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The Effects of Local Hot and Cold Applications on Knee Joint Position Sense in Non-Elite Athletes: Experimental Study

Elit Olmayan Sporcularda Lokal Sıcak ve Soğuk Uygulamaların Diz Eklemi Pozisyon Duyusuna Etkisi: Deneysel Çalışma

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ABSTRACT Objective: Many athletes who are slightly injured and have pain during the game return to play immediately after a short cold application. However, athletes who have recently recovered from injury and still have hot applications also enter the play in a controlled manner when necessary. This study aimed to explore the specific effects of hot and cold applications on active joint position sense (JPS). **Material and Methods:** Twenty-seven (14 males and 13 females) athletes without any injury or complaint related to the knee participated in this study. JPS measurements were repeated for both knees at target angles of 15°, 30°, 45°, and 60°, before and immediately after the hot application. One week later, the same tests were repeated with cold application. Local cooling and heating were applied for 15 min, by using gel-packs at 0°C and 44°C. **Results:** JPS was not affected by extremity dominance. The main effect of gender was significant only in 60°, and females made lower errors. Although no differences were observed before the hot and cold application, the absolute errors in all angles were higher for the cold than for the no-cold condition and lower for hot than the no-hot condition. Significant difference levels were at 15°, 30°, 45°, and 60° after the cold application, and at 45° and 60° after the hot application. Absolute errors increased as the target angle increased in all conditions. **Conclusion**: Results showed that hot application improves the proprioceptive quality of the knee joint in athletes, but cold application deteriorates.

Keywords: Joint position sense; hot application; cold application; knee proprioception

ÖZET Amaç: Oyun sırasında hafif yaralanan ve ağrıları olan birçok sporcu kısa bir soğuk uygulamadan hemen sonra oyuna döner. Öte yandan sakatlığı yeni atlatan ve hâlen sıcak uygulamaları olan sporcular da gerektiğinde kontrollü bir şekilde oyuna dönerler. Bu çalışma, sıcak ve soğuk uygulamaların aktif eklem pozisyon hissi "joint position sense (JPS)" üzerindeki spesifik etkilerini araştırmayı amaçladı. **Gereç ve Yöntemler:** Bu çalışmaya diz ile ilgili herhangi bir yaralanma veya şikâyeti olmayan 27 (14 erkek ve 13 kadın) sporcu katıldı. Sıcak uygulamadan önce ve hemen sonra 15°, 30°, 45° ve 60° hedef açılarında her iki diz için JPS ölçümleri tekrarlandı. Bir hafta sonra aynı testler soğuk uygulama ile tekrarlandı. 0°C ve 44°C'de jel paketleri kullanılarak 15 dk boyunca lokal soğutma ve ısıtma uygulandı. **Bulgular:** JPS ekstremite baskınlığından etkilenmedi. Cinsiyetin ana etkisi sadece 60°de anlamlıydı ve kadınlar daha az hata yaptı. Sıcak ve soğuk uygulama öncesinde herhangi bir farklılık görülmemesine rağmen tüm açılardaki mutlak hatalar, soğukta soğuk olmayan duruma göre daha yüksek, sıcak için ise sıcak olmayan duruma göre daha düşüktü. Soğuk uygulamadan sonra 15°, 30°, 45° ve 60°de, sıcak uygulamadan sonra 45° ve 60°de önemli fark seviyeleri olmuştur. Her koşulda hedef açısı arttıkça mutlak hatalar arttı. **Sonuç:** Sonuçlar, sporcularda sıcak uygulamanın diz ekleminin propriyoseptif kalitesini iyileştirdiğini ancak soğuk uygulamanın bozduğunu gösterdi.

Anahtar Kelimeler: Eklem pozisyon duyusu; sıcak uygulama; soğuk uygulama; diz propriyosepsiyonu

Local cold treatments are commonly used methods to treat acute sports injuries. When athletes are injured during a game, they use a cold pack or other forms of cooling. And usually, they may return to play immediately after cold treatment.[1] The cold application's effects on joint position sense (JPS) are not completely established; however, it is paramount to understand its impact on peripheral feedback to as-

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certain the safety of using cold therapy before resuming the game.[2] However, athletes who have recently recovered from injury and still have hot applications also enter the play in a controlled manner when necessary. Hot applications are one of the most used practices in the treatment of sports injuries. Results of these modalities on different tissues have been widely investigated and well documented. The hot application increases the nerve conduction velocity (NCV), while cold application decreases it.[3-10] The changes in NCV that occurred with hot and cold applications may affect proprioception during the play.

Previous research that analyzes the effect of the cold application on proprioception indicates contradictory results. Some of these show that cold application worsened the proprioception while the others had no effect.[2,11-16] Although athletes who are injured during sporting events returned to play due to the reduction in pain after cold application, previous studies have shown that performances of the sprint, vertical jump, and throwing have deteriorated.[17-19] The authors advised that individuals should be cautious when they return to play immediately after cooling; however, no study exists about the effect of the hot application on proprioception.[1,17-20]

This study aimed to explore whether the hot and cold application had any effects on knee proprioception in 4 different target angles. It hypothesized that hot application would improve the proprioceptive quality, and cold application deteriorates.

MATERIAL AND METHODS

This study was carried out with the approval of the Manisa Celal Bayar University (19.07.2006, 2006/0098) Health Sciences Ethics Committee. The current study was conducted under the principles of the Declaration of Helsinki. After the researchers made verbal and written explanations about the method and aims of the research, the volunteers agreed to participate in the research by signing the informed consent form.

PARTICIPANTS

Participants were asked not to do exhaustive physical activity 24 hours before the tests and not to use any medication that could affect the nervous system function. Volunteers with orthopedic disorders, acute or chronic neuromuscular disease on the knee joint were not included in the study. Those with a history of trauma or other complaints in the knee were excluded from the study. The participants consisted of 27 (14 males and 13 females) non-elite team game players with an average age of 22.2±2.5 years. Volleyball, basketball, football, and handball players who have been regularly participating in competitions and team training for the last 2 years were included in the study. Based on the Tegner Activity Scale, they had 5 and 6 activity levels with at least 3 exercises per week.[21] The dominant foot was right side in all the volunteers. The participants were examined in a supine position with the test protocol modified by Barrett et al.[22-25] To familiarize the participants with the entire procedure and apparatus, they participated in preliminary trials.

PROPRIOCEPTION TEST PROTOCOL

All data were collected in the university performance research laboratory. Participants were evaluated with the active JPS test method, which has been proven to be a reliable method for measuring knee position sense.[26-28] A 1° sensible digital goniometer (Guymon, Model 1129, Lafayette Instruments Co., Lafayette, IN, USA) was used to assess JPS.[12,24,29] The selected measurement method and goniometer have been used and validated in previous studies.[12,22-24,29] Two researchers conducted the tests. Inter-rater and intra-rater reliability was r=0.81 and r=0.73 respectively (p=0.001). The measurers had a lot of experience with their previous studies.[12,24,30]

A single data collection session consisted of a total of 8 consecutive knee flexion measurements in random order at 15°, 30°, 45°, and 60° angles performed immediately before and immediately after heat application on one leg. First, JPS measurements were conducted without any heat application. At the beginning of each test, the researchers demonstrated to the participants the target knee angle twice. The participants were then asked to reproduce this predetermined target angle actively. Once they were ready, participants with the eye closed flexed their limb from knee extension to target angle and stopped at the point where they felt they had reached the target for 4 s. The procedure was repeated 3 times, and the arithmetic mean of 3 trials was used for comparison. With one-week intervals, the same test protocol was repeated by applying hot packs and then cold packs for 15 min, respectively. Absolute differences between the targeted and reproduced angles were evaluated as JPS error values.

HEAT APPLICATIONS

Hot/cold packs were used for hot and cold applications. The packs maintained the same temperature for a long time due to the gel content. The hot packs were heated for 45 min in a system containing water at 44 °C before the hot application. Before cold application, the cooling packs were kept for 4 hours in the freezer at 0 °C. The large size (26x12 cm) cold/hot gel packs wholly covered the knee joint, with the center of the packs applied over the tip of the patella and were secured by an elastic bandage without compression. Packs were put into their thin cotton cases after they were taken from the heater/freezer to avoid skin damage. During the applications, participants were seated with an average of 15° of knee flexion. A thermometer was placed between the skin and the pack. The temperature before the application was 44 °C, and after 15 min application, it decreased to 40 °C. After 15 min of cooling, the temperature rose from 0 °C to 10 °C.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS (version 23.0; SPSS Inc, Chicago, IL). The level of significance was set at $\alpha=0.05$ in all tests. For normally distributed variables according to gender ($p>0.05$), descriptive analyses were presented using means and standard deviations. To explore whether target angles of 15°, 30°, 45°, and 60° differed significantly among the baseline to cooling and heating conditions conducted a series of repeated measures of analysis of variance (ANOVA). Genders and extremity sides were entered the model as the between-subject factors. Repeated measurements of ANOVA were reported using the corrected degree of freedom through the Greenhouse-Geisser sphericity estimates. The paired sample t-tests were performed to compare before and after heat applications JPS error values. Repeated measures of ANOVA were carried out to explore whether JPS errors may vary as a result of hot/cold conditions. Multiple comparisons were conducted with Bonferroni correction to see the significant main effect of hot and cold applications.

RESULTS

There was no difference between non-dominant and dominant knees' error scores in the same tasks. In other words, JPS was not affected by extremity dominance. When comparing the heat conditions, the differences were significant or insignificant, depending on the dominant and non-dominant subgroup. Thus, its regular presence cannot be unequivocally demonstrated on dominance. There was no difference between the genders in the first 3 angles. However, females made lesser reproduction errors at 60° of knee flexion ($p=0.003$).

ANOVA results indicated that the main effect of the extremity side and gender x extremity side interaction was not significant. On the other hand, the main effect of gender was significant before hot application ($F_{(2.46,\ 123.17)}=8.28$, $p=0.025$, $\eta^2=0.07$), before cold application ($F_{(2.26,\ 113.08)}=3.76$, $p=0.022$, $\eta^2=0.07$), and after cold application ($F_{(2.44,\ 121.83)}=2.98$, $p=0.044$, $\eta^2=0.06$).

Absolute error values and comparisons of the entire sample according to cold and hot conditions are shown in Table 1 and Figure 1.

TABLE 1: Absolute position error comparison before and after cold and hot application independent of gender and dominance.

	Before cold		After cold				Before hot		After hot			
Target angle	Mean	SD	Mean	SD	t value	p value	Mean	SD	Mean	SD	t value	p value
15°	0.51	0.37	0.77	0.56	-3.29	**0.002****	0.51	0.76	0.36	0.60	1.35	0.182
30°	0.97	0.80	1.34	0.77	-2.86	**0.006****	0.95	1.20	0.76	0.80	1.00	0.321
45°	1.11	0.66	1.34	0.98	-1.48	0.144	1.19	0.93	0.76	0.72	3.08	**0.003****
60°	1.20	0.94	1.53	1.25	-3.01	**0.004****	1.39	1.19	0.94	0.86	2.61	**0.012***

*p<0.05; **p<0.01; SD: Standard deviation.

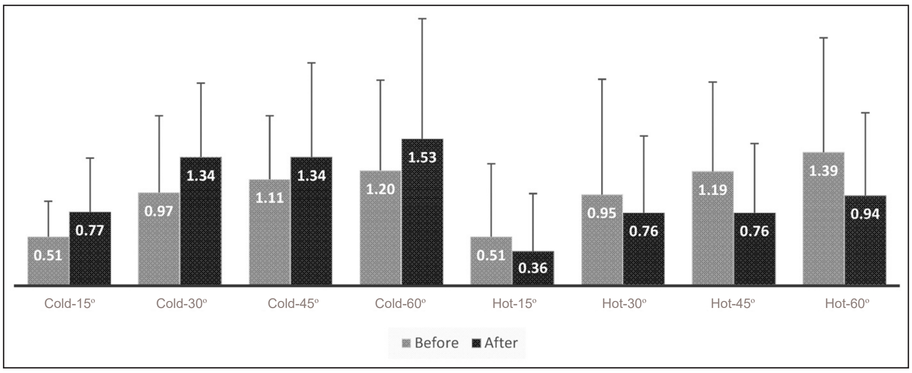

FIGURE 1: Comparison of joint position sense absolute error values performed with hot and cold conditions.

TABLE 2: Repeated measurement outcomes and pairwise comparisons.

	Between 15° and 30°	Between 15° and 45°	Between 15° and 60°
Before cold	p=0.001**	p=0.000**	p=0.000**
After cold	p=0.000**	p=0.002**	p=0.001**
Before hot	p=0.056	p=0.000**	p=0.000**
After hot	p=0.050*	p=0.004**	p=0.000**

*p<0.05; **p<0.01

Prior to heat applications, participants showed similar reproduction errors in all target angles; indeed, at baseline, no differences were observed before the hot and cold applications. The cold applications induced a significant increase in absolute angular errors of 15°, 30°, and 60°. Errors also increased at 45° flexion, although not statistically significant. However, the hot application significantly affected the proprioceptive levels of the participants, especially in high target angles. After the hot application, error scores significantly decreased at 45° (p<0.01) and 60° target angles (p<0.05). Although error scores decreased at 15° and 30° as well, the differences were not statistically significant (Table 2).

Figure 1 presents that joint reposition errors increased as the target angle increased. There were significant differences between the error values in almost all of the pairwise comparisons. Only the difference between 15° and 30° before the hot application was found to be very close to the significance level but not significant.

Results of repeated measures indicated the significant main effect of heat [Before cold ($F_{(2.23, 118.29)}$=9.83, p=0.000, η^2=0.16), after cold ($F_{(2.43, 128.72)}$=8.15, p=0.000, η^2=0.13), before hot ($F_{(2.43, 128.90)}$=7.87, p=0.000, η^2=0.13) and after hot ($F_{(2.39, 126.70)}$=6.73, p=0.001, η^2=0.11)].

DISCUSSION

The primary finding of this study is that after a short period of hot application in healthy individuals, hot application in joint position sensation independent of limb dominance and gender difference provides better results. In line with previous studies, the current study was not able to observe differences either between the proprioception of the dominant and the non-dominant leg or between men and women.[22,25,31] Although no differences were observed before the hot application and cold application, the absolute errors in all angles were higher for the cold than for the pre-application condition and lower for hot than the pre-application condition. The present study showed significant reductions in the ability to accurately replicate knee joint positioning in 3 of the 4 target angles during the knee flexion following cold application. However, replication errors at 2 target angles significantly decreased after the hot application. These results demonstrated that proprioceptive response quality worsens with the cold application, while it improves with the hot application when compared to normal conditions. Although the amount of error varies according to the applied angle, these effects generally occurred. The proprioceptive process proceeds through afferent and efferent nerves between the central nervous system and periphery.[20] Changes in NCV caused by the hot or cold application may directly affect the proprioceptive quality.[2,11,14,15,20,32] An increase or decrease in NCV will cause faster or slower proprioceptive responses.[4-10] The authors previously proposed the reducing of NCV after cold treatment as the justification for the observed decrease in JPS.[11,15] On the other hand, it is also suggested in the literature that NCV decreases linearly with tissue cooling, not skin cooling.[10,33,34]

The effect of the cold application on proprioception has been investigated in a limited number of studies, and conflicting results were obtained.[11,13-15,19,35,36] When the designs of these studies are analyzed in detail, the methods used to measure proprioception as well as data analysis and statistical methods are very different. In a recent meta-analysis, Costello and Donnelly criticized the three studies in which no effect of ice application on proprioception was found, and they reported some errors in data analysis methods.[13,14,19,20] According to this report, if the researchers had analyzed the absolute error instead of the relative, they would have found a statistically significant decrease in knee JPS after ice application.[20] Also, because different cooling techniques provide different degrees of joint cooling, the cooling modality may be critical in managing the impact on JPS.

In most sporting activities, it is a common procedure to recommend a return to the game immediately after a cold application following an injury. Despite some authors suggesting no loss in JPS following cold application, it is possible that the cold application may reduce proprioception and predisposes an athlete to injury due to decreases in NCV, muscle force production, proprioceptive afferent information or a combination of these factors.[2,11,13-15,19,32] It has been shown that poor proprioception is associated with an increased risk of injury.[35] Thus, returning to the game immediately after the cold application may jeopardize the athlete for new injuries due to the deteriorated proprioception. Results of the present study, along with previous ones, support that proprioception has worsened after the cold application.

The normalizing time of proprioception after the cold application is not well-known. However, the effects of cold application on edema, pain, and elasticity have been reported to resolve in 3-30 min after the procedure is ended.[20] In a study evaluating the period required to normalize JPS, the authors found that at least 15 min were needed for normalization of proprioception following cryotherapy.[36] It means that athletes are encountered with the risk of injury for 15 min following cold application due to the impaired proprioception. Some researchers reported normalization in the knee JPS at 15 min post-cooling.[11,15] Ribeiro et al. indicated that the detrimental effect of the cold application on proprioception is mitigated by low-intensity exercise, and the time necessary to normalize knee JPS reduces from 15 to 10 min.[36] In a review article, Bleakley et al. reported that athletes would likely experience a loss of performance if they return to game immediately after cooling for longer than 20 min according to the current evidence base.[1] They suggest that until better evidence is available, athletes should apply shorter cooling or perform a warm-up before returning to play. Besides, other authors reported that returning to sports competitions immediately after cold applications decreased sprint, vertical jump, and throwing performances.[17-19] Magalhães et al. showed that the warming-up before sporting activity improves knee JPS.[37] Considering that cold application causes loss of proprioceptive sensation, it may be appropriate to wait for 15 min or to take extra precautions such as doing some exercise instead of allowing the athlete to return to the game immediately after the cold application.

Increasing proprioceptive quality is one of the main objectives of many rehabilitation programs. The hot application is often used in rehabilitation programs. In the literature reviewed, there is no other study examining the effect of the hot application on position sense just before exercise. Besides all other effects, for the first time, this study demonstrated that the quality of proprioception increased even in short-term hot applications. Improvement effect may be due to an increase in NCV, but there is no evidence for this in the current study. In this study, not measuring the NCV is a limitation in terms of providing evidence.

Another important finding of the present study was the increase in the absolute angular error as the evaluation angle increases. In this study, the mid-knee flexion range suggested by Olsson et al. was evaluated because the information provided by muscle sensory receptors in this range of motion is believed to be more dominant in mediating knee position sense.[28] Olsson et al. showed findings of an increase in absolute errors from 30° to 50° and a decrease from 70° to 100°.[28] The change of the absolute angular errors based on the application angle observed for knee flexion in this study appears to be consistent with this previous study. Also, Olsson et al. indicated that the best expression of knee JPS was the absolute error, with an average JPS of 4.16° in sitting and 5.06° in prone.[28] In the current study, as the knee flexion was measured in the supine position, less absolute error may have been obtained. The females made significantly fewer mistakes than males only at 60° of knee flexion. As reported in previous studies, JPS at angles less than 60° was not affected by gender.[38,39]

CONCLUSION

Results have been shown that hot application improves the proprioceptive quality of the knee joint in healthy athletes, but cold application deteriorates, and also, the dominance or gender are not affected. It should be known that these findings do not represent the health status of the injured athlete during training or competition. Scientific research should also be done on this subject. However, it can be used as a criterion to compare with the perception of a healthy knee in determining the level of recovery after a knee injury. Consequently, the present study provided preliminary evidence for the argument that the active JPS method with the hot application may be an improved method to evaluate joint positions sense, especially for the decision to return to sport following a severe joint injury.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Muhammet Özer, Devrim Akseki; **Design:** Muhammet Özer, Muammer Altun, Haydar Kaynak; **Control/Supervision:** Haydar Kaynak, Devrim Akseki; **Data Collection and/or Processing:** Muhammet Özer, Haydar Kaynak; **Analysis and/or Interpretation:** Muammer Altun, Nuri Karabulut, Devrim Akseki; **Literature Review:** Muhammet Özer, Nuri Karabulut; **Writing the Article:** Muhammet Özer, Muammer Altun, Nuri Karabulut; **Critical Review:** Muammer Altun, Nuri Karabulut, Devrim Akseki.*

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