumference and range of motion did not differ significantly among the methods. In accordance with these findings, H_{0-2} and H_{0-3} have been accepted. Furthermore, patients were most satisfied with the combined cold and compression system due to some of its advantages. In accordance with these findings, H_{1-4} has been accepted.

The temperature measurements in this study were made at a single location at which the temperature probe was placed, and the skin temperature of other areas of the knee could not be assessed. Consequently, the development of an instrument that can measure the skin temperature over the entire surface of the knee, and thus more comprehensively investigate the effects of various cold application methods on the reduction of skin temperature, would be beneficial for future research.

In this study, it is observed that number of nurses who took in service training related cold application methods is low. For this reason, in orthopedics clinics, it is recommended that in service training programs related cold application methods are organized and performed regularly for nurses.

Realizing applications in proper manner to standards decreases mistakes and increases the quality of nursing care. Therefore, in orthopedics clinics, standard application guidelines related cold application should be formed and cold application should be performed to patients in the direction of these guidelines.

Relevance to Clinical Practice

In orthopedics clinics of our country, it is observed that cold compression is used by nurses regardless of its effect of decrease in skin temperature and knee circumference and increase in joint range of motion and satisfaction of patient. In this study, these findings indicate that ice packs are an effective method for patients who have undergone arthroscopic surgery; however, the choice of the cold application method to be used should also account for the advantages and disadvantages of each method as well as the potential for patient satisfaction in order to deliver quality nursing care.

Acknowledgements

The writers would like to thank Research Assistant Dr. Sevilay Karahan from the Hacettepe University Faculty of Medicine, Department of Biostatistics, for her contribution to the statistical analyses in the study; the nurses of the orthopedic clinic, Professor Ahmet Ozgur Atay and Professor Mahmut Nedim Doral, members of the faculty of the Department of Orthopedics and Traumatology, for their support in carrying out the study; and Edutek Company officials and Ms. Dilek Onal for providing the data logger that was used during the research.

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