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PREVENTION AND REHABILITATION: ORIGINAL RESEARCH

Therapeutic heat and cold around the elbow on the response of median neurodynamic test 1

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ABSTRACT

Objective: To compare the effects of the application of therapeutic heat and cold on the mechanical response of the median nerve neurodynamic testing.
Design: Single-blinded randomized crossover trial.
Methodology: 56 asymptomatic university students (mean age = 21.82 ± 1.64 years) of either gender with a limited elbow extension range of motion during a Median Neurodynamic Test 1 were recruited. Each subject was administered 3 testing conditions on separate days with a 24-hr washout period. The interventions included 1) therapeutic moist heat around the elbow, 2) therapeutic cold around the elbow and 3) no thermal agent as a controlled condition. Outcome measure of elbow extension range of motion at the onset of pain and submaximal pain were recorded before the intervention, immediately after the removal of the thermal agents (20^{th} min) and at 2 subsequent readings of 30 min and 1 hour after the removal of the thermal agent.
Results: There was a significant effect of using a thermal agent with time on the elbow range of motion at the onset of pain [$F(2,165) = 3.622$, $p = 0.029$] and submaximal pain[$F(2,165) = 3.841$, $p = 0.023$] at the 20th min. A posthoc comparison indicated that at the 20th min the mean elbow range at the onset of pain and submaximal pain for the therapeutic heat condition (mean = 33.5, S.D = 13.37 and mean = 16.80, S.D = 12.99 respectively) was significantly different than the no thermal agent condition (mean = 40.17, S.D = 12.34 and mean = 23.4, S.D = 13.82 respectively). However, therapeutic cold condition did not significantly differ from both the other conditions.
Conclusion: Therapeutic heat causes an immediate increase in elbow extension range of motion during a Median Neurodynamic Test1 and testing post the application of thermal agents can alter the test response.

1. Introduction

Neurodynamics describes the inter-dependent relationship between the mechanics and the physiology of the nervous system (Shacklock, 2005). Neck and arm related conditions can have a clinical presentation of perceived nociception from any innervated structure with pathomechanic contributions from the cervical, thoracic or the upper extremity region itself (Isabel de-la-Llave-Rincón et al. 2011). The prevalence of neurogenic sources as compared to non-neurogenic sources is 19.9% (Gangavelli et al., 2016).

Mechanosensitivity is a protective mechanism through which the nervous system becomes a source of pain (Shacklock, 2005). Neurodynamic tests are a valid tool to depict the mechanosensitivity of the nerve, with inflamed nerves giving rise to impulses at much lower strain rates (Schmid et al., 2009). Moreover, in asymptomatic individuals, a neurodynamic test can yield sensory responses associated with a positive structural differentiation maneuvre, indicating that normal mechanosensitivity is heightened when there is a dysfunction that alters the mechanical and physiological properties of the neural tissue (Nee et al., 2012a,b).

With various contributing factors to painful syndromes of the upper quarter, there is a cluster of treatment techniques used to alleviate symptoms (Sterling et al., 2010; Salt et al., 2011; Nee et al., 2012a,b). It has been found that in carpal tunnel syndrome, the impaired median nerve excursion contributes to the kinematic dysfunction. This supports the importance of neural mobilization in conditions with heightened mechanosensitivity (Ellis and Hing,

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2008). Other manual therapy techniques like soft tissue mobilization (Costello et al., 2016; Wolny et al., 2016) and cervical lateral glide mobilizations (Sterling et al., 2010)) are directed primarily to the structures that form the interface to a mechanosensitive nerve and are employed for the management of neck and arm related conditions by inducing physiological changes that allow adequate gliding of the nerve along its path thereby increasing the threshold to nociception.

Electrophysical modalities like thermal agents have been incorporated as adjuncts to the treatment of conditions with or without heightened mechanosensitivity with its use indicated primarily towards pain modulation (Graham et al., 2013). The use of a heating and cooling modality have known effects that alter the pain mechanism in symptomatic individuals. However, their physiological and mechanical effects vary (Nadler et al., 2004). Therapeutic heat increases the extensibility of soft tissues, thus improving the range of motion available at a joint. Whereas, a topical cold application has an opposite and almost negligible effect on the same (Robertson et al., 2005; Mustalampi et al., 2012). Thermal agents induce alterations in the physiological properties of the nerve and have a similar effect on the viscoelastic properties of the neural tissue as it does on other soft tissue (Laymon et al., 2015).

The addition of a deep heating modality as an adjunct to neural mobilization produces a better effect as compared to neural mobilization alone (Nunes et al., 2016). However, whether the heating agent directly had an impact on the mechanosensitivity was not known, and the lasting effect after the removal of the heating agent was not documented. Moreover, the heating agent used was a dry heating modality (infrared). Hence the effects of moist heat as compared to a dry heating modality may differ as they varies in terms of rate and depth of penetration (Petrofsky et al., 2009).

Therefore, further research is required to interpret the efficacy of thermal agents on the direct alteration of mechanosensitivity. To compare the effects of therapeutic heat and cold on the mechanosensitivity, the elbow region can be used as the median nerve is superficial, after the wrist, and elbow extension with wrist extension is associated with a large excursion proximal to the elbow (McCahon and Bedforth, 2007; Silva et al., 2014). Therefore, the aim of this study was to investigate the effects of therapeutic heat and cold given around the elbow on the response during a Median Neurodynamic Test 1.

2. Methods and materials

2.1. Study design

The study was a randomized crossover trial with 3 different conditions administered on separate days. The 2 experimental conditions involved the application of therapeutic heat and therapeutic cold and the controlled condition involved exposure to no thermal agent. The study protocol was approved by the Institutional Research Committee of School of Allied Health Sciences, Manipal Academy of Higher Education, Manipal, and ethical clearance was obtained from the Institutional Ethics Committee.

2.2. Participants

Asymptomatic university students who volunteered to participate in the study were screened for the inclusion criteria between February 2016 to February 2017. According to the inclusion criteria, asymptomatic individuals of either gender, aged 18–40 years were recruited. As a part of a screening tool and to fulfill the requirements of the inclusion criteria, individuals with a deficit in elbow angle of 20° or more with a positive MNT1 with contralateral neck flexion for structural differentiation were recruited. The side with a greater range of motion deficit was included. A positive test was indicated as “stretch, ache, pain, burning, or tingling” over the anterior aspect of the shoulder, cubital fossa, lateral aspect of the forearm, lateral 3 fingers and the thumb. Individuals with impaired sensations over the upper extremity, acute or chronic pain, recent injury or trauma, and any present or previous history of neuromuscular or musculoskeletal involvement in the upper quadrant including the cervical region were excluded (see Fig. 1).

2.3. Randomization and blinding

Randomization was done using sealed opaque envelopes. Each envelope was randomly selected by a constant individual who was not involved in the study. Each envelope consisted of 6 sequences that ensured each was administered each testing condition with a 24-h washout period between each test condition. After obtaining a signed informed consent, the subject selected a sequence which was handed over to the primary investigator. The primary investigator administered the testing procedure and condition and a secondary investigator, who was blinded to the condition, assessed the outcome measures.

2.4. Intervention

Median Neurodynamic Test1 (MNT1) was conducted to complete the recruitment process which was performed by the primary investigator.

The subject was positioned in supine without a pillow under the head, and the following sequence for Neurodynamic testing was standardized for each subject.

- Shoulder girdle elevation prevention with a force 40 mmHg using the pressure biofeedback
- Glenohumeral abduction to 90°
- Glenohumeral lateral rotation
- Forearm supination and wrist and fingers extension
- Slow passive elbow extension

Each subject was administered all the three conditions that are Therapeutic heat, Therapeutic cold and no thermal agent (as a control group) on 3 separate days. The intervention was administered to each subject by investigator-1 which was blinded to

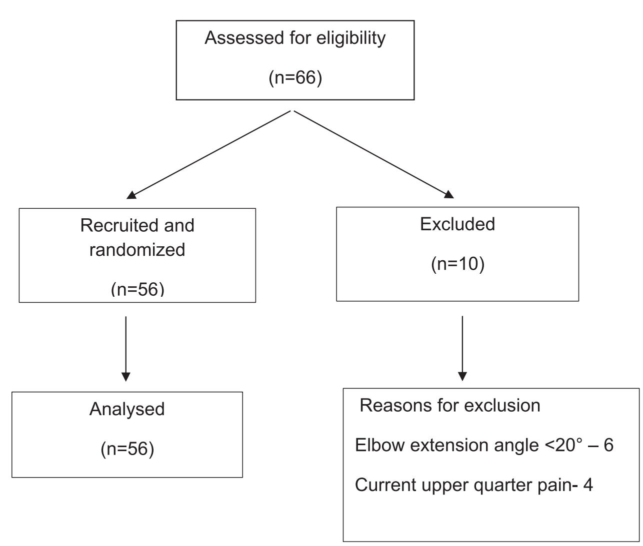

Fig. 1. Screening and allocation of subjects.

investigator-2. For all 3 conditions, the treatment began by performing an MNT1 and the assessment of outcome at baseline. Following this, the subject received the condition of the sequence that they were allotted to. For the interventions of therapeutic heat and therapeutic cold, moist heat from the hydrocollator unit (preheated at 75 to 80°c) and gel cold packs (pre-cooled at −10 to −20°c) respectively, were given around the elbow ensuring that the elbow was circumferentially provided with the thermal modality. This was administered for a duration of 20 min with subjects instructed that the temperature felt should be as tolerated. If the temperature perceived was above the tolerance level, appropriate layers of towel were added till tolerated. For the no thermal agent condition, individuals were made to rest for 20 min as the duration of the thermal agent conditions. In the case of all the conditions, the outcome measure was re-assessed at t = 20min (after the removal of moist heat and cold pack), t = 50min and t = 80min (30 min and 1 h, respectively after the removal of the thermal agent).

2.5. Outcome measure

Elbow extension angle was used as an outcome measure. MNT1 was performed by the primary investigator in the sequence stated above. The elbow extension angle was measured at the point of ‘onset of pain’ (E1) and at the point of ‘submaximal pain’ (E2). ‘Submaximal pain’ is a substantial discomfort which corresponded with the greatest level of pain which the subject was prepared to tolerate, knowing that the test had to be performed repeatedly (Coppieters et al., 2002). The fulcrum was placed on the medial epicondyle with the stationary arm placed along the long axis of the humerus, and the movable arm was placed along the long axis of the ulna. The outcome measure was assessed by the secondary investigator. During the measurement, the wrist extension component was released to avoid any undue prolonged strain on the neural tissue.

2.6. Data analysis

Data analysis was done using SPSS software version 15. Descriptive statistics were used for summarizing demographic data. Elbow extension range at different time points between conditions was analyzed using one-way ANOVA, and a posthoc test was done using Tukey HSD. Repeated measures ANOVA was used for within-group analysis. The level of significance was set at $p \leq 0.05$.

3. Results

Table 1 depicts the baseline characteristics of the participants. A posthoc comparison indicated that at the 20th min the mean elbow range at the onset of pain and submaximal pain for the therapeutic heat condition (33.5 ± 13.37; 16.80 ± 12.99 respectively) was significantly different (p value = 0.022; 0.020 respectively) than the no thermal agent condition (40.17 ± 12.34; 23.4 ± 13.82 respectively). However, the therapeutic cold condition did not significantly differ from both the other conditions for onset of pain and submaximal pain (37.21 ± 13.76; 21.26 ± 11.80 respectively) (see Tables 2 and 3).

Results of the study reveal a statistically significant change in elbow extension angle ($p < 0.05$) within all the three conditions.

As seen in Table 3, a significant difference was noted with the elbow extension angle at submaximal pain at T80 min from the baseline ($p = 0.012$) with no thermal agent. Moreover, a significant difference was noted with elbow extension angle at the onset of pain and submaximal pain ($p < 0.001$; $p = 0.009$ respectively) immediately after the removal of therapeutic heat and 30 min after for the elbow angle at the onset of pain ($p = 0.012$) from the baseline values.

After the removal of therapeutic heat, the change in elbow extension angle after 30 min for the onset of pain ($p < 0.001$) and after 1 h for the onset of pain and submaximal pain showed significance ($p < 0.001$).

A significant change was noted in the change in elbow angle for the onset of pain immediately after the removal of therapeutic cold ($p < 0.001$).

Similarly, 30 min and 1 h after the removal of therapeutic cold, a significant change ($p = 0.001$; $p = 0.002$ respectively) was noted in the elbow angle with the onset of pain from the baseline.

The trend in the change in elbow extension angle within all the

Table 1
Demographic data.

Variable		Mean(SD)	
Age (in years)		21.82(1.64)	
Baseline elbow angle of MNT1 (in degrees) with dominant side	Baseline elbow angle of MNT1 (in degrees) with non-dominant side	42.95(10.9)	46.80(11.91)
Variable		**n (%)**	
Gender			
Male		12 (21.4%)	
Female		44 (78.6%)	
Side selected			
Dominant		41 (73.2%)	
Non-dominant		15 (26.8%)	

Table 2
Post-hoc pairwise comparison between the conditions.

Comparison between conditions across 4 time points (p value)	T = 0 min		T = 20 min		T = 50 min		T = 80 min	
	E1	E2	E1	E2	E1	E2	E1	E2
No thermal agent vs Therapeutic heat	.91	.745	.022*	.020*	.946	.937	.931	.926
Therapeutic heat vs therapeutic cold	.975	.471	.277	.163	.847	.629	.687	.816
No thermal agent vs therapeutic cold	.804	.898	.486	.650	.971	.834	.887	.97

E1-elbow angle at onset of pain; E2 – elbow angle at submaximal pain; T0min-baseline; T20min-immediate post condition; T50min- 30 min post condition; T80min- 1 h post condition.

Table 3
Post-hoc pairwise comparison within group.

	No Thermal Agent		Therapeutic Heat		Therapeutic Cold	
	E1 Mean difference (p-value)	E2 Mean difference (p-value)	E1 Mean difference (p-value)	E2 Mean difference (p-value)	E1 Mean difference (p-value)	E2 Mean difference (p-value)
Baseline and T20 min	2.571 (.606)	3.268 (.356)	10.179 (<0.001)*	12.607 (0.009)*	6.839 (<0.001)*	3.786 (0.015)*
Baseline and T50 min	4.143 (0.09)	4.821 (.042)	4.357 (0.012)*	8.339 (0.217)	6.071 (0.001)*	1.839 (1.000)
Baseline and T80 min	3.768 (0.602)	4.518 (0.012)*	3.929 (0.021)*	6.411 (0.595)	6.179 (0.002)*	3.393 (0.254)
T20 min and T50 min	1.571 (1.000)	1.554 (1.000)	−5.821 (<0.001)*	−4.268 (0.033)*	-.768 (1.000)	−1.946 (.457)
T50 min and T80 min	1.196 (1.000)	1.250 (1.000)	−6.250 (<0.001)*	−6.196 (<0.001)*	-.661 (1.000)	-.393 (1.000)
T50 min and T80 min	−.375 (1.000)	−.304 (1.000)	−.429 (1.000)	−1.929 (1.000)	.107 (1.000)	1.554 (1.000)

three conditions is seen in Fig. 2. It was noted that there was no return of elbow extension angles to baseline values with the final testing procedure in all the conditions.

4. Discussion

This study aimed at comparing the application of therapeutic heat and cold given around the elbow on the range of motion of the elbow at the onset of pain and submaximal pain during Median Neurodynamic Test1.

The results suggest that the administration of therapeutic heat yields an alteration in the mechanosensitivity during a neurodynamic test immediately after the removal of the heating agent as compared to the application of therapeutic cold and the control condition. The difference in elbow extension angle at the onset of pain and the submaximal pain was noted to be clinically and statistically significant. The mean difference of the elbow angle was 10.17° for the onset of pain and 12.60° for submaximal pain, which is higher than the MCID value (Coppieters et al., 2002) for neural mobility.

The above results can be explained by multiple mechanisms. The neurophysiological effects induced on the neural tissue (Nadler et al., 2004, Laymon et al., 2015) may alter the sensitivity of the nociceptors present on the nerves (Baselgia et al., 2017) and furthermore increase the threshold of the nervi-nervorum leading to a delayed perception of pain thus altering the response assessing the mechanosensitivity during a neurodynamic test (Fedorczyk, 1997, Jaberzadeh et al., 2005). Heating of the soft tissue also results in an increase in the range of motion due to its effect on the extensibility of the collagen (Robertson et al., 2005, Bleakley and Costello, 2013). Furthermore, the application of heat reduces the extra-fusal muscle tension and muscle spindle activity leading to a delayed response to stretch (Fedorczyk, 1997). There also may be a transfer of heat to the neural tissue thus altering its viscoelastic properties (Laymon et al., 2015) however, the effect of heat on altering the direct strain on the nerve with elongation is unknown and beyond the scope of this study.

There were no significant differences between the conditions for all the other time points. A study done by Monara et al. also showed that Infrared, when combined with neural mobilization yields a greater change of elbow extension with a neurodynamic test indicating that there are acute effects with the addition of a heating modality (Nunes et al., 2016). However, the addition of ultrasound as a deep heating modality was not beneficial when compared to soft tissue mobilization (Costello et al., 2016). The current study, nevertheless, yielded improvements in neural mobility immediately after the application of heat. Hence, the application of moist heat improves the neural mobility immediately after its removal as compared to the application of no thermal agent.

There was no significant difference between therapeutic cold and heat at all the time points. The trend observed with therapeutic cold was similar as compared to therapeutic heat and was also observed after the removal of the cooling agent. The pain modulating mechanism gets altered with cryotherapy leading to a reduced activation of the nociceptors and altered sensitivity thus increasing the threshold, like that of therapeutic heat (Nadler et al., 2004). A reduction in the nerve conduction velocity may also contribute to the neurophysiological effects that alter the mechanosensitivity of a neurodynamic test.

The effects with the application of therapeutic cold are attenuated as compared to that of therapeutic heat. As opposed to the effects of heat on the mechanical properties of the tissues (Fedorczyk, 1997, Jaberzadeh et al., 2005), cooling of the muscle tissue can produce a reduction in the viscoelastic properties resulting in a tense and stiff muscle tissue (Mustalampi et al., 2012). Moreover, hence its effect on the mechanical properties of the neural tissue may be negligible (Laymon et al., 2015). This has been documented when the neural tissue is subjected to compressive forces, and the direct effects of the changes on the strain of the nerve are unknown. An induced decrease in reflex reactivity may also be overlooked by the increase in passive stiffness (Price and Lehmann, 1990).

At subsequent time points, there was no difference between therapeutic heat and cold on the neurodynamic test. The lack of difference between therapeutic heat and cold maybe due to their similar effects on the pain mechanism (10). The lack of difference between therapeutic cold and no thermal agent across all the time points maybe due to their negligible alteration on the viscoelastic properties (18,19).

There was also a significant improvement in the elbow extension range of motion within the controlled condition. This, however, was found to be contradictory to the findings of Coppieters et al. who reported no significant change with three repetitions of neurodynamic testing (Coppieters et al., 2002). Nevertheless, there may be a transient effect of repetitive neurodynamic testing involving five repetitions (Vanti et al., 2010) which elucidate the findings of this study which comprises of four repetitions. These effects of repeated testing can be underpinned by the thixotropic properties of the tissue (Shacklock, 1995).

The lasting effect of the application of thermal agents on the mechanosensitivity of the median nerve in unknown. In both the conditions with thermal agents, it was noted that there was no

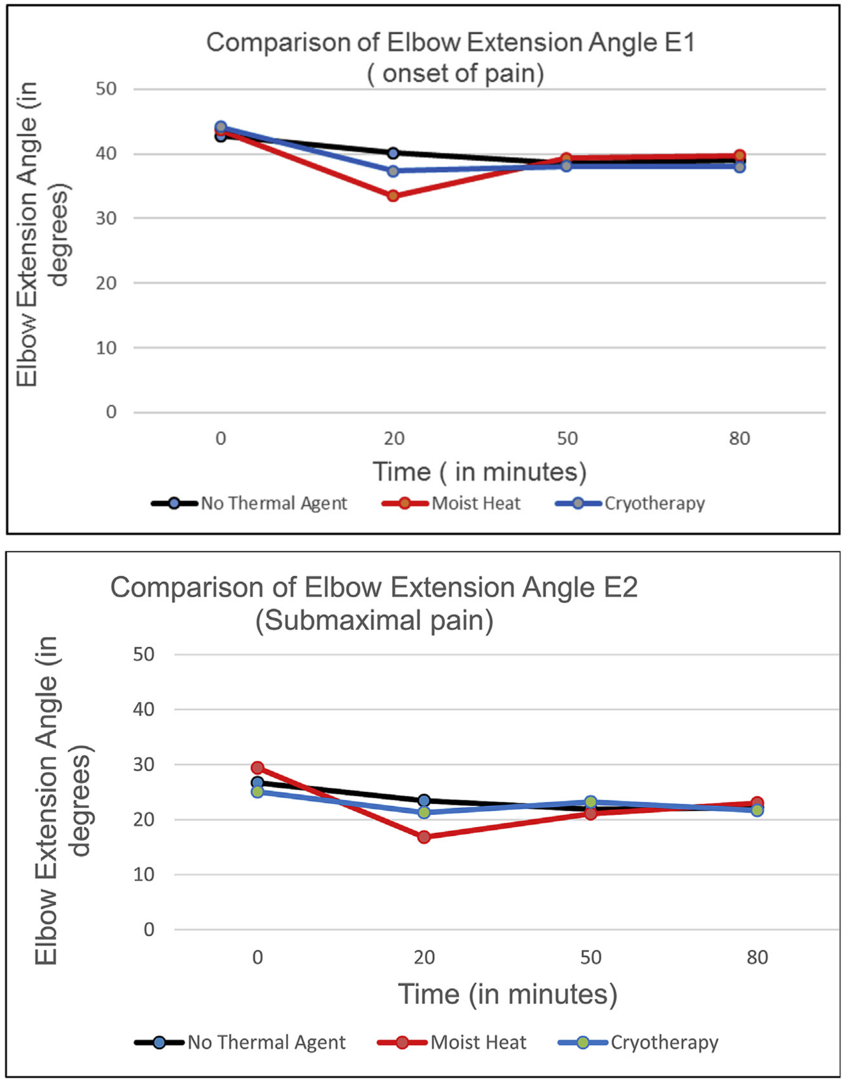

Fig. 2. Comparison of the lasting effect of all 3 conditions.

return to baseline of the elbow extension range of motion. However, a previous study has reported improvements in hip range of motion lasting up to thirty minutes when combined with stretching (Henricson et al., 1984). For the effects of therapeutic cold, the reduction in the viscoelastic properties is noted till fifteen minutes after the removal of the thermal agent (Mustalampi et al., 2012). However, in this study, the elbow extension range of motion remained lower than the baseline values up to one hour after the removal of the thermal agent. This can be attributed to a remnant effect of the thermal agent.

This is the first study that compared the effect of a heating and cooling therapeutic agent on the response of a neurodynamic test 1. Assessor blinding and randomization increase the validity of the study. However, to reveal if the application of therapeutic heat and cold has a direct effect on the longitudinal strain thus altering the mechanical response will require alternative methods of research. As the current study was done on asymptomatic individuals, the results cannot hold the same for symptomatic individuals. The effect of thermal agents in appropriate symptomatic individuals will need to be further studied. The temperature of the thermal agents could not be continuously monitored during the administration of the intervention. However, the thermal agents were pre-heated and pre-cooled at a set constant temperature. As the thermal agents used were therapeutic of nature, it depended solely on the tolerance of the individuals. During the controlled condition, although the individuals were advised complete rest, they were not restrained from movement. Other confounding variables such as recreational activity or being subjected to environmental temperatures that could alter the core body temperature before the testing procedure, were not controlled.

5. Conclusion

Therapeutic heat and cold affect the mechanical response of a median neurodynamic test in asymptomatic individuals. There is an increase in elbow extension range of motion with MNT1 immediately after the application of therapeutic heat. Moreover, there was no return to baseline up to 1 h after removal of the thermal agents. Hence, the application of thermal agents prior to neurodynamic test may alter the interpretation of the test results.

Conflict of interest declaration

The authors declare that there is no conflict of interest.

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