# A New Method for Assessing Back Pain in Relation to Range of Motion for the Assessment of Pain Relieving Modalities

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## ABSTRACT

A combined "range of motion" and "back pain" scale was developed called the Range of Motion Pain Index (RMPI). It is based on range of motion and pain measurements during back extension, side-to-side rotation, and left and right rotation at the waist (0 = worst score, 100 = less pain and greater range of motion). The subjects (120) had either chronic back pain (P), or were controls (C) with no back pain. In P, there was a linear relationship between the degree of movement of the back in each of the 3 planes and the RMPI. Repeated use of the measure every 1, 2 or 4 hours exacerbated the pain, making the second measurements worse than the first unless greater than 8 hours were used between measurements. The Roland Morris scores were very significantly correlated to the RMPI. When core strengthening exercises were used in back pain patients, there was a reduction in lower back pain (57 % on physical movement of the lower back in extension and rotation and 54% on the Roland Morris Disability Questionnaire), and an increased range of motion before the onset of pain (5.78 degrees for extension, 5.5 degrees in left rotation and 5.6 degrees in right rotation of the hip). There was a corresponding reduction in the RMPI score. Application of heat to the lower back in people with back pain also increased the RMPI score. Thus, the RMPI appears to be an effective, objective pain assessment index that combines motion and pain scores in a reliable and valid manner.

## INTRODUCTION

Back injuries are a major healthcare cost in the world (Chibnall, Tait, Andresen, & Hadler, 2005; Crill & Hostler, 2005; Edlich, Winters, Hudson, Britt, & Long, 2004; Schultz, Crook, Berkowitz, Milner, & Meloche, 2005). An initial back injury usually occurs when people are in their twenties with a reoccurrence in their forties and fifties (Fuortes, Shi, Zhang, Zwerling, & Schootman, 1994; Krause, Rugulies, Ragland, & Syme, 2004; Lind & Petrofsky, 1978). These back injuries cost billions of dollars each year in medical care and lost wages (Gluck & Oleinick, 1998; Jarvis, Phillips, & Morris, 1991; Wasiak & McNeely, 2006).

A variety of therapeutic treatments have been published for back injuries. These include the McKenzie technique to realign the discs in the back (Slade & Keating, 2006), sauna, hydrotherapy (Konlian, 1999), core muscle strengthening (Baker & Patel, 2005; Powers & Wagner, 2004) and non-steroidal anti-inflammatories or steroids (Baker & Patel, 2005). If severe enough, back surgery is often indicated (Oner, van der Rijt, Ramos, Dhert, & Verbout, 1998).

Numerous studies have shown that strengthening the core muscles in the body reduces the chance of back injury (Crill & Hostler, 2005; J. Petrofsky et al., 2005a; J. S. Petrofsky et al., 2005b; J. S. Petrofsky et al., 2004; Schultz, et al., 2005). Because these muscles are used to stabilize the trunk, strength in these muscle groups stabilizes the spine and improves balance. For this reason, the United States Army uses core muscle strength as a predictor of the chance of a recruit sustaining a back injury (Szasz, Zimmerman, Frey, Brady, & Spalletta, 2002). In addition, core muscle strengthening has been used in the treatment of recurrent back injury to allow healing to occur quicker and to prevent further injuries (Baker & Patel, 2005; Powers & Wagner, 2004).

While abdominal exercise has been shown to aid in the treatment or prevention of back injury in a clinic, unfortunately, due to insurance restrictions, the amount of exercise that can be accomplished is very limited (Di Fabio, Mackey, & Holte, 1995, 1996; Noren, Ostgaard, Nielsen, & Ostgaard, 1997). Therefore, therapeutic exercise in a clinical setting is difficult to achieve for any extended period of time.

Heat has also been used to reduce the symptoms of low back pain. However, past outcomes have been subjective and not readily quantifiable for both heat and exercise interventions for back pain (J. S. Petrofsky et al., 2008; J. S. Petrofsky et al., 2005c). This paper reports the development of a test of back pain based on range of motion and the point in range where pain occurs. This technique is called the Range of Motion Pain Index (RMPI) and was validated on patients with acute and chronic back pain in the present investigation. Two series of experiments were conducted. The first was performed to see if the testing procedure itself caused increased soreness and, if so, how long it would last. The second series was conducted to see if the test correlated with the standardized Roland Morris Disability Questionnaire before and after treatment. In the second series, the intervention consisted of either exercise for a month or a single application of local heat.

## SUBJECTS

The subjects (120) in the experiment consisted of approximately half men and half women (n=65 men, n=55 women). All participants were screened by an intake assessment. Exclusion criteria included any person that had chronic low back pain associated with sciatica (pain going down one or both of the legs), neurological impairments from low back pain, or cardiovascular disorders. Subjects were excluded if they were pregnant, had acute inflammation or diabetes. Inclusion criteria for subjects with back injury included non-specific low back pain that has existed for greater than 4 weeks due to L4, L5 spondylolisthesis. The level of pain at the time of the study was greater than 2 on a 6 point pain scale. Control subjects were free of back pain. The subjects were divided into 2 series of experiments as described under procedures. Series 1 included a total of 40 subjects and Series 2, 80 subjects. In Series 1, half of the subjects had back pain and half were free of back pain. In series 2, all 80 subjects had back pain. The general characteristics of the subjects are given below in Table 1 (control, pain free subjects) and Table 2 (subjects with chronic back pain).

*Figure 1*- *Subject lying prone and being placed in back extension*

All methods and procedures were explained to each subject who signed a statement of informed consent as approved by the Institutional Review Board of Loma Linda University and Azusa Pacific University.

## METHODS

Assessment of back pain on life - Quality of Life Outcomes to assess chronic pain in each "pain" subject involved a well established index, the Roland Morris Disability Questionnaire (RMDQ) (Statford et al., 1998). The RMDQ was chosen because it is standardized and is one of the most frequently cited and studied assessment tools applied to patients with low back pain (Riddle, Stratford, & Binkley, 1998). It consists of 24 items chosen from the sickness impact profile to cover a variety of activities of daily living. The RMDQ was self-administered and took approximately 5 minutes to complete. Comparison studies and critical literature reviews suggest that the measurement properties of the Roland Morris questionnaire are equal to or better than those of other measures (Baecke, Burema, & Frijters, 1982; Deyo, 1983; Hall & Brody, 1999; Stratford et al., 1996). The Pearson Correlation Coefficients assessed at 3 weeks were 0.83 to 0.86 comparing injury to disability level (Baecke, et al., 1982; Deyo, 1983; Hall & Brody, 1999; Stratford, et al., 1996). Sensitivity to change, a form of validity, refers to the capacity of a measure to detect change from patient's functional status over time, and is distinguished between patients who change by differential amounts.

Measurement of the relationship between the onset of discomfort at different back angles - Subjects laid supine on a mobilized Plinth model R27841 (Cardon LT D, Niagara Falls, NY) and range of motion in extension, side-to-side movement, and rotation at the hips were assessed. The plinth allowed for free movement of the back in extension, side-to-side movement and rotation. Digital readouts were added accurate to 0.1 degrees for assessment of plinth movement. The maximum extension tested here was 20 degrees, side-to-side movement was +/-10 degrees and rotation was +/-20 degrees. Whereas this is less than full range of motion for these 3 movements, for subjects with back pain this was, in our experience, more than they could normally tolerate. The subject was first placed in the prone position as shown below in Figure 1.

For any position of the 5 possible motions being tested, the table was moved from neutral at approximately 1 degree per second to the maximum movement for the test in that direction (20 degrees for extension, +/- 10 degrees for side to side and +/- 20 degrees for rotation). These measures were done sequentially and 1 minute was allowed between each test. These movements were well within the normal range of motion of the back during ordinary movement (e.g. 30 degrees extension, +/- 30 degrees side to side movement, and +/- 30 degrees rotation). The plinth was moved, for each of the 5 measurements, to the point where the subject felt mild pain. At that point, the subject was asked to place a mark on a 10cm visual analog scale to assess comfort level. The movement was then reduced toward neutral by 5 degrees but not past the zero, neutral position. At that point, the subject was asked to place a mark on the visual analog scale to assess comfort level. Finally, the movement was increased by 5 degrees past the position at which they stated that they were first uncomfortable and the visual analog scale was checked again.

Pain scale- The back movement and pain data from the Paris plinth were used to generate a combined pain scale involving range of motion and the level of pain (Range of Motion pain index, RMPI). The pain recorded with the angle observed for extension, right or left side flexion or right and left rotation of the lower back were both used for this scale. The visual analog pain scale that was used in this study was from 0 to 10. Subjects placed a vertical mark across a 10 cm horizontal line such that the closer they marked the mark to the 10 cm point, the greater was their pain. The first step in calculating the combined pain scale was to multiply the visual analog score by 10. Thus, the score went from 0 to 100. One hundred on this scale was extremely painful whereas zero showed no pain. Since a larger angle of movement for extension, flexion, or rotation, without pain was better, this measurement was in numeric opposition to the pain scale. Therefore, the number that the subject chose on the visual analog scale pain scale was subtracted from 100. After this was accomplished, a pain score of 100 now represented no pain and a score of 0 was extremely painful. Next, the angle was normalized. Obviously, the greater the range of motion, the less impairment the subject had. Since each range of motion was associated with a different maximum angle for that particular test, the actual angle in degrees achieved by the subject at each of the three measurements was then divided by the maximal angle they could achieve and multiplied by 100. This then provided a scale that also went from 0 to 100, with 100 representing the subject achieving the maximum achievable movement in any direction, whereas 0 represented no movement measured for the back in that direction. The corrected visual analog scale was then multiplied by the angle scale and divided by 100 to achieve the final combined pain angle scale. Thus, a score of 100 would be a full range of motion with no pain, whereas a score of 0 would be no range of motion with extreme pain with any movement in the back.

***Exercise***- Subjects exercised to a video (Bender Core Video, Van Nuys, CA). There were 3 levels of exercise on the video; mild, moderate and advanced training. The video lasted about 30 minutes and was followed 3 days per week. The exercise used a mini stability ball and a combination of core exercises for strengthening and aerobic exercise. Subjects exercised both on the floor and standing with the goal to increase core muscle stability. Subjects started at the lowest level of exercise and were asked to progress the intensity as they could during the one month period.

***Application of heat***- Heat was applied with either a dry heat wrap (Thermacare, Wyeth Consumer Healthcare, Richmond, VA) or a moist heat wrap producing a similar skin temperature but keeping the skin moist. The warm wrap kept the average skin temperature about 42 degrees C as did the moist heat wrap as checked by thermocouple measurements.

## PROCEDURES

Two series of experiments were conducted. The purpose of the first series was to determine if the testing procedure itself caused increased soreness and if so, how long it would last. The second series compared this technique of assessing soreness to the Roland Morris questionnaire and then examined the effect of 2 modalities, exercise training and acute heat, on this index.

***Series 1***- In this series, control subjects and subjects with back pain were evaluated during extension, side-to-side movement and rotation of the back. To assess the effect

*Table 1- General characteristics of control group (mean and standard deviation (SD)*

| | age (years) | Height (cm) | Weight (kg) | BMI |
|---|---|---|---|---|
| mean | 48.7 | 168.2 | 88.3 | 31.2 |
| SD | 13.6 | 11.1 | 26.9 | 9.6 |

*Table 2- General characteristics of the group who had pain (mean and standard deviation(SD)*

| | age (years) | Height (cm) | Weight (kg) | BMI |
|---|---|---|---|---|
| mean | 49 | 163.4 | 79.5 | 29.7 |
| SD | 16.1 | 11.2 | 20.4 | 6.5 |

of repeated measurements with this technique, after an initial measurement, repeat measurements were taken at 1, 2, 4 and 8 hours, and 30 days. For measurements at 1, 2, 4 and 8 hours after the first measurement, studies were done on separate days such that only 2 series of measurements were done on a single day. For control subjects, since they had no pain, range of motion was taken to the limit of that measurement for the "Pain", "pain plus 5 degrees", and "pain minus 5 degrees" of full movement.

***Series 2***- Here, a larger population of subjects with and without back pain were evaluated. The subjects with pain used the Roland Morris back pain questionnaire and their scores were correlated with the pain index. Part of the subjects then exercised for one month as described under methods and were reevaluated by, the Roland Morris Disability Questionnaire scale and the plinth pain scale. Other subjects participated in 1 of 2 acute experiments where they were exposed to either 6 hours of dry heat with Thermacare dry heat wraps or 5 hours of moist heat. The pain scale was assessed before and after treatment.

## DATA ANALYSIS

Data analysis consisted of the calculation of means, standard deviations and T tests. The level of significance was $p<0.05$.

## RESULTS

***Series 1***- The effect of the testing technique on muscle soreness; the effect of repeating measurements in the same day and over a month.

The results of the first series of experiments are shown in Figures 2 and 3. As shown in Figure 2, when control subjects with no back pain (Figure 2A) were placed in back extension, as described under methods, there was no pain until the maximum range of motion was examined. Thus, the mid and high measurements were at 100% range of motion and no pain giving an RMPI of 100. Since 5 degrees were still reduced for the lowest measurement, the RMPI was 80. When the measurements were repeated at 1, 2, 4, and 8 hours, there was no difference in the pain or range of motion as shown in this figure ($p>0.05$). The same was true when the measurements were repeated for extension in 30 days as shown in Figure 3A. This is as might be expected since there was no back pain in this group. The same pattern was seen for left and right side rotation, and left and right side movement. However, for the back pain subjects, the results were different.

As shown in Figure 2A for extension, for the other movements in the control subjects, including side to side movement of the lower back and left and right back rotation, RMPI averaged 80.2+/- 1.3 for the -5 degree measurements and was 100 for the RMPI at the other 2 range of motion measures as was seen in figure 2A.

In contrast, for the subject with pain, the relationship between the RMPI and range of motion for the 10 subjects is shown in Figure 2B. As shown here, at the level at which

***Table 3***- *Effect of exercise on Pain Scores vs. Roland Morris*

| | pain | pain +5 |
|---|---|---|
| extension | -0.68 | -0.75 |
| r side to side | -0.63 | -0.81 |
| l side to side | -0.65 | -0.85 |
| r rotation | -0.71 | -0.83 |
| l rotation | -0.68 | -0.82 |

pain was perceived for back extension, the average angle was only 6.4+/-1.4 degrees. This translated on the graph in Figure 2B into an RMPI of 32.1+/-12.8 where pain occurred first; above and below this angle, the RMPI was greater and less respectively, as shown in this figure. If the measurements were repeated in 1 hour, pain was significantly worse at all the angles ($p<0.01$). Pain was less but still worse than the initial measurement after 2 and 4 hours ($p<0.05$) but by 8 hours, there was no significant difference than was seen in the initial data.

When the tests were repeated on the same 10 control and 10 subjects with chronic back pain after 30 days as shown in Figures 3A and 3B, there was no difference in the results for either group except for the fact that the back pain group showed impairment. While Figure 3 only shows the results for extension, the results were the same for the other 4 movements.

***Series 2***- Correlation to Roland Morris Back Pain Questionnaire to the RMPI, effect of mild exercise and heat.

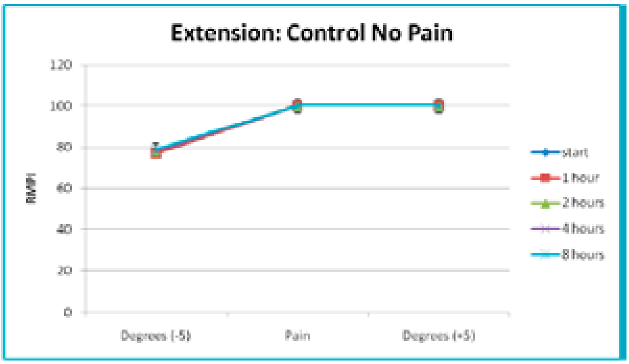
In the second series of experiments, the RMPI was correlated to the Roland Morris Back Pain Questionnaire and then 2 modalities were used to see how the pain scale was affected. Those modalities are: exercise and heat.

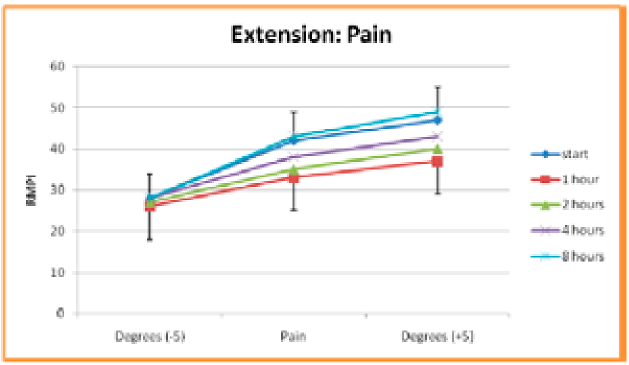
***Correlation to Roland Morris***-

The correlation between the Roland Morris Pain Questionnaire and the RMPI at the highest 2 range of motion measures for the 5 tests conducted here is shown in Table 3 for all 80 subjects with back pain. The correlations were significantly higher at the minimum range of motion where pain occurred plus 5 degrees; however, both pain scores were predictive of back pain when compared to the Roland Morris Back pain questionnaire. At the range of motion of pain minus 5 degrees, most of the measures were significantly correlated, but not all were.

In 25 subjects with back pain, the RMPI and Roland Morris scores were measured before and after 1 month of core muscle strengthening, as described under methods,

***Figure 2 A and B***- *Illustrated here is the RMPI for control subjects (Figure 2A) and subjects with back pain (Figure 2B) measured for back extension at 3 different levels of extension illustrated for the first measurements in a day (start) and with measurements repeated at 1 hour, 2 hours, 4 hours and 8 hours on different days.*



with exercise 3 days per week. The results are shown in Figure 4. Here, back extension and left and right rotation were used for the RMPI scores. For back extension, the average increase was 5.7 degrees without pain, or, an increase of 37% in back extension without pain. For left rotation, the angle at which pain occurred increased from 15.75 degrees to 21 degrees and for right rotation, the angle increased from 17.9 to 21.6 degrees. These increases were also significant ($p<0.05$). The effect of the intervention on RMPI is shown in Figure 4 for extension, which was typical of the 3 measurements made. For all 3 measurements in the RMPI, the scores increased after the month. This was paralleled in the Roland Morris Back pain questionnaire where the score was reduced by 7.2+/3.2, a significant reduction ($p<0.01$).

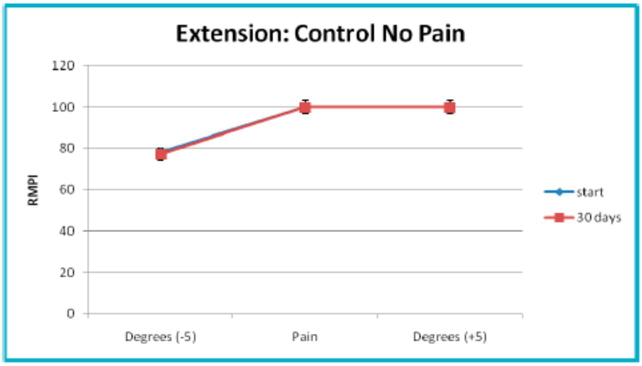
***Effect of heat-***

The results showed that without physical therapy, there was a reduction in lower back pain (57 % on physical movement of the lower back in extension and rotation and on the Roland Morris back pain survey, 54 %), an increase range of motion before the onset of pain (5.78 degrees for extension, 5.5 degrees in left rotation and 5.6 degrees in right rotation of the hip) and an increase in core muscle strength (26.1%) in people with back pain who exercised.

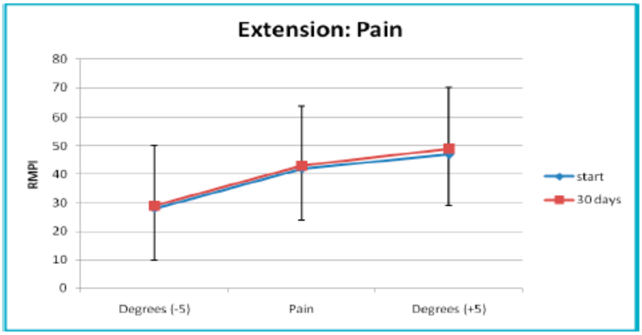
***Effect of heat-***

Finally, in 20 subjects, either dry (Figure 5) or moist heat (Figure 6) was used for 4 hours and the change in the RMPI was measured for extension, and left and right rotation. Here, as shown in the extension in Figure 5, both types of heat caused a reduction in pain and an increase in range of motion resulting in higher RMPI scores. Initially, the Roland Morris scores were 12.1+/-2.8 and 11.3+/-2.1. Since the Roland Morris is a long term questionnaire, it could not be used after the heat intervention. The increase in RMPI was significant comparing pre to post heat data.

***Figure 3 A and B****- Illustrated here is the RMPI for control subjects (Figure 3A) and subjects with back pain (Figure 3B) measured for back extension at 3 different levels of extension illustrated for the first measurements in a day (start) and with measurements repeated at 30 days.*




3b




## DISCUSSION

For people of working age, the costs of lower back pain exceed that of diabetes and coronary artery disease both in medical costs and lost work days (Dagenais, Caro, & Haldeman, 2008; Hanney, Kolber, & Beekhuizen, 2009; Roffey, Wai, Bishop, Kwon, & Dagenais, 2010). It is of no surprise then, that a number of different studies have tried to quantify lower back pain. But back pain classification has been elusive and the diagnosis of back pain severity has often been purely subjective. A recent publication shows that over the decades, 28 separate pain scales have been developed and published for assessing lower back pain (Longo, Loppini, Denaro, Maffulli, & Denaro, 2010). Each of these scales evaluates back pain by using different variables (Longo, et al., 2010). Some studies have tried to evaluate back pain based on causal relationships such as jobs involving sitting, but these studies have failed to show significant causal relationships or predicative value of these variables in assessing back pain incidence or severity (Billis et al., 2010). Most studies use questionnaires and many recent studies have evaluated both correlation of these questionnaires to pain (Bowey-Morris, Purcell-Jones, & Watson, 2010; Heneweer, van Woudenberg, van Genderen, Vanhees, & Wittink, 2010), and test-retest reliability (Bowey-Morris, et al., 2010). But no one test seems to reliably show the relationship between movement and pain.

In the present investigation, a movable plinth, modified with digital readouts was used to place subjects through a range of the lower back through 3 planes. By using an analogue visual pain scale in conjunction with these movements, a total motion related evaluation of sensitivity of the back to movement was assessed through a scale called the Range of Motion Pain Index (RMPI). The issues to be tested here were: 1) does the test itself cause exacerbation of pain, 2) is there test-retest reliability and does it correlate with accepted pain indices that incorporate activities of daily living and, 3) does the scale show improvement with known modalities that relieve back pain.

In the first series of experiments, the test did cause exacerbation of pain. Care was taken not to move the subjects back too quickly and the test limited range of motion to less than half of the normal range. In spite of this, if the test was repeated in less than 8 hours, there was increased pain on the second test. Thus, the test cannot be used to effectively evaluate back pain in repeated tests unless 8 hours or more is allowed between tests; this simply shows how sore the back is in these chronic pain subjects. However, the entire battery of movement was tested here. Perhaps if only a single movement was measured, this test could be used more often.

Test retest reliability was high over a

***Figure 4**- Back Pain RMPI scores before and after a 1 month exercise program*

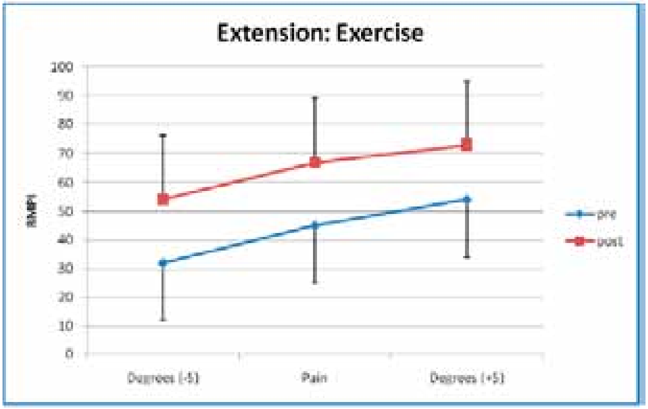



***Figure 5**- RMPI scores before and after dry heat application on the lower back in 20 subjects.*

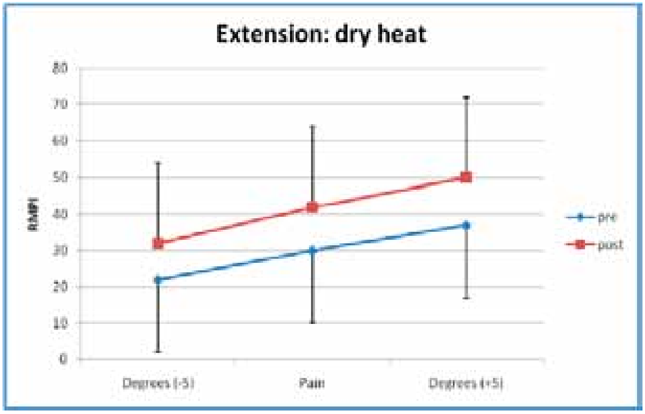
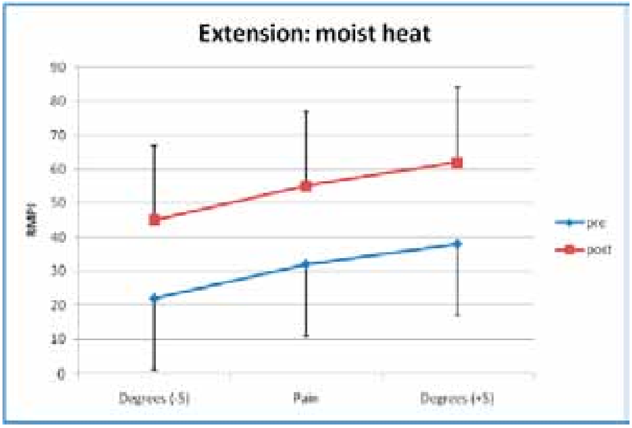


*Figure 6- RMPI scores before and after moist heat application on the lower back in 20 subjects.*




period of a day and even a month as shown in Series 2. Further, the correlation between these results and the Roland Morris back pain questionnaire was highly significant. Thus, compared to a well accepted measure of pain and mobility index (the Roland Morris Disability Questionnaire) (Baecke, et al., 1982; Deyo, 1983; Hall & Brody, 1999; Stratford, et al., 1996), this test worked well. The advantage of this test is that it shows the effect of range of motion on pain and scores different movements to the pain that they cause. In this respect, it is much more telling than the Roland Morris Disability Questionnaire in that the Roland Morris shows total outcomes of back pain on daily living and this test shows the specific movement that causes the most pain while correlating it to activities of daily living.

Finally, scales such as Roland Morris examine long term effect of pain on daily living activities and cannot score the specific effect of a modality on pain in relation to range of motion and in what plane of movement. This test offers a significant advantage in showing the effects of local heat and exercise and other modalities on pain relief. Since the test exacerbates itself if done repeatedly, modalities that are used as intervening therapy of less than 4 hours will cause a bias in the results, but this can be accounted for by using the data present here.

Thus, the new RMPI scale offers a novel approach to pain and pain relief assessment and evaluation. Further studies are needed to examine different types of back pain and the effect of other modalities.

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