Research Article

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The Effects of Cold and Hot Applications on Knee Joint Laxity and Post-Jump Landing Biomechanics in Healthy Individuals

Sağlıklı Bireylerde Diz Eklemi Üzerine Soğuk ve Sıcak Uygulamanın Diz Laksitesine ve Sıçramadan Sonra Yere İniş Biyomekaniğine Etkisi

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ABSTRACT

This study aims to determine the effects of thermal agents applied to the knee region on the Landing Error Scoring System (LESS) score and knee laxity. Participants were included in the study using a crossover randomization method and participated over three days with a two-day interval between cold, hot, and control applications. After the application sequence group for the participant was determined, descriptive data were recorded by the researcher. The range of motion (ROM) values of the participant's lower extremity joints and knee Q angle were measured using a goniometer, and Beighton criteria scores were assessed by the researcher. Following the day's application, measurements of LESS and knee laxity using a rolimeter were performed. During the cold, hot, and control applications, the ambient temperature during the application, the temperature of the applied cold/hot material, and the joint temperature before and after the application were measured using a thermal camera to ensure optimal application of the thermal agent. A total of 41 participants, 28 women (68.3%) and 13 men (31.7%), were included in the study. A statistically significant difference was observed in knee temperatures before and after the applications and in joint temperatures after hot/cold applications ($p<0.001$). However, no statistically significant difference was observed in the LESS scores and dominant/non-dominant extremity laxity values measured during the control period and after the applications ($p>0.05$). The study concluded that thermal agents applied to the knee region did not result in a significant difference in LESS scores and knee laxity.

Keywords: *Thermal agents, Joint laxity, LESS, Knee joint*

ÖZ

Çalışmamızın amacı, diz bölgesine uygulanan termal ajanların Sıçramadan Sonra Yere İniş Hata Puanlama Sistemi (İng. Landing Error Scoring System, LESS) puanı ve diz laksitesi üzerine etkilerini saptamaktır. Çalışmaya dahil edilen katılımcılar, çapraz randomizasyon yöntemi kullanılarak soğuk, sıcak ve kontrol uygulama olmak üzere ikişer gün arayla toplam üç gün çalışmaya katılmıştır. Katılımcının alt ekstremite eklem hareket açıklığı değerleri ve diz Q açısı değeri gonyometre ile ölçülmüş, daha sonrasında da Beighton kriterleri puanlaması araştırmacı tarafından değerlendirilmiştir. Katılımcıya o günkü uygulaması uygulandıktan sonra LESS ve rolimetre ile diz laksitesi ölçümleri gerçekleştirilmiştir. Soğuk, sıcak ve kontrol uygulama sırasında tüm katılımcılara optimal şekilde termal ajanın verildiğinin tespiti için termal kamera ile uygulama sırasındaki ortam sıcaklığı, uygulanan soğuk/sıcak materyalin sıcaklığı ve uygulama öncesi/sonrası eklem sıcaklığı ölçülmüştür. Çalışmaya 28 kadın (%68,3), 13 erkek (%31,7) toplam 41 katılımcı dahil edilmiştir. Katılımcıların uygulamalar öncesi ve sonrası diz sıcaklıklarında, sıcak/soğuk uygulamalar sonrası diz eklem sıcaklıklarında istatistiksel olarak anlamlı fark gözlemlenmiştir ($p<0,001$). Ancak, kontrol sırasında ve uygulamalar sonrasında ölçülen Sıçramadan Sonra Hata Puanlama Sistemi Puanı ve dominant/nondominant ekstremite laksitesi değerleri arasında istatistiksel olarak anlamlı fark gözlenmemiştir ($p>0,05$). Araştırmanın sonucunda diz bölgesine uygulanan termal ajanların LESS puanı ve diz laksitesi üzerinde anlamlı fark oluşturmadığı saptanmıştır.

Anahtar Kelimeler: *Termal ajanlar, Eklem laksitesi, LESS, Diz eklemi*

INTRODUCTION

The use of cold and hot thermal agents is quite common in physical therapy applications. Hot applications are particularly used before treatment to increase muscle elasticity (Atalay et al., 2018). This aims to soften the muscles before exercise, making it easier and less painful to perform. Cold thermal agents, on the other hand, are frequently used for quick recovery purposes after acute musculoskeletal injuries and post-exercise (Atalay et al., 2018). The use of cold and hot thermal agents among athletes for various reasons is also increasing day by day. Therefore, the effects of thermal agents on different parameters have become a common research interest among researchers working in the field of sports rehabilitation. Existing research indicates that hot applications acutely increase joint range of motion, while the effects of cold applications on various parameters are conflicting (Bleakley and Costello, 2013).

Preventing sports injuries is another important issue that researchers focus on. Preventing sports injuries before they occur offers many financial and moral benefits for athletes (Lu et al., 2021). Preventing sports injuries is far more advantageous than dealing with the psychological and financial strain of medical care and being away from sports (Finch et al., 2015). As is known, sports injuries are most frequently seen in the lower extremities, with knee injuries being the most common among them (Van Gent et al., 2007). Among knee injuries, anterior cruciate ligament (ACL) injuries are a significant concern both in terms of frequency and severity and have always been a subject of research among sports professionals (Brinlee et al., 2022).

The Landing Error Scoring System (LESS), developed by Padua et al. (2009) and validated in Turkish by Ercan et al. (2021), is a movement analysis system. This system was developed to identify movement patterns that could pose a risk for ACL injuries in advance and to take preventive measures. Studies have been conducted and are still being conducted on the effects of different parameters on the LESS score (Hanzlíková et all., 2021). To the best of our knowledge, apart from our current study, no study has been observed on the effects of thermal agents on the LESS score.

Knee laxity is also a parameter used in predicting knee injuries (Colosio et all., 2023). Joint laxity affects jump performance by influencing power transfer, as well as negatively impacting balance and proprioception, which increases the risk of injury (Myer et all., 2008). The measurement of joint laxity is also important in predicting sports injuries. Lachmeter is a digital rolimeter with a sensitivity of 89% and a specificity of 95% when compared to the gold standard (Ganko et al., 2000). Thermal agents, commonly applied in physical therapy, can have varying effects on knee laxity and associated symptoms (Bjordal et all., 2007). As with LESS, no other study has been observed in the literature on the effects of thermal agents on anterior knee laxity measured with Lachmeter, apart from our current study.

Our study aimed to determine the effects of thermal agents applied to the knee region on the LESS score and knee laxity. In this way, it is aimed to reveal whether the use of thermal agents causes or prevents sports injuries concerning these two parameters.

METHOD

Research Design: This study utilizes an experimental design to investigate the effects of cold and hot applications on knee joint laxity and post-jump landing biomechanics in healthy individuals. The research follows a pre-test/post-test structure, wherein participants undergo both interventions sequentially, allowing for a comprehensive assessment of each application's impact. The study was approved by the Clinical Research Ethics Committee of the Faculty of Medicine at Süleyman Demirel University with the decision number 11, dated 12/01/2023.

Participants: Healthy individuals aged 18-25 who did not meet the exclusion criteria were included in the study, in accordance with the purpose and rationale of the research. Informed consent forms were obtained from the participants in line with the Helsinki Declaration.

A post hoc power analysis (G*Power v.3.1), conducted using the data obtained from the study, concluded that the sample size of 41 participants was sufficient. When the dominant joint temperature data were used, the effect size was calculated to be 1.16, with a type I error value of 0.05 and a power value of 0.99. The 41 participants included in the study participated over three days with two-day intervals between cold, hot, and control applications. These three application sequences were randomly assigned to different groups by the researcher using various combinations (Table 1). This randomization prevented the risk of bias in measurements between applications by ensuring that participants did not learn and adapt to the Landing Error Scoring System Test.

Table 1
Randomization of Groups

Group	Application Sequence
Group 1 (7 persons)	Cold, Hot, Control
Group 2 (7 persons)	Cold, Control, Hot
Group 3 (7 persons)	Hot, Cold, Control
Group 4 (7 persons)	Hot, Control, Cold
Group 5 (7 persons)	Control, Cold, Hot
Group 6 (6 persons)	Control, Hot, Cold

After determining the application sequence group for the participant, the descriptive data of the participant (gender, age, height, body weight, body mass index, dominant extremity, regular exercise habits) were collected by the researcher in a face-to-face setting and recorded in a data collection form.

The lower extremity joint range of motion (ROM) values and the knee Q angle of the participants, whose descriptive data were recorded, were measured using a goniometer (Baseline, Stainless Steel, USA). Additionally, the Beighton criteria scores were assessed by the researcher and noted in the data collection form. Participants who scored ≥4 points according to the Beighton criteria were excluded from the study. It was assessed by the same researcher in terms of test-retest reliability.

After recording the relevant information on the data collection form, the participant was included in the first application (cold/hot/control) according to their group. The data for each participant were recorded over subsequent sessions with a two-day interval between each application.

Data Measurements:

The cold/hot/control applications: During the cold application, cold gel packs (25x32 cm), wrapped in a moist towel, were applied around both knees for 10 minutes, completely covering the knee area. Similarly, during the hot application, hot packs (36x33 cm), enclosed in a dry towel, were applied around both knees for 10 minutes. For both applications, these durations are expressed as acceptable times in terms of effectiveness and tissue safety (Cameron, M.H., 2017). The participant could request to stop the procedure if any discomfort was felt. No intervention was applied during the control application, and measurements were taken directly.

Throughout the cold, hot, and control applications, thermal cameras (Thermacam P25 Flir, USA) were used to ensure optimal application of the thermal agent. Ambient temperature during application, temperature of the applied cold/hot material, and joint temperature before and after application were recorded in the data collection form. Thermal images were evaluated using analysis software (Grayess® IRT Analyzer, Version 6.0) in a computer environment (Atalay et al., 2018).

After the mentioned applications, biomechanical assessment was performed using the Landing Error Scoring System, followed by measurements of knee laxity using the Lachmeter (The Digital Roliometer®, Brazil).

Laxity measurement: For quantifying laxity, the digital rolimeter (Lachmeter, The Digital Roliometer®, Brazil), which has been compared to the gold standard KT-1000 knee ligament arthrometer in terms of sensitivity (89%) and specificity (95%) (Ganko et al., 2000), was used. The participant lay in a supine position with a 30° inclined pillow under their right knee. The rolimeter was then stabilized, and a foot strap was secured around the participant's right leg just above the ankle, with a plate fixed distally to the patella. The researcher proceeded by performing a modified Lachman test on the participant's right knee. During the Lachman test, the digital display of the rolimeter simultaneously showed the amount of anterior displacement of the tibia relative to the femur in millimeters (mm). Measurements were repeated three times, followed by repeating the same procedures for the left knee, and the average laxity values were recorded in mm.

Landing error scoring system: Evaluation was conducted using the scoring system validated for Turkish language and reliability by Ercan et al. (2021). The participants performed a jump test from a non-slip wooden box set at a height of 30 cm. Each participant was instructed to jump a distance equal to half of their body length. The half-body length distance is a measure that can be adjusted according to each individual's stature, ensuring an appropriate jump based on their physiological characteristics. The choice of the 30 cm box height was based on literature suggesting that optimal jump performance is typically achieved with jump heights ranging from 20 to 60 cm (Addie et all., 2019). During the test, no commands were given, and participants were expected to perform a free landing followed immediately by a jump. The jumping protocol was repeated three times consecutively. Two cameras were fixed to the right side and front of the landing mat. The cameras were positioned at a distance of 345 cm from the landing mat and 122 cm above the ground, respectively. Video recordings of the test were made for evaluation using the error scoring system. The recorded video footage is protected under the Personal Data Protection Law and was evaluated by the researcher using the Kinovea v.0.9.5 application, with error scores noted accordingly.

Statistical Analysis: Statistical analysis was performed using SPSS version 26 software. Normal distribution of the data was assessed using the Shapiro-Wilk test. For analysis of dependent groups, Friedman and Wilcoxon tests were utilized. Mann-Whitney U test was employed for comparisons between dominant and non-dominant extremities. Results are presented as percentages (%), frequencies (n), and median (25th percentile - 75th percentile). A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 41 participants were included in the study, comprising 28 females (68.3%) and 13 males (31.7%). Descriptive characteristics of the participants are presented in Table 2.

Table 2

Descriptive Characteristics of Participants

		Sample (n=41)
Gender	**Female**	n=28, %68,3
	Male	n=13, %31,7
Age (years)		22 (22-23)
Height (cm)		168 (162-177)
Weight (kg)		60 (54-71)
Body Mass Index (kg/m^2)		22,03 (20,34-23,48)
Beighton score		0 (0-2)
Dominant Extremity	**Right**	n=39, %95,1
	Left	n=2, %4,9
Regular Exercise Habit	**Yes**	n=7, %17,1
	No	n=34, %82,9

Results are presented as median (25th percentile - 75th percentile) or n, %.

Table 3 presents the lower extremity length, knee Q angle values, and lower extremity joint range of motion for the participants. There were no statistically significant differences observed between the data of dominant and non-dominant extremities.

Table 3

Lower Extremity Characteristics of Participants

Variable	Dominant side (n=41)	Non-dominant side (n=41)	p^M
Lower Extremity Length (cm)	88 (84,5-95)	88 (84,5-95,25)	0,985
Q Angle (°)	13 (10,5-18)	13 (10-18)	0,848
Ankle Plantar Flexion (°)	45 (45-55)	45 (42,5-50)	0,517
Ankle Dorsiflexion (°)	20 (15-22,5)	20 (15-22,5)	0,927
Ankle Inversion (°)	23 (20-25)	20 (15-25)	0,735
Ankle Eversion (°)	20 (15-25)	15 (15-20)	0,137
Knee Flexion (°)	130 (130-140)	130 (129-140)	0,887
Knee Extension (°)	0 (0-0)	0 (0-0)	1,000
Hip Flexion (°)	120 (110-125)	120 (110-125)	0,818
Hip Extension (°)	20 (10-25)	20 (11,5-25)	0,921
Hip Abduction (°)	35 (30-45)	40 (30-45)	0,879
Hip Adduction (°)	20 (10-25)	20 (10-25)	0,985

Analysis was performed using the Mann Whitney U test. Results are presented as median (25th percentile - 75th percentile).

The temperature values measured by the thermal camera before and after applications are presented in Table 4. A statistically significant difference was observed between the temperatures of hot and cold packs ($p<0.001$). Furthermore, statistically significant differences were observed in knee temperatures before and after applications, as well as in knee joint temperatures after hot/cold applications ($p<0.001$).

Table 4

Temperature Values Before and After Applications

	Control	Cold Application	Hot Application	*p* $^{F-W}$
Ambient temperature (°C)	24 (23,7-25)	24 (23,25-24,65)	24 (23,5-25)	0,929
Pack temperature (°C)	-	13 (10-17)	45 (40,8-48,9)	**<0,001***
Pre-application Dominant Knee Temperature (°C)	30 (26,9-31,25)	30 (28-31,4)	30 (26,25-31,5)	0,799
Post-application Dominant Knee Temperature (°C)	-	17,6 (15-21,6)	38,8 (32,15-39,2)	**<0,001***
p ^{W}	-	**<0,001***	**<0,001***	
Pre-application Non-dominant Knee Temperature (°C)	30 (26,85-31,15)	30,3 (28,1-31,2)	30,3 (26,8-31,3)	0,552
Post-application Non-dominant Knee Temperature (°C)	-	18 (15,05-22,4)	38,8 (32,05-39,25)	**<0,001***
p ^{W}	-	**<0,001***	**<0,001***	

In the analysis, Friedman and Wilcoxon tests were employed. The findings are presented as median (25th percentile - 75th percentile).
p $^{F-W}$: For comparisons among the cold application, hot application, and control groups, the p-value obtained from the Friedman test was considered significant at the 0.05 level. For comparisons between the cold application and hot application groups, the p-value obtained from the Wilcoxon test was also significant at the 0.05 level.
p ^{W}: The p-value obtained from the Wilcoxon test for within-group comparisons between pre-application and post-application was considered significant at the 0.05 level.

No statistically significant difference was observed between the Control condition and post-application measurements in terms of the Landing Error Scoring System score and dominant/non-dominant extremity laxity values ($p>0.05$). Results are presented in Table 5.

Table 5

LESS and Laxity Results after Applications

	Control	Cold Application	Hot Application	*p* ^{F}
LESS score	8 (5-10)	8 (6-9,5)	8 (5-10)	0,907
Dominant Knee Laxity (mm)	2,9 (1,95-3,85)	2,6 (2-3,45)	2,9 (2,1-3,9)	0,592
Non-dominant Knee Laxity (mm)	3,3 (2,25-4,05)	3 (2,3-4,15)	3,2 (2,35-4)	0,330
p ^{M}	0,199	0,254	0,356	

LESS: Landing Error Scoring System. Friedman and Mann Whitney U tests were used for analysis. Results are presented as median (25th percentile - 75th percentile).

DISCUSSION

In this study investigating the effects of thermal agents applied to the knee region on LESS scores and knee laxity, it was found that thermal agents applied to the knee region did not create a significant difference in LESS scores and knee laxity. Statistically significant differences were observed in knee temperatures before and after applications, as well as post-application joint temperatures following hot/cold application. However, no statistically significant differences were observed in Landing Error Scoring System (LESS) scores during control or post-application assessments, nor in dominant/non-dominant extremity laxity values.

Understanding factors influencing the LESS score, developed to detect movement patterns that may predispose to ACL injuries and to implement preventive measures, is crucial for achieving optimal outcomes in risk assessment. Various studies have explored factors affecting the LESS score. Hanzlikova et al., in their systematic review and meta-analysis, evaluated the effects of age, gender, previous injury, and neuromuscular training programs on LESS scores (Hanzlíková et al., 2021). Adams et al. investigated the impact of dehydration (Adams et al., 2021), while Distefano et al. examined the effects of hypohydration and hyperthermia (Distefano et al., 2013). Another study assessed the influence of scoring criteria and previous performance on error scores (Hanzlíková and Hébert-Losier, 2020a). Various studies have explored the effects of fatigue and exhaustion (Gokeler et al., 2014; Liveris et al., 2021; Van Melick et al., 2019), landing distance (Hanzlíková and Hébert-Losier, 2021), jump distance (Hanzlíková and Hébert-Losier, 2020b), and landing surface (Jacobs et al., 2021). Studies have also examined the effects of shoe use (Hébert-Losier et al., 2023), dynamic taping (Wu et al., 2022), and prophylactic ankle bracing (Hueber et al., 2017) interventions on LESS error scores. To the best of our knowledge, no studies have evaluated the relationship between the use of thermal agents and joint temperature with LESS error scores. Therefore, our study is unique in this regard.

Literature examining the use of thermal agents reveals studies investigating the effects of cold applications on muscles. Alaca et al. explored the impact of a cooling spray application on the biomechanical properties of the rectus femoris muscle, highlighting muscle cooling via thermal imaging. They observed an increase in muscle tone and stiffness following the cooling process (Alaca and Kablan, 2022). Point et al. noted that cryotherapy induced an increase in muscle stiffness in the gastrocnemius muscle, suggesting that this acute biomechanical alteration could potentially reduce the muscle tissue's elasticity (Point et al., 2018). Both studies emphasize that tissue stiffness can reduce the extent of muscle stretching. Although our findings indicate that knee laxity decreased following the cold application compared to the hot application, no significant difference was found between the two measurements. This may be attributed to differences in the laxity of muscle tissue and tendon structures.

Miniello et al. aimed to assess the effects of cold water immersion on muscle activity and dynamic stability of the lower extremity in 17 healthy women. They examined the preparatory and reactive electromyographic activities of the tibialis anterior and peroneus longus, as well as the stabilization time after landing from a jump (Miniello et al., 2005). Following the intervention, they reported an increase in preparatory activity of the tibialis anterior, while both preparatory and reactive activities of the peroneus longus decreased, returning to baseline levels after a 5-minute recovery period. Because stabilization time remained constant, the researchers came to the conclusion that cold water immersion had no negative effects on dynamic stability in healthy women doing a hopping task (Miniello et al., 2005). Our study revealed that biomechanical changes assessed using the Landing Error Scoring System did not vary with the thermal agents applied to the muscles.

A systematic review including 7 studies was conducted to investigate the effect of cryotherapy on joint position sense in healthy participants. It was reported that cryotherapy had no effect on joint position sense in 4 studies, while a negative effect was reported in 3 studies (Costello and Donnelly, 2010). The researchers in this review highlighted the need for further research due to differences in evaluated joints, cooling methods, measurement techniques, and varying qualities of reviewed studies, emphasizing that conclusive answers regarding the effect of cryotherapy on joint position sense require more investigation (Costello and Donnelly, 2010).

In a study conducted with 20 healthy participants in Japan, researchers evaluated the effects of cryotherapy on knee laxity and joint position sense using KT-2000 arthrometer measurements. They reported a reduction in knee laxity and decreased sensitivity in joint position sense measured with a computerized dynamometer. They noted that these effects returned to normal 15 minutes after the cooling application (Uchio et al., 2003). In contrast, Benoit et al. conducted a study with 15 participants where they found no evidence that either hot or cold treatments altered knee laxity assessed with KT-1000 after treatment (Benoit et al., 1996). Similarly, in our study, we did not observe significant differences in knee laxity values between dominant and non-dominant extremities measured during control conditions and after hot/cold applications.

CONCLUSION

The study concluded that thermal agents applied to the knee region did not result in significant differences in LESS scores or knee laxity. The use of thermal agents was not found to be effective in influencing the risk of sports injuries specifically related to these two parameters in the knee region.

Strengths: This study holds the distinction of being the first to evaluate the relationship between the use of thermal agents, joint temperature, and LESS error scores.

Limitations: The study's single-center design and the homogeneity of the participant group in terms of gender (predominantly female) and age (reflecting a specific age range) constitute significant limitations.

All scores were evaluated by a single researcher in this study. While the measurements were considered in terms of test-retest reliability by the same researcher, no statistical reliability value was provided. This limitation arises from the absence of reliability calculations and the fact that the measurements were conducted by a single evaluator. Future studies should incorporate multiple assessors to include inter-rater reliability, enabling a more comprehensive analysis of reliability.

Future research could benefit from multicenter data collection and the inclusion of diverse age groups to enhance generalizability.

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1. **Görkem KIYAK:** Idea/Concept, Design, Checking, Data Collection and Processing, Analysis-Interpretation, Writing, Critical Review
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Information about Ethical Board Permission

Committee Name: Süleyman Demirel University Faculty of Medicine Clinical Research Ethics Committee

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