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Effects of Hold-Relax and Active Range of Motion on Thoracic Spine Mobility

Few studies address the use of manual muscle stretching to improve spinal active range of motion(AROM). There is evidence that 'Hold-Relax'(HR) is effective for increasing ROM in the extremities, which leads the researchers to anticipate similar benefits in the spine. The purpose of this study is to investigate the effects of HR(trunk flexors) and active thoracic flexion and extension on thoracic mobility, specifically flexion and extension in healthy individuals. A convenience sample of 30 physical therapy students(22-38 years) were randomly assigned to intervention sequence 'A-B' or 'B-A', with at least 7 days between interventions. Intervention 'A' consisted of HR of the ventral trunk musculature while 'B' consisted of thoracic flexion-extension AROM. Thoracic flexion and extension AROM were measured before and after each intervention using the double inclinometer method. Paired t-tests were used to compare AROM pre and post-intervention for both groups, and to test for carry-over and learning effects. There was a statistically significant increase(mean=3°; p=0.006) in thoracic extension following HR of the trunk flexors. There were no significant changes in thoracic flexion following HR, or in flexion or extension following the AROM intervention. No carryover or learning effects were identified. HR may be an effective tool for improving AROM in the thoracic spine in pain free individuals. Further investigation is warranted with symptomatic populations and to define the minimal clinical difference(MCD) for thoracic spine mobility.

Key words: *Manual Therapy; Muscles; Physical Therapy; Stretching; Range of Motion*

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INTRODUCTION

There is an emerging body of evidence supporting the clinical observation that adequate, pain-free thoracic spine mobility is necessary for optimal spinal posture and function, and maintenance of a functional shoulder complex, lumbar spine, and cervical spine(1-6). The most common thoracic spine intervention reported in the current literature is thoracic manipulation(1-6). Thoracic manipulation(both thrust and non-thrust) may be beneficial in the treatment of shoulder girdle(1) and cervical spine dysfunctions(2-6). In a case study by Lewis et al(1), spinal posture, glenohumeral motion, shoulder pain an dysfunction improved following thoracic mobilization with movement in a patient with adhesive capsulitis. Thrust manipulation for the thoracic spine has been shown to decrease cervical pain(2, 3, 5, 6), improve cervical range of motion(ROM)(5, 6), and improve function in patients with mechanical neck pain(6).

While treatment of the thoracic spine may improve function of adjacent regions, little evidence exists to support the effectiveness of thoracic interventions on pain and/or stiffness of the thoracic spine itself. Gavin(7) reported small improvements in thoracic spine ROM, and Schiller(8) found that thrust manipulation was effective for increasing thoracic side bending only. Despite this lack of evidence, the thoracic spine may be the spinal region most of ten manipulated(9).

In addition to thrust and non-thrust manipulation, physical therapists may use soft tissue interventions and therapeutic exercise to increase spinal range of motion(10, 11). Proprioceptive neuromuscular facilitation(PNF) includes soft tissue interventions used to increase muscle length. Examples include Hold Relax(HR) and Contract Relax(CR). Kabat(12) is credited for developing PNF for us with individuals with paralysis. Techniques and theoretical foundations were then expanded for more general use by Knottand

Voss(13). Evjenth and Hamberg, further described and illustrated the use of HR to increase extremity and spine muscle length(10). Some authors report greater range of motion(ROM) gains with PNF techniques than with static stretching(14-16), while others disagree(17, 18-20). The effectiveness of HR specifically has been documented for the extremities, most frequently for the hamstrings(14-16, 21-26). Unfortunately, the operational definitions vary greatly between studies and often differ from the original definitions by Knott and Voss; this may compromise accurate comparisons between studies(14-16, 21-23, 25, 27-28).

While the effectiveness of HR has been widely investigated for the extremities, no studies were located that examined the effects of HR of the spinal musculature on spinal range of motion. One study examined the effectiveness of 'Contract-Relax'(CR), on the cervical spine. CR was reported to be effective for improving cervical mobility when incorporated into a home exercise program(29). CR and HR techniques and the principles behind them are different(13). CR uses a maximal concentric contraction on the muscle being stretched throughout its full ROM(13) while HR uses a submaximal and graded isometric contraction. Therefore, the two techniques cannot be directly compared.

Active range of motion(AROM) is commonly used in physical therapy practice as a therapeutic exercise. Repeated active movements may contribute to a 'warm-up' of muscles and other soft tissues resulting in increased muscle length, joint mobility, and AROM(30, 31). Taylor and Twomey(30) found that the lumbar mobility increased with repeated active movements. The authors hypothesized that because muscle plays an important role in limiting spinal mobility, a warm-up of muscles via repeated movements may contribute to increased spinal mobility. Keeley et al(31) proposed that the "5-repetition warm-up" prior to their measurement process may have contributed to ROM values being larger than studies using fewer repetitions. These two studies provide evidence that repeated AROM is able to increase ROM therefore is appropriate to use as a comparison for other interventions to increase ROM.

There is some evidence that spinal manipulation and active range of motion have a positive effect upon spinal mobility. The effect of stretching, specifically HR, on spinal mobility has not been investigated. The purpose of this study is to investigate the effects of HR and active thoracic flexion and extension on thoracic mobility, specifically flexion and extension in asymptomatic individuals.

METHODS

Subjects

The study was first reviewed and approved by Oakland University's Institutional Review Board for the Protection of Human Subjects. Recruitment of Oakland University entry level and post-professional physical therapy students was done via flyers, verbal invitation, and/or e-mail contact. Current Oakland University Physical Therapy students were invited to participate(7, 32). Exclusion criteria were thoracic or lumbar pain within the previous month; pregnancy; physician diagnoses of ankylosing spondylitis, scoliosis, spinal fusion and any contraindications to exercise or to the prone lying position. Prior to admission into the study, each participant had the opportunity to read the informed consent and ask questions before giving written consent to participate. A convenience sample of 30 physical therapy students(mean age±SD was: 26±5 years; range 22-39 years; 6 males, 24 females) participated in this study. Asymptomatic participants were chosen to exclude pain related changes in ROM and because asymptomatic thoracic spines are frequently treated in the overall physical therapy management of cervical, lumbar and shoulder girdle dysfunctions.

Protocol

Participants were randomly assigned to intervention sequence 'A-B' or 'B-A'. Intervention A consisted of HR of the ventral trunk musculature, and B consisted of active trunk flexion and extension. Active thoracic flexion and extension were measured before and after each intervention using double inclinometers. The interventions were separated by at least 7 days to minimize the likelihood of carry-over effect(29). Because the time of day may affect spinal mobility, the two data collections were scheduled at the same time of day(33).

Measurement

Active thoracic flexion and extension were measured using the double inclinometer method described in the American Medical Association Guide to Evaluation of Permanent Impairment(Fig. 1)(31, 32, 34) While the reliability of the double inclinometer method has not been determined for thoracic mobility, acceptable to good reliability for use in the lumbar spine has been established(31, 35). Repeatability of thoracic flexion in sitting using a single inclinometer was determined to be good(r=.81) by Mellin et al(36). An unpublished study by Rajdl et al. found excellent intra-rater reliability for thoracic flexion(ICC=0.90) and extension(ICC=0.90) for the double inclinometer method(37). Because of the scarcity of published data on the dual inclinometer reliability, a separate pilot study was conducted prior to the current study to assess intra-examiner reliability of the dual inclinometer method. The reliability of the examiner was ICC(3.1)=0.90 for flexion and ICC(3.1)=0.97 for extension.

The participant sat on a plinth, with the greater trochanter positioned slightly higher than the knee joint line for the purpose of stabilizing the pelvis and the lower extremities(36, 38). Each movement was described and demonstrated by the research assistant. The verbal instructions for thoracic flexion were: "Bring your chin toward your chest bone and chest bone toward your belly button as if trying to bring your head between your knees". For extension the instructions were: "Cross your hands over your shoulders, look up, bring your chest bone upward and arch your upper back". The middle of the base of one inclinometer was positioned over the C7-T1 interspace and the second over the T12-L1 inter space. The participant was asked to repeat thoracic flexion and extension six times. The first three repetitions served as a warm-up and training of the movement requested. End range active thoracic flexion(Fig. 2) and extension(Fig. 3) were measured at the fourth, fifth, and sixth repetitions of each motion by subtracting the value of the T12-L1 inclinometer from the C7-T1 inclinometer. Movements were carefully observed, and verbal cues were provided to limit movement substitutions in other planes as well as from the lumbar spine. One physical therapist with 30 years of clinical experience and 5 years of experience using the double inclinometer

Fig. 1. Dual inclinometers positioned at C7-T1 and T12-L1

Fig. 2. Measurement of flexion

Fig. 3. Measurement of extension

took all the measurements. She was blinded to group assignment. Her reliability measured in a prior pilot was very good as mentioned previously.

Interventions

Intervention A: Hold-Relax

Many inconsistencies regarding the definition and technique for performing HR are found in the literature. To help clarify the readers to the technique used in this study, the specific steps of the HR intervention are presented in Table 1. HR was performed using the process described by Evjenth and Hamberg(10). The sequence of the HR intervention to stretch the torso into right rotation and extension is described in Table 1. This intervention was provided by the same physical therapist for all participants(Fig. 4). The therapist had 19 years of clinical experience, including manual therapy instruction at entry-level and post-professional levels.

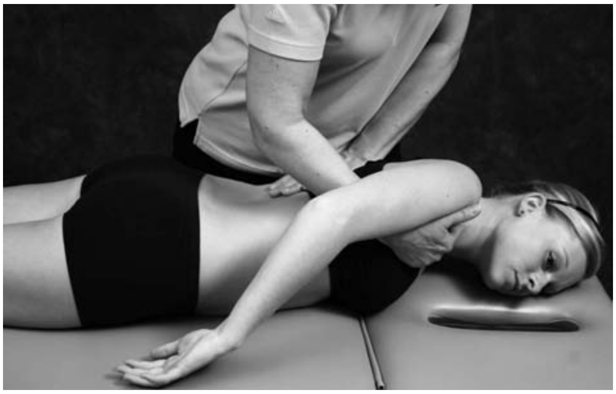

Fig. 4. Hold-Relax

Intervention B: AROM

Participants performed the AROM in the same sitting position and with the same verbal cues as described for the measurement process. Each participant was cued to repeat this sequence three times: flex the thoracic spine, return to neutral, and then extend the thoracic spine. One therapist with over 10 years of clinical experience guided the AROM intervention for all participants.

Data Analysis

Q-Q plots were used to examine the data for normal distribution. Paired t-tests were used for all comparisons; significance level was set at $p<.05$. The effect of each intervention upon thoracic flexion and extension was tested by comparing the means of the 3 pre and the 3 post-intervention measures. The impact that the order of intervention(HR-AROM vs. AROM-HR) may have had on the results was examined by comparing the differences of the post to pre intervention means between intervention sequence 'A-B' and 'B-A'. Carry-over of gains in ROM from the first intervention to the pre-intervention assessment of the second intervention was calculated by comparing the first pre-intervention measures of flexion(and extension) for the two data collection dates. Finally, the relationship of baseline mobility and response to either HR or AROM was assessed by comparing the pre and post-intervention means of the 10 most mobile and the 10 least mobile participants. Post hoc power analysis was estimated using the method described by Portney and Watkins(39). All statistical tests were performed using SPSS 19.0 SPSS Inc., Chicago, Illinois.

RESULTS

The mean flexion and extension values pre and post-intervention were normally distributed as demonstrated by Q-Q Plots. There was a statistically significant increase in active thoracic extension following the HR intervention(3°, $p=.006$)(Table 2). The changes in thoracic flexion following HR intervention, and thoracic flexion and extension following the AROM intervention were not significant, regardless of intervention sequence "A-B" or "B-A". The intervention order had an effect upon extension AROM: sequence 'B-A'(AROM→HR) resulted in greater extension than 'A-B'(HR→AROM). There was no evidence of learning effect or carry-over effect. The difference between the mean changes in flexion or extension following HR for the 10 most hypomobile and hypermobile participants was not significant. Finally, given a large effect size(0.80) and 30 participants, the power for this study is 0.92; for a medium effect size the power is 0.61(40).

Table 1. Hold-relax steps and rationale for effects

Steps in Hold-Relax	Rationale for effects
STARTING POSITION: Participant: lie prone on a treatment table with the therapist standing on his/her left side. Therapist: Left hand presses ventrally on the left side of the lower thoracic spine to provide stabilization. Right hand is positioned on the right anterior aspect of the rib cage.	
1. The therapist lifts the right anterior chest dorsally away from the table to generate extension and right thoracic rotation until the therapist feels the first sign of resistance.	- Movement speed should remain below the threshold of the myotatic reflex(tendon jerk) to allow relaxation. - Moving too quickly may trigger the myotatic reflex and cause contraction of the ventral trunk muscles.

Steps in Hold-Relax	Rationale for effects
2. The participant is instructed to press ventrally into the therapist's right hand. This force is performed isometrically with a force that both the patient and therapist can easily control and without motion occurring), for a total of 10-15 seconds(10).	- Inverse Myotatic Reflex(IMR): Voluntary contraction of muscle is influenced by Golgi Tendon Organs(GTO). These fibers decrease the contraction of their own muscles by inhibition of the alpha motor neurons. - The role of the 'IMR' is autogenic inhibition, which protects the tendon from injury and also plays a role in muscle fatigue(51, 52) - Facilitates the antagonist(dorsal musculature)
3. The participant is instructed to release the isometric contraction, while the spine is passively moved further into right rotation to the new position where resistance is felt.	- The individual intentionally releases the contraction and allows support by the therapist.
Repeat steps 1-3 for 3 repetitions, until no additional passive extension and right rotation are achieved.	
4. When no further joint motion/muscle lengthening is achieved, the PT maintains the stretch for 20-30 seconds.	- Muscle spindle inhibits the dorsal musculature; but GTO facilitates the dorsal musculature due to increased tension in the tendons.
5. Instruct the participant to actively move into right thoracic rotation several repetitions(10).	- 'Gamma motor fibers' are the last contracted and are 'biased' or preset for future activity
6. The same procedure is performed on the left side.	

Table 2. Hold-Relax(HR) and active range of motion pre-/post- intervention measures.

Hold-Relax(n=30)						
Measurement	Mean ± SD(Degrees)	SE	SEM	(95% CI)	Significance	Percent change
Flexion pre-HR	34.46±6.7	1.46	1.46	(-5.03 to 0.92)	p=.169	+6.46%
Flexion post-HR	36.51±9.30	1.70				
Extension pre-HR	28.8±8.11	1.48	1.00	(-5.03 to -0.93)	p=.006*	+10%
Extension post-HR	31.73±9.30	1.70				
Active Range of Motion(n=30)						
Flexionpre-AROM	35.33±7.73	.96	0.96	(-1.40 to 2.52)	p=.566	-.76 %
Flexionpost-AROM	34.78±7.62	1.39				
Extension pre-AROM	29.89±7.08	1.29	1.12	(-0.55 to 4.02)	p=.131	-5.59%
Extension post-AROM	28.16±8.03	1.47				

a. SD: standard deviation b. SE: standard error of the mean c. SEM: standard error of measurement
d. CI: confidence interval
*significant at p<.05

DISCUSSION

The purpose of this study was to investigate the effects of HR and active thoracic flexion and extension on the thoracic mobility of asymptomatic participants. The participants experienced a statistically significant increase in active thoracic extension($\bar{X}$=3°, p=.006) following the HR intervention of the ventral trunk musculature. The flexion AROM improvements following HR of the trunk flexors did not reach statistical significance. Consistent with the HR theory, thoracic extension improved more than flexion.

The potential explanation for improved extension may lie in the rationale for the effectiveness of HR. he proposed mechanism of action at each step of the

HR technique is presented in Table 1. The effect of HR is primarily based upon two neuromuscular mechanisms: reciprocal inhibition, and the inverse myotatic reflex(IMR), which is also known as autogenic inhibition(41, 42). In addition to neuromuscular mechanisms, a number of other mechanisms may have played a role in improving AROM in this study. The positions and movements included in the HR sequence may have improved fluid dynamics(movement of blood and synovial and interstitial fluid around muscles, joints and connective tissue) and/or contributed to a prolonged warm up effect. Also, the static stretch component may be credited for the improved thoracic extension. Finally, facet capsule stretching may have been achieved through activation of the multifidi musculature(43).

The clinical significance of the three degree improvement in thoracic extension observed is not known, and minimal clinical differences have not been determined in the thoracic spine. Consideration of a three-degree change from other perspectives may help to clarify the importance of this improvement. A three-degree increase represents a 10% improvement over the participants' initial values. It is also greater than the standard error of measurement(SEM) for extension found in this study(1.0). While this gain is modest, it is similar to or greater than the change Gavin noted following spinal manipulation(7).

No significant improvement in sagittal movement was found following the AROM intervention in this study. In fact, the participants experienced a non-significant decrease in both flexion(−0.27; p=.775) and extension(−1.67; p=.149). These findings are contrary to the warm-up effect noted in the lumbar study by Taylor and Twomey(30). This introduces the possibility that the warm-up effect may be different in the thoracic spine. One possible explanation is that the osseous components play a larger role in restricting movement in the thoracic than the lumbar spine. Also it is possible that the number of repetitions performed in this study may not have been sufficient to demonstrate a clinical effect.

There was no evidence of 'carry-over effect' in our study as the ROM improvements following HR did not carry over to the second intervention, one week later. This was anticipated by the authors(44). The ideal dosing and frequency of HR to achieve long-term effects requires further investigation. The sequence of intervention was important; participants who received AROM prior to HR made greater extension gains than those who received HR prior to AROM. The significance of this finding is unknown to the authors especially after they observed no significant learning or carry over effect. It is possible that participant expectation of the most effective intervention may have biased the results. Finally, there was no statistically significant difference in AROM improvement with HR between the ten least mobile and ten most mobile participants. This seems to suggest that the quantity of AROM prior to intervention may not be the best predict or of AROM gains following intervention. This warrants further investigation.

Clinical implications

The impact of thoracic stiffness on pain and function is not fully understood. Lundberg(45) found poor correlation between thoracic mobility and disability while Odebiyi(46) uncovered positive inverse correlations only in the following items thoracolumbar flexion and repeated trunk flexion($r=-0.488$; $p<.05$); left lateral trunk flexion and repeated sit-to- stand($r=-0.424$; $p<.05$); thoracolumbar extension and 50-foot walk($r=-0.462$; $p<.05$). Mellin(35, 47, 48) found positive correlations between decreased thoracic mobility and chronic low back pain(LBP) severity(35), and concluded that limited thoracic mobility was more frequent in the female participants with LBP in the previous year compared to participants without LBP(48).

Despite inconclusive evidence regarding the thoracic spine specifically, restoration of normal thoracic mobility is an important goal for physical therapists. Hypomobility within the thoracic spine may alter the mechanics of adjacent spinal segments or body parts, leading to excessive compensatory movements and biomechanical stresses(49). Restoring thoracic mobility has therefore the potential to reduce dysfunction in the cervical spine, lumbar spine, and/or shoulder girdles. HR may be a good alternate strategy for changing thoracic extension ROM.

HR is a safe way to improve spinal mobility. Due to the continuous ability for either the therapist or the participant to terminate the treatment, HR is unlikely to produce a stretch beyond tissue tolerance. HR requires a different set of skills than manipulation and may be a good alternative for some therapists. It is also possible to use HR as part of a home exercise program, which may be beneficial. Finally, it may be a better option for apprehensive patients or patients with muscle guarding.

Limitations and Suggestions for Future Research

There are several limitations to this study. The data was a convenience sample of asymptomatic participants, which limits the generalizability of the study. However, hypomobility is very common dysfunction in the thoracic spine and must be frequently addressed in physical therapy. In addition, pain free thoracic spines are often treated successfully for the purpose of helping adjacent body regions such as the cervical spine or shoulder girdle(1-6, 50). This study included hypomobile subjects. Nevertheless, repeating this study with participants experiencing various levels of thoracic hypomobility, spinal pain, and/or pathology is needed. The sample size of 30 participants was also small although the post-hoc power analysis revealed acceptable power. This study should be replicated using greater number of participants, symptomatic participant, and using repeated measures over time to investigate the long-term effectiveness of the HR intervention in the spine.

CONCLUSION

Thoracic extension increased significantly following HR of the ventral trunk musculature. The results of this study provide preliminary evidence that HR of the ventral trunk musculature may be an effective method for increasing thoracic spine extension in asymptomatic individuals.

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