UNIVERSITY OF ALBERTA

# POSTEROANTERIOR MOTION TEST OF A LUMBAR VERTEBRA. A STUDY OF ACCURACY OF PERCEPTION AMONG PHYSICAL THERAPISTS, AT DIFFERENT EDUCATIONAL AND EXPERIENCE LEVELS, BEFORE AND AFTER A TRAINING SESSION

by

SIGRÚN VALA BJÖRNSDÓTTIR ©

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## DEDICATION

This thesis is dedicated to my loving grandmother, Sigrún.
She has always been a source of inspiration and it was heartbreaking for me when she unexpectedly passed away last October.

Thank you, Amma Sigrún, for always believing in me.

## ABSTRACT

The objectives of the study were to determine the accuracy of perception among two groups of physical therapists at different levels of education and experience. This was determined for force and displacement when the therapists applied posteroanterior pressure to a vertebra, before and after a training session. Group differences were determined.

To conduct the study a spinal model was used that measured the actual forces and corresponding displacement. The therapists estimated these factors. These factors were tested before and after a training session.

The results of the study suggest that inexperienced physical therapists have accurate perception of the displacement. Experienced manual therapists, have poor perception of the displacement and both groups have poor perception of the force.

It is suggested that physical therapists, regardless of experience improve their accuracy of perception of the force applied towards a significant level, following a training session, and improve the accuracy of perception of the displacement, when applicable.

## ACKNOWLEDGEMENTS

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# Chapter I

# THE PROBLEM

## A. Introduction

The aim of this study was to determine the accuracy of perception of relatively inexperienced physical therapists and experienced manual therapists when estimating the forces applied and the magnitude of displacement that occurred when posteroanterior pressure was applied to a lumbar vertebra. A further aim was to determine whether practice on a spinal model led to improved accuracy of perception when estimating the forces applied and the magnitude of displacement.

To conduct the study, a spinal model was used to test groups of relatively inexperienced physical therapists as well as experienced manual therapists performing posteroanterior spinal mobilisation, prior to and following a training session.

Physical therapists practicing within the field of manual therapy treat many patients suffering from various spinal problems. The patients are seeking professional help regarding their problems and it is expected that the procedures of the diagnosis and effective treatment are valid and reliable.[40]

Manual therapy has become more widespread within physical therapy and there have been expanded instructions in mobilisation in undergraduate programs.[4] The number of continuing education courses has also increased,[4] giving physical therapists opportunities to learn mobilising techniques. This trend among physical therapists to seek education and utilise manual techniques has been happening at the same time as investigators raise questions about standardisation of techniques.

The posteroanterior motion test, often acknowledged as the Maitland technique,[34] is one of many tests used to determine the diagnosis and treatment of spinal problems. The test has been used by physical therapists to evaluate the function of a single segment and is customarily interpreted in terms of grades of motion (Appendix A).

In today's clinical practice, it is recognised that reliable, valid and accurate measurements are needed for decision making and for the purpose of documentation.[17,40]

Numerous studies,[6,22,32] have shown that there is a lack of reliability when posteroanterior motion testing is used. However, physical therapists and other practitioners have put increased effort into evidence based practice in order to meet the requirements of standardisation, including research on reliability and validity of posteroanterior motion testing. Investigators have been measuring the forces applied[21,26,29,30,31,45] and the magnitude of motion[26,30,31,45] that occurs, using various instruments and for miscellaneous purposes. It was not until the last decade that measurements of forces and motion became of a concern to clinicians. They had relied on their own perception of stiffness and end-feel to detect abnormalities in intervertebral motion.[13,34]

The spinal model used in the present study is the only instrument found in the literature that measures the forces applied and the motion that occurs, simultaneously, when physical therapists apply posteroanterior pressure on a vertebra. Training and feedback have been shown to improve therapists ability to estimate the forces applied by using force platforms.[21,29] Thus, the spinal model may be of use as a training tool. In addition, this is the first study that the author is aware of to investigate whether training can improve the estimation of the magnitude of displacement that occurs. Finally, there are no other published studies where two groups of physical therapists at different educational and experience levels have been compared.

**B. Objectives of the Study**

1. To determine the accuracy of perception among relatively inexperienced physical therapists and experienced manual therapists, when estimating the magnitude of displacement and the forces applied, during posteroanterior pressure to a lumbar vertebra.
2. To determine whether a training session changes the accuracy of perception among relatively inexperienced physical therapists and experienced manual therapists, when estimating the magnitude of displacement and the forces applied, during posteroanterior pressure to a lumbar vertebra.

3. To determine if there are differences between relatively inexperienced physical therapists and experienced manual therapists, in the accuracy of perception when estimating the forces they apply and the magnitude of displacement that occurs, before and after a training session.

**C. Research Hypotheses**

The specific research hypotheses of this study are stated below.

1a. There will be a statistically significant difference, between the means of the actual forces applied and the estimated values obtained from relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

1b. There will be a statistically significant difference, between the means of the actual forces applied and the estimated values obtained from experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

1c. There will be a statistically significant difference, between the means of the actual magnitude of displacement that occurs and the estimated values obtained from relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

1d. There will be a statistically significant difference, between the means of the actual magnitude of displacement that occurs and the estimated values obtained from experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

2a. There will be a statistically significant difference, between the absolute errors of the force, before and after a training session, among relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

2b. There will be a statistically significant difference, between the absolute errors of the force, before and after a training session, among experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

2c. There will be a statistically significant difference, between the absolute errors of the magnitude of displacement, among relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

2d. There will be a statistically significant difference, between the absolute errors of the magnitude of displacement, among experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

3a. There will be a statistically significant difference, between relatively inexperienced physical therapists and experienced manual therapists estimating the force, when applying grade II posteroanterior pressure to a vertebra, before and after a training session, when using the means of the absolute errors for the statistical analysis.

3b. There will be a statistically significant difference, between relatively inexperienced physical therapists and experienced manual therapists, estimating the displacement that occurs when applying grade II posteroanterior pressure to a vertebra, before and after a training session, when using the means of the absolute errors for the statistical analysis.

**D. Operational Definitions**

Accuracy of perception - the amount an estimated value of force or displacement deviates from the actual value when applying posteroanterior pressure to a vertebra, representing the degree of inaccuracy. The closer these two values are the better is the accuracy.

Relatively inexperienced physical therapist - a person who graduated with a B.Sc. degree in physical therapy within a year prior to the investigation date.

Experienced manual therapist - a person who is a qualified manual therapist, who has completed part A examination as a manual therapist in Canada or equivalent, and has been working for at least five years within the field of manual therapy.

Force application - the force that is required for a certain amount of motion in a spinal model.

Displacement - the magnitude of motion that occurs in the vertebra mounted in the spinal model when force is applied.

Posteroanterior pressure - pressure applied to a vertebra from posterior to the anterior direction using the heel of the hand or the thumbs.

# Chapter II

# LITERATURE REVIEW

## A. Efficacy of Manual Treatment

In the literature there is some ambiguity regarding the terms mobilisations and manipulations. In the book, Managing Low Back Pain, Saunders, an author of a chapter on physical therapy, used the term mobilisation but did not define the term.[41] Authors of a chapter on manipulations, in the same book, operationally defined the term manipulation. The authors, on the other hand, failed to define what they meant by mobilisation despite the fact that they indicated manipulations to be more effective than mobilisations.[8] Some other authors distinguish clearly between manipulations and mobilisations and leave no confusion.[33,34,37,47]

This inconsistency in utilisation of terms has considerable influence in evaluating the literature for the efficacy of manual treatment. Numerous investigators have reviewed the literature to summarise and evaluate the studies that have been conducted in the past.[1,2,3,9,10,15,38,42,49] Some of the studies evaluated the quality of the methodology, the experimental design and/or the statistical analysis to decide on the inclusion criteria for their discussion or analysis. These studies excluded the vast majority of clinical studies that had been conducted. Two review articles included 21[1] and 23[2] studies for analysis and the most recent one included 51,[3] however, these reviewers did not mention how many studies were excluded from analysis. One review article included only 14 studies out of 146.[9] The authors consistently concluded that manual and/or manipulative therapy, depending on terminology used, can be recommended as a treatment tool for low back pain.[1,2,3,9] These results are in accordance with the recommendations from the Clinical Practice Guidelines: Acute Lower Back Problems in Adults, where 112 studies were screened and 12 met the inclusions criteria for review.[5] The Guidelines, however, excluded any kind of mobilisation technique, according to their definition of manipulations and, unfortunately, did not offer any discussion on mobilisations.

Some authors use the term manipulative therapy interchangeably with the term manual therapy and also concluded in their reviews, that manual therapy is effective in the treatment of low back pain.[15,38] One author states that manipulation is a form of manual therapy, and also concludes this form of treatment to be effective for spinal problems.[42]

An extensive search of the literature, using MEDLINE, was not successful in revealing the efficacy of posteroanterior pressure as a treatment method. As mentioned earlier the terminology was often confusing and when studies have been conducted on this topic, the methodology was frequently poor including which techniques specifically were used.

The physiological effects of manual therapy, including manipulations and mobilisations, still remain speculative but, investigators have reviewed the literature extensively in order to discuss these effects on the human body.[11,14,46,48,50] Authors have concluded that manual therapy, including posteroanterior pressure on the spine, can have a pain-relieving effect on the spine as well as restoring voluntary movement.[14] It has, further, been demonstrated that the utilisation of passive and active movements of the lumbar spine aid nutrition of the cartilage covering the zygapophysial joint surfaces as well as the intervertebral disc nutrition.[50] Further, passive and active movements help the preservation of the full range of motion and the strength and flexibility of the periarticular soft-tissues.[50] Additionally, there is some support from the literature that manual therapy has some ability to affect connective tissue remodelling and that physical forces alter the connective tissue.[46]

**B. Reliability of Perception**

Subjective as well as objective examination is used among physical therapists to evaluate patients' musculoskeletal problems. Based on the examination's outcome, diagnosis and treatment is determined. In terms of a correct diagnosis, each component of the examination has to be valid and reliable. Posteroanterior pressure on the spine is one of the components used among physical therapists to evaluate intersegmental motion.

The concern of the physical therapy profession that their treatment regimes are valid and reliable is demonstrated by numerous reliability studies.[6,12,16,18,21,25,32,44,45] Yet the accuracy of therapists' perceptions in detecting the magnitude of intersegmental motion and the forces applied has been argued. A number of studies have been conducted to test reliability and many authors conclude that interrater reliability is very poor when examiners perform posteroanterior pressure to detect intervertebral motion.[6,22,32] Some studies have shown that there is better interrater reliability when pain is used to identify the involved segment than by the use of palpation alone.[7,22,32] However, there is some evidence that physical therapists are able to correctly identify the involved segment without feedback from the patient. Jull *et al.* (1994) concluded, from their study on cervical joint dysfunction, that physical therapists can identify the symptomatic segment without any verbal feedback from the subject. The therapist performed motion testing, on each central and zygapophysial joint in the cervical spine, using passive accessory and physiological intersegmental movements. The therapist recorded the motion of each joint according to a seven point rating scale and if there was any change in muscle reactivity. The subject reported if there was pain present or not and used a three point rating scale. There was 97.8% agreement between the therapist and the subject on normal joints and 94.4% agreement on the most symptomatic joints.[19]

Further, Jull *et al.* (1988) compared a manual therapist's examination and a nerve block to diagnose cervical zygapophysial joint pain syndromes. The results of the study illustrated perfect accuracy in detecting the presence or absence of the syndrome by the manual therapist who, further, detected the correct spinal level in all cases. In this study the manual therapist used a full subjective and an objective examination to evaluate the patients.[18] These studies demonstrate that without an accurate palpation and identification of the involved segment an accurate diagnosis would not have been possible, even though some authors have questioned the reliability of the therapists' ability to palpate subcutaneous structures.[6,36,44] However, in each of these studies[18,19] only one manual therapist assessed all subjects demonstrating that these manual therapists are accurate in their diagnosis. It would add to the value of these studies if they were repeated with comparison of more than one therapist to test for reliability.

The spinal examination consists of many components constructing the whole picture. Since the diagnosis and the following treatment are based on the examination, it is important that the whole procedure is reliable, valid and accurate.

### C. Determination of Reliable Testing

In terms of evaluating the reliability of intersegmental motion testing, some authors have emphasised instrumentation.[16,21,25,26,28,29,30,31,45] Various instruments have been designed to objectively evaluate the physical therapists' capability of detecting, manually, abnormality of an intervertebral motion.

Simmonds *et al.* (1995) used a spinal model to determine the magnitude of applied forces on the spine when physical therapists utilised posteroanterior pressure, used to test the motion of a spinal segment. They also used the model to determine the magnitude of vertebral motion resulting from the forces applied and how stiffness influenced the applied forces. Further, they determined from the model the perceptual accuracy of therapists in terms of force application and detection of motion.

Ten experienced manual therapists participated in the study who all stated familiarisation with the Maitland technique (Appendix A). The results of the study indicate that force application and the perception of motion differs between experienced physical therapists, suggesting that the posteroanterior motion testing was unreliable. This was true for all of four grades of mobilisation (Appendix A) and across three stiffness conditions.[45]

Harvey and Byfield (1991) used a different kind of a spinal model to evaluate the palpated spinal motion. Their instrument consisted of an artificial skeleton of the spine constructed with intersegmental fixating devices with the characteristics of universal joints. In the study the examiners were asked to determine if there was a fixation present or not at any of five segments tested with posteroanterior pressure. The results indicate that the therapists could easily detect mobile segments when one segment was fixed.[16] Even though these instruments are very different in nature, both may be used as teaching tools, therefore, increasing the reliability of manual testing.

**D. Training to Improve Perception**

Considering the inability of experienced physical therapists to determine the magnitude of the forces applied and the resultant displacement of the joint, it would be valuable to investigate learning skills in future studies. Keating *et al.* (1993) and Lee *et al.* (1990) focused on quantifying the ability to learn vertebral joint mobilisation.[21,29] In both studies the authors used force platforms to measure the applied forces during posteroanterior mobilisation. In the study by Keating *et al.* (1993) the students practised posteroanterior pressure for ten minutes per day for 30 days. The control group kept on with the usual program without any specific training. Both groups undertook a pre- and a post-test to compare the results.[21] Lee *et al.* (1990) used the force platform to test two groups. The experimental group practised with a feedback on a given "ideal" force and both groups were then tested again as well as one week later.[29] The results of both studies indicated that the students improved their ability to quantify the forces they apply to the human spine following a period of feedback or training.[21,29]

The force platforms are indirect methods for the estimation of applied forces during the posteroanterior mobilisation, indicating a cautious generalisation to the clinical situation. However, they can give direct feedback to the physical therapist applying posteroanterior mobilisation and, therefore, can be considered as valuable teaching tools.

**E. Artificial Mobilisers**

A few instruments serving as motor-driven mobilisers have been designed and described in the literature.[24,30,31] These instruments measure the joint displacement that occurs when force is applied on the human spinal vertebra and can therefore be used to evaluate stiffness and changes, if any, before and after a treatment procedure.

The spinal physiotherapy simulator (SPS) was introduced by Lee and Svensson (1990). The device consisted of a parallelogram linkage connected to a padded indenter that applied an oscillating load to the selected spinous process on a human subject. The device was tested for reliability and validity. The intraclass correlation coefficient (ICC) for the test-retest reliability of the stiffness coefficient and intercept were found to be .88

and the Pearson's correlation coefficient appeared to range from .996 to 1.000 for the force-displacement data.[30]

Lee R. and Evans (1992) used a spinal mobiliser to determine the load-displacement-time characteristics of the human lumbar spine under posteroanterior mobilisation. The device was driven by two electric motors producing the upward and the downward movements. The applicator delivered the force to mobilise and was placed over the selected spinous process. A load cell was used to measure the force. Two displacement transducers were located at the spinous processes above and below the one selected and were used to measure the joint displacement. The device was used on $L_3$, $L_4$ and $L_5$ spinous levels and the results demonstrated that posteroanterior mobility varies with different segments. The greatest posteroanterior mobility was observed at $L_5$, while $L_3$ proved to be the one with least mobility.[31] These results disagree with the results of the study by Lee M. and Liversidge (1994) who found $L_5$ to be the stiffest and $L_3$ to be the least stiff level by using the SPS.[28] A possible explanation of this discrepancy could be related to the different instruments used in these studies. In one of the studies[28] the posteroanterior pressure was applied to the vertebrae at an angle ($L_3$ at +5.5° cranial, $L_4$ at -4.5° caudal and $L_5$ at -16° caudal),which might have influenced the results.

Latimer *et al.* (1996) described a new portable device that measured posteroanterior responses in the lumbar spine. This device applied forces on a selected spinous process on the human lumbar spine and measured the resultant motion that occurred. The device had a mechanical head that controlled the motion of the indenter that applied the force and measured the force applied and the motion that occurred. The device was connected to a laptop computer for operation control and data collection. This device was used to measure the stiffness in "the most painful segment" in 22 subjects who had had low back pain the last 24 hours prior to the experiment. The therapists had to be able to provoke the pain by manually applying posteroanterior pressure. The experiment was the first one on symptomatic subjects. It was a study on test-retest reliability and the results showed that the measurements were highly reliable.[24]

The SPS has been utilised to investigate the effect of manipulation on stiffness and to measure if there was a difference before and after the manipulative process. This study was on asymptomatic subjects and showed no significant difference.[26] Moreover, the SPS was used to investigate the effect of extensor muscle activation on the responses to lumbar posteroanterior forces in asymptomatic subjects. The results showed a significant difference in stiffness when the subject was relaxed on one hand and under maximal voluntary contraction on the other hand.[25] One study was conducted to determine the effect of posteroanterior pressure on $L_3$ on sagittal plane rotation of the pelvis. The authors concluded that during posteroanterior force application on the lumbar spine, anterior rotation of the pelvis occurred.[27] Another study was conducted to investigate the relationship between lumbar posteroanterior mobility and low back pain. This was a pilot study and included two symptomatic and six asymptomatic subjects. Force and joint displacement were measured and erector spinae activity were recorded through EMG. The results suggested that posteroanterior mobility was reduced in people with low back pain and the muscle activity was greater when compared to asymptomatic people.[43]

Load-displacement curves for posteroanterior pressure on the lumbar spine have been published.[25,26,30,31] The curves consistently show that there is a non-linear trend in the beginning of the range, called the toe region. This region occupies the first 2-3 millimetres of the range under 20 Newton force. After that the relationship between force and joint displacement is linear. Researchers have questioned physical therapists ability to perceive intersegmental motion. However, it is interesting to see that these curves come from highly reliable and validated measurement tools and physical therapists have for years, described the behaviour of the intervertebral motion using their perception. "Taking up the slack",[20,46] "first stop" [20] and "R1" [34] or the neutral zone[23] of a joint are terms commonly used among physical therapists. An interesting speculation is whether the perceived resistance of the first stop, these clinicians described, is the same as the end of the toe region of the force-displacement curves. If so, is the grade II mobilisation then applied to the end of the toe region and grade III beyond that point? If so, are we seeing an indication of possible standardisation, of forces and joint displacement, for each grade of mobilisation, in the near future?

The artificial mobilisers can be valuable in terms of measuring objectively the ability to influence stiffness, since they can be used to measure stiffness changes and there is some evidence that posteroanterior stiffness is related to low back pain.[43] The tools can measure the posteroanterior mobility by applying the pressure on a selected spinous process. However, these instruments only apply central pressure on the spinous processes and can, therefore, be considered to have limited value as treatment tools. Conversely, the physical therapist can apply unilateral mobilisations on the transverse processes or give a transverse mobilisation on either side of the spinous process, depending on the results of the examination.[34]

**F. Summary**

The practice of physical therapy require that their techniques are standardised and based on science. One of the techniques of interest is posteroanterior pressure on the spine. Studies have shown that the physical therapists' perception of detecting abnormalities of a single intervertebral segment is unreliable when using posteroanterior pressure. These results have forced investigators into extensive research of the vertebrae's mechanical responses to posteroanterior pressure. It is now known that load-displacement curves differ between individual segments and a recent study suggests that the curves also vary between symptomatic and asymptomatic populations.

# Chapter III

# METHODS

## A. Study Design

An experimental design was used for this study to assess the effect of a training program on the accuracy of perception of force applied and displacement produced of two groups of physical therapists that had a different background of education and experience.

Since the study contained two different groups of physical therapists it allowed a comparison of the accuracy of perception between the two groups before and after a training session. It also allowed determination of the effect of training on each group separately, which could help to account for the source of improvement in accuracy of perception.

## B. Subjects

Ten physical therapists, who graduated within a year from the investigation date, and ten experienced and qualified manual therapists, participated in this experiment. Their participation was voluntary. Eight of the relatively inexperienced physical therapists were female and two were male. Six of the manual therapists were female and four were male. All of the relatively inexperienced physical therapists gained their B.Sc. degree from the University of Alberta. Nine of the manual therapists gained their B.Sc. degree from various Universities within Canada and one from Australia. Table 3.1 demonstrates the characteristics of the twenty participants.

Since the group of relatively inexperienced physical therapists had been working for less than a year in the field of physical therapy, their varying clinical experience was not expected to bias the results. However, seven of them were working within the field of outpatient orthopaedics, and used manual techniques daily. The other three were working in various departments in hospitals and generally did not use manual techniques.

**Table 3.1.** Descriptive statistics for the characteristics of all the participants.

| Statistics | Age (years) | | Height (cm) | | Weight (Kg) | | Clinical work | | Years since MT[3] education started | Years of MT practise |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inexp.[1] | Exp.[2] | Inexp. | Exp. | Inexp. | Exp. | Inexp. Years | Exp. Years | Exp. | Exp. |
| **Mean** | 25 | 43 | 163.3 | 171.2 | 65 | 68.9 | 0.8 | 18.8 | 15.7 | 16.2 |
| **St. Dev.** | 2.3 | 5.2 | 5.9 | 9.4 | 11.5 | 12.4 | 0.0 | 5.6 | 4.6 | 4.4 |
| **Minimum** | 22 | 37 | 152 | 157 | 52 | 52 | 0.75 | 10 | 10 | 10 |
| **Maximum** | 28 | 52 | 172 | 185 | 82 | 91 | 0.92 | 27 | 22 | 22 |

[1] Inexp. = Relatively inexperienced physical therapists

[2] Exp. = Experienced manual therapists

[3] MT = Manual therapy

The experienced manual therapists had at least ten years experience within the field of manual therapy. Seven of the manual therapists had completed part B examination in manual therapy (essential for practicing manipulations in Canada). One manual therapist had a similar degree from Australia. Two manual therapists had part A examination in manual therapy which does not include manipulations.

All the therapists answered questions on their experience and the utilisation of posteroanterior pressure. One of the questions was, how many patients they treated, each working day, by using posteroanterior pressure (Appendix B).

In order to recruit volunteers for the study, the principal investigator sent an announcement to every hospital, rehabilitation centre, and physical therapy clinic in Edmonton. Those who were eligible and interested in participating in the study were invited to call the principal investigator for further information or to confirm their participation. If more than ten eligible therapists for each group volunteered, all names for each group were to be included in a selection pool and ten names would have been randomly selected. However, the desired number was not gained by using this method. The six relatively inexperienced participants who responded to this method asked their colleagues if they would like to participate. These two methods recruited ten relatively inexperienced physical therapy participants.

In order to locate and obtain the names and telephone numbers of experienced manual therapists practicing in Edmonton, the principal investigator called the orthopaedic division of the Canadian Physiotherapy Association and The Alberta Physiotherapy Association. The principal investigator called each physiotherapy facility where manual therapists were working and solicited volunteers until the desired number of participants was gained. After the therapists had volunteered, a detailed introductory letter and a consent form were mailed (Appendices C and D).

## C. Equipment

A spinal model constructed at the University of Alberta (Edmonton, Alberta, Canada), was utilised for this study. It has been described in detail before[45] and will thus briefly be discussed here (Appendix E includes a more detailed description).

The mobilisations were applied to a vertebra that was mounted on top of a spring-resisted housing. The structure of the model allowed a variable number of springs (one to five) to be placed in the model, to simulate different levels of stiffness.

A load cell had been placed under the brass housing allowing for the force applied to the vertebra to be monitored. The magnitude of the displacement of the vertebra was measured, in millimetres, by a linear variable differential transformer (LVDT).

The device was placed on a platform and covered by a cloth. Calibration of the model was conducted prior to the first experiment each day by using a standardised weight of a 1.250 pounds and precisely measured motion of 0.5 millimetres for the movable components using a Mitutuoyo Digital Calliper. The logical reason to use a cloth instead of the shell that was used in the former study was based on the argument that the magnitude of the resistance from the shell was not known. This would not have mattered if the therapists used only the tip of their thumbs to apply the force since in that case they would only have touched the rubber cover in the groove of the shell and not the shell itself. This would on the other hand matter if the therapists used the heel of their hand, some times referred to as the pisiformis technique, because they might or might not rest their hands on the shell while applying the force, depending on the size of their hands or their habits. All the participants in this study used the heel of their hand, therefore, a cloth was used instead of the shell, to cover the device so that the therapists were not able to visualise the motion that occurred. A piece of leather was used as padding for the vertebra.

For the resistance, one spring was placed in the middle of the housing. That spring was 57 millimetres in length and had a spring constant of 100 N/cm. Two springs were placed in the outer region of the housing, each of them was 51 millimetres in length and had a spring constant of 50 N/cm. The depth of the holes for the springs were adjusted so that there would be precisely ten millimetres difference in length between the middle spring and the two outer springs. This was done to give the therapists a specific range of motion and an end-feel which was defined as the point in range where the increased resistance of the second set of springs was sensed.

Grades of motion have been defined operationally as a portion of the range of motion, therefore, a standardised magnitude of force application and joint displacement can not be found in the literature. However, a load-displacement curve for posteroanterior pressure applied to $L_4$ on normal human subjects, using a spinal mobiliser, has been documented. When 100 Newton force was applied to $L_4$ the displacement was 9.28 ±1.95 and 10.10 ±1.86 millimetres on $L_{3/4}$ and $L_{4/5}$, respectively.[31] Based on this information, a spring with a spring constant of 100 N/cm was obtained.

Figure 3.1 shows a typical load-displacement curve for posteroanterior pressure on the asymptomatic lumbar spine. The toe region occupies approximately two to three millimetres and the force is under 20 Newton. After two to three millimetres of displacement the relationship between the force and the displacement is linear. At the end of the range, the displacement is approximately 10 millimetres and the force is nearly 100 Newtons. Figure 3.2 demonstrates how each grade of motion is typically shown to occupy a portion of the range.[34] Figure 3.3, on the other hand, demonstrates the portion of the range each grade would occupy according to the load-displacement curve and the written definitions of each grade (Appendix A).

There were some limitations in using the model. It only allowed and measured force and motion in one plane but it could give the therapists a good idea of their perception of force applied as well as the magnitude of the motion. The linear stress/strain relationship in the model did not totally simulate the viscoelastic properties of biological tissue.[45] Thus, one must be cautious in generalisation to the clinical situation. Another factor that might have influenced the generalisability was the fact that the model only had one vertebra which excluded the possibility of comparing the motion of two or more spinal levels as physical therapists commonly do in the clinical setting.[34] Further, even though the author made an effort to simulate an end-feel of a joint by using two sets of springs, it is not known whether that end-feel simulated the normal end-feel of a vertebra in the human lumbar spine.

For the training session, a digital oscilloscope (Appendix F) was used to give direct feed-back. The scope was connected to the spinal model and displayed two visible

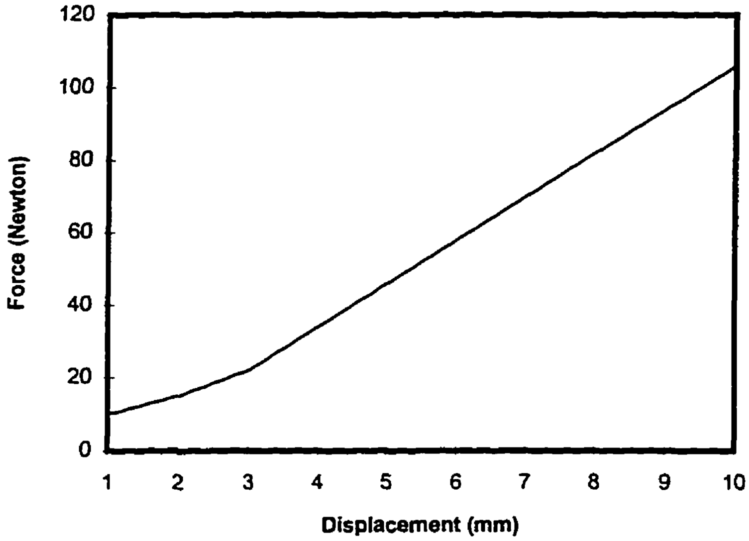


**Figure 3.1.** A load-displacement curve for posteroanterior pressure on the on the lumbar spine.

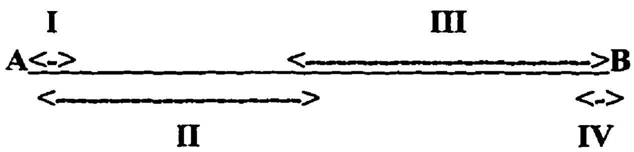


**Figure 3.2.** Grades of movement in a normal intervertebral joint. A = Beginning of range of movement. B = End of normal, average range of movement.

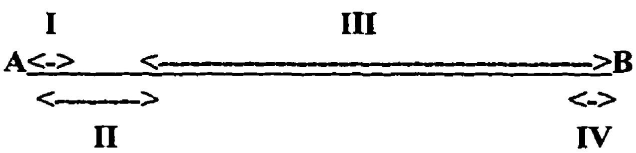


**Figure 3.3.** Grades of movement in a normal intervertebral joint, according to load displacement curves and the definitions of the grades.

lines on the screen, one for the force and one for the displacement. After each line had been adjusted to its baseline, one at the bottom and one at the middle of the screen, weight corresponding to 60 N was placed on the spinal model, elevating the lines on the screen. White tape was then adhered to the screen where the elevated lines were and the weight was removed bringing the two lines back to its baselines and leaving the tape as "target" lines for grade II mobilisations.

**D. Data Collection**

Each therapist visited The Department of Physical Therapy at the University of Alberta, five times during a three-week period. During the therapists' first visit, a self-administered information sheet (Appendix B) was filled out and a consent form (Appendix D) was signed by the participant and the principal investigator. The procedures of the experimental testing were explained and any questions were answered. This was followed by administering the pre-test. The spinal model was placed on a table and the therapists were able to adjust the height to their normal working posture. The therapists applied 30 oscillations to the vertebra where they reached the "end-feel" which had been described for them earlier (Appendix G). They were told to use the full range of motion as a reference to decide where in the range grade II should be applied according to definition (Appendix G). The definition of grade II was: a large amplitude movement performed within the free range but not moving into resistance or stiffness.[34] The therapists had access to the definition at all times. The therapists had the chance to find grade II and when they were ready the data was collected on line using a 386 computer connected to the spinal model through an A to D card (Data Translation 2801). The sample was collected for 30 seconds at a frequency of 50 Hz. The therapists were asked to estimate the magnitude of the peak force that was applied to the spinal model. The therapists were allowed to estimate the forces in pounds, kilograms or Newtons, whichever was customary to the individual. Their interpretation was converted into Newtons. They were also asked to estimate the magnitude of the motion that had occurred either in inches or millimetres which then were converted to millimetres, if applicable.

The 2nd, 3rd and 4th visits consisted of the training sessions which each took approximately 45 minutes. Each training session consisted of three components which then were repeated (Appendix H). The first component consisted of a direct feedback on force, the second on the displacement of the vertebra and the third on both factors simultaneously. For the force, the therapists were asked to apply 30 oscillations until they reached the end-feel and were told that at the point where the end-feel was reached they were applying 100 Newton. They were then asked to apply 30 oscillations of grade II, which was the target line on the screen, and repeat this three times. The same procedure was followed for the displacement. The only difference was that at the point where they reached the end-feel, the motion that had occurred was 10 millimetres. The third component gave them feedback on both factors and the same procedure was followed as before and now they knew that at the point of end-feel they were applying 100 Newton force and the motion was 10 millimetres. The three training sessions were identical.

The fifth visit included only the post-test and the same procedure was followed as for the pre-test.

## E. Statistical Analysis

The outcome measures for the statistical analysis were obtained as follows. The actual values for the force and the displacement were obtained by taking the average of a few values, representing the peak of each oscillation. The number of values for each peak depended on the frequency of oscillations for each subject, therefore, the same number of values were taken for the force and the displacement for each oscillation. The average of all the obtained peak values was then calculated and used as the outcome measure from the device. This procedure was followed for both the force and the displacement, and prior to and following the training. The actual force from the load cell was measured in pounds and converted to Newton and the magnitude of displacement from the LVDT was measured in millimetres.

The estimated values for the force and the displacement, prior to and following the training were obtained from the participants and were only treated by conversion when required. The eight variables for each subject were, therefore: actual force, estimated force, actual displacement and estimated displacement, for each of the two tests.

To meet the first objective of this study, that is, to determine the accuracy of perception prior to training, the actual and the estimated values for the pre-test were used as the outcome measures. Two-way analysis of variance (ANOVA) was chosen because there were two independent variables,[39] the groups and the estimate. Two two-way ANOVAs were computed, one for each dependent variable, the force and the displacement. Interaction effect would be expected if the two groups showed dissimilar and quantitatively different response to the same treatment.

To meet the second and the third objectives of the study two two-way ANOVAs were selected. The outcome measures for the analysis were the absolute error obtained by subtracting the estimated from the actual value for the force and the displacement, separately. Again there were two independent variables, the groups and the training and two dependent variables, the force and the displacement, which required two separate ANOVAs. Interaction effect would be expected if the relatively inexperienced physical therapists, on one hand, and the experienced manual therapists, on the other hand, do not respond to the same training quantitatively by similar amounts. For example, if one group shows improvement in their accuracy of perception, whereas the other group might not.

The correlation between the actual force and the actual displacement, for both groups and both tests was calculated by using the Pearson's Correlation Coefficient. This was done in order to determine whether the device gave consistent measures. Since the displacement occurs as a consequence of the force applied to the vertebra, a strong correlation (close to 1.00) is expected between those variables, regardless of from which group the set of data is used, or whether the pre- or the post-test data is used.

The descriptive statistics, including the mean, standard deviation, maximum and minimum values were computed for each of the eight variables of actual and estimated force and displacement, pre- and post-training, for each group, also for the absolute errors. The descriptive statistics of the therapists' characteristics, and the question on the utilisation of posteroanterior pressure, were calculated. All data analysis was conducted using the software program, Excel 5.0 for windows.

The Alpha level of significance for all the tests was set at .05 level and the total number of twenty subjects was chosen for a study power of .80 (Appendix I). The sample size calculations for a two-way ANOVA showed that nine subjects was sufficient for each group.

# Chapter IV

# RESULTS

## A. The Accuracy of Perception Before Training

### i) Force

The descriptive statistics for all outcome measures are presented in Table 4.1 and the raw data in Appendix J. The results of the two-way ANOVA for the actual and the estimated values for the force are presented in Table 4.2 The results show that there was a statistically significant difference between the actual and the estimated values but no difference between the two groups. The results indicate a poor perception of the magnitude of force the therapists in both groups applied.

The fact that the relatively inexperienced physical therapists worked within various fields of physical therapy was not expected to bias the results, since they had only been working for a few months. However, in Figures 4.1 and 4.2 all the relatively inexperienced physical therapists have been ranked. The therapist number one on the scatter plot uses posteroanterior pressure the least and number ten is the one who most frequently uses this technique. The Figures 4.1 and 4.2 show the actual and the estimated values for each therapist for force and displacement, respectively. The three therapists who do not use manual techniques are ranked first and if it did matter there would be more distance between the points of actual and estimated values for these therapists. However, the figures clearly show that this discrepancy did not affect the results.

Both groups underestimated the force they applied therefore, no interaction occurred as Figure 4.3 clearly shows. The figure also shows that the experienced group tended to use considerably more force for grade II posteroanterior pressure than did the inexperienced therapists.

**ii) Displacement**

Table 4.3 demonstrates the results of the two-way ANOVA for the actual and the estimated values for the displacement. There was a statistically significant difference between the actual and the estimated values and also between the two groups. The results show that the inexperienced physical therapists were able to accurately estimate the magnitude of displacement that had occurred, whereas the experienced manual therapists' estimates were off the actual values. The experienced manual therapists overestimated the magnitude of displacement that occurred as shown in Figure 4.4 Since one group had an accurate estimate and the other did not a significant interaction occurred.

**Table 4.1.** Descriptive statistics for the actual measurement and the estimated values for force and displacement, before and after a training session, for both groups. Also the absolute error between the actual and the estimated values.

| | Before training | | | | | | | | After training | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Force | | | | Displacement | | | | Force | | | | Displacement | | | |
| | Inexp. [1] | | Exp. [2] | | Inexp. | | Exp. | | Inexp. | | Exp. | | Inexp. | | Exp. | |
| | AF [3] | EF [4] | AF | EF | AD [5] | ED [6] | AD | ED | AF | EF | AF | EF | AD | ED | AD | ED |
| **Mean** | 61.1 | 28.4 | 77.1 | 38.1 | 4.8 | 4.9 | 5.8 | 8.8 | 62.4 | 41.3 | 72.1 | 43.9 | 5.3 | 5.1 | 5.9 | 6.0 |
| **St. Dev.** | 20.5 | 29.7 | 25.9 | 29.1 | 1.6 | 2.0 | 2.1 | 2.7 | 13.0 | 16.9 | 19.1 | 12.7 | 1.3 | 0.9 | 1.5 | 2.0 |
| **Min.** | 35.8 | 2.2 | 42.1 | 9.8 | 2.5 | 3.0 | 3.3 | 3.0 | 46.2 | 14.7 | 36.3 | 22.2 | 3.4 | 4.0 | 3.0 | 3.0 |
| **Max.** | 100.2 | 89.0 | 118.6 | 89.0 | 7.5 | 10.0 | 8.9 | 12.0 | 89.4 | 66.7 | 108.5 | 68.7 | 7.6 | 7.0 | 8.6 | 10.0 |
| | Error [7] | | Error | | Error | | Error | | Error | | Error | | Error | | Error | |
| **Mean** | 39.9 | | 40.2 | | 2.3 | | 4.4 | | 21.6 | | 29.8 | | 1.0 | | 1.5 | |
| **St. Dev.** | 23.0 | | 32.8 | | 2.0 | | 2.3 | | 15.7 | | 16.8 | | 0.5 | | 1.0 | |
| **Min.** | 8.7 | | 0.9 | | 0.2 | | 1.1 | | 0.5 | | 8.2 | | 0.3 | | 0 | |
| **Max.** | 74.6 | | 105.3 | | 7.3 | | 8.3 | | 53.1 | | 54.1 | | 1.7 | | 3.3 | |

1) Inexp. = Relatively inexperienced physical therapists
2) Exp. = Experienced manual therapists
3) AF = Actual force measured by the spinal model
4) EF = Estimated value for the force obtained from the participants
5) AD = Actual displacement measured by the spinal model
6) ED = Estimated value for the displacement obtained from the participants
7) Error = Absolute error obtained by subtracting the estimated from the actual value

**Table 4.2** Results of the two-way ANOVA for the force, using the actual and the estimated values, before the training.

| Source of Variation | SS[1)] | DF[2)] | MS[3)] | f-value | P-Value |
|---|---|---|---|---|---|
| **Groups[4)]** | **1650.7** | **1** | **1650.7** | **2.344** | **0.1345** |
| **Estimation[5)]** | **12828.6** | **1** | **12828.6** | **18.218** | **0.0001** |
| **Interaction[6)]** | **98.1** | **1** | **98.1** | **0.139** | **0.7112** |
| **Error** | **25350.6** | **36** | **704.2** | | |
| **Total** | **39928** | **39** | | | |

[1)] SS = sum of squares
[2)] DF = degrees of freedom
[3)] MS = mean squares
[4)] Groups = Relatively inexperienced physical therapists and experienced manual therapists.
[5)] Estimation = Comparing the estimated value to the actual
[6)] Interaction = groups x estimation

**Table 4.3.** Results of the two-way ANOVA for the displacement, using the actual and the estimated values, before the training.

| Source of Variation | SS[1)] | DF[2)] | MS[3)] | f-value | P-Value |
|---|---|---|---|---|---|
| **Groups[4)]** | **62.3** | **1** | **62.3** | **13.739** | **0.0007** |
| **Estimation[5)]** | **24.2** | **1** | **24.2** | **5.337** | **0.0267** |
| **Interaction[6)]** | **19.7** | **1** | **19.7** | **4.357** | **0.0440** |
| **Error** | **163.1** | **36** | **4.5** | | |
| **Total** | **269.3** | **39** | | | |

[1)] SS = sum of squares
[2)] DF = degrees of freedom
[3)] MS = mean squares
[4)] Groups = Relatively inexperienced physical therapists and experienced manual therapists.
[5)] Estimation = Comparing the estimated value to the actual
[6)] Interaction = groups x estimation

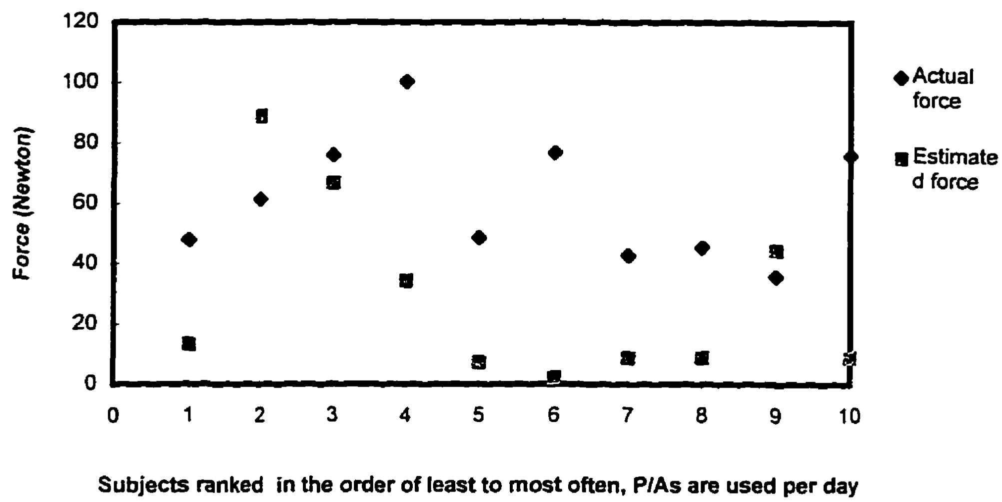


**Figure 4.1.** The actual and the estimated force for each inexperienced physical therapist, ranked according to the frequency of posteroanterior pressure per day.

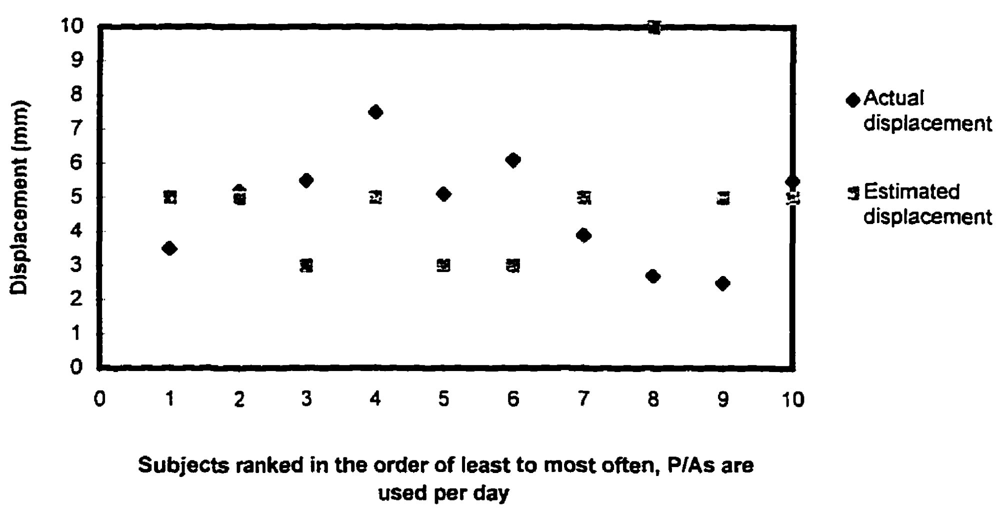


**Figure 4.2.** The actual and the estimated displacement for each inexperienced physical therapist, ranked according to the frequency of posteroanterior pressure used per day.

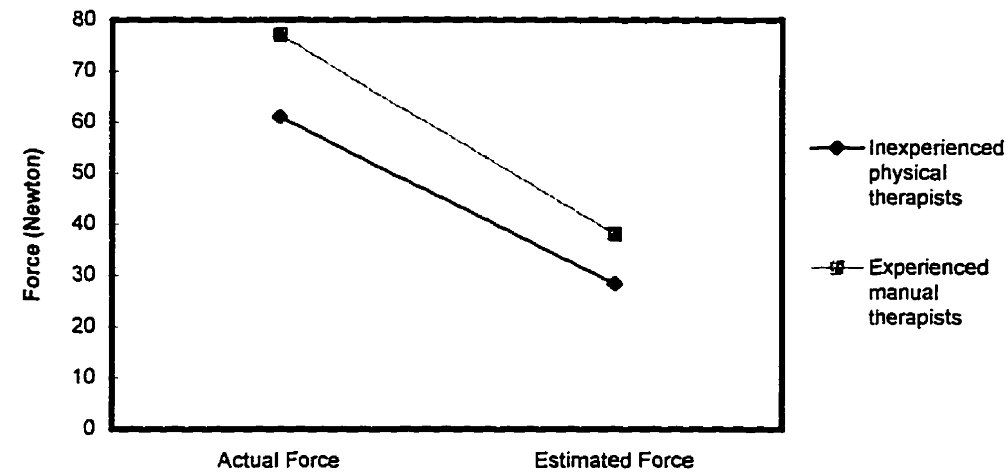


**Figure 4.3.** Means of the actual and the estimated values of the force, for both groups of therapists, before the training.

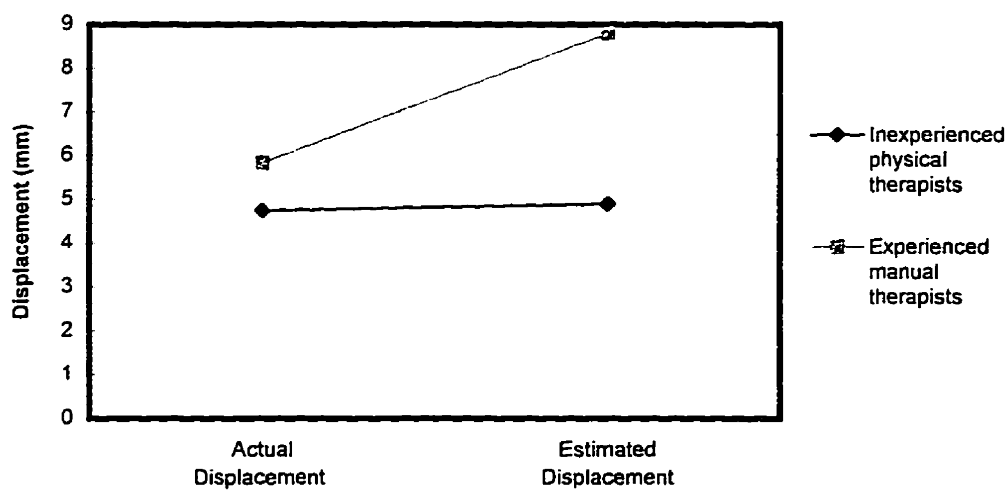


**Figure 4.4.** Means of the actual and the estimated values of the displacement, for both groups of therapists, before the training.

**B. The Accuracy of Perception After Training**

**i) Force**

The results of the two-way ANOVA of the absolute errors of the force show that there was not a statistically significant difference between the pre- and the post-test, although the p-value of 0.057 approached significance (see Table 4.4). There was no difference between the two groups and there was no interaction. However, as Figure 4.5 shows, both groups have a similar error before the training. Both groups tended to decrease their error but the inexperienced physical therapists' error decreased more, however, not at a significant level.

**Table 4.4.** Results of the two-way ANOVA for the force, using the absolute error when subtracting the estimated value from the actual value.

| Source of Variation | SS[1] | DF[2] | MS[3] | f-value | P-Value |
|---|---|---|---|---|---|
| Groups[4] | 176.7 | 1 | 176.7 | 0.332 | 0.568 |
| Training[5] | 2055.8 | 1 | 2055.8 | 3.862 | 0.057 |
| Interaction[6] | 159.2 | 1 | 159.2 | 0.299 | 0.588 |
| Error | 19164.6 | 36 | 532.3 | | |
| Total | 21556.3 | 39 | | | |

[1] SS = sum of squares
[2] DF = degrees of freedom
[3] MS = mean squares
[4] Groups = Relatively inexperienced physical therapists and experienced manual therapists.
[5] Training = pre-training and post-training
[6] Interaction = groups x training

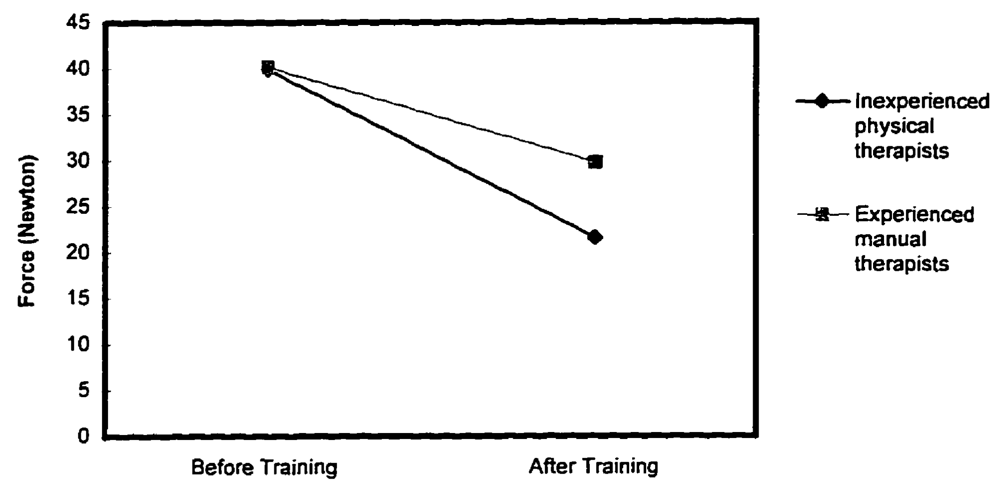


**Figure 4.5.** Means of the absolute error calculated from the actual and the estimated values for the force.

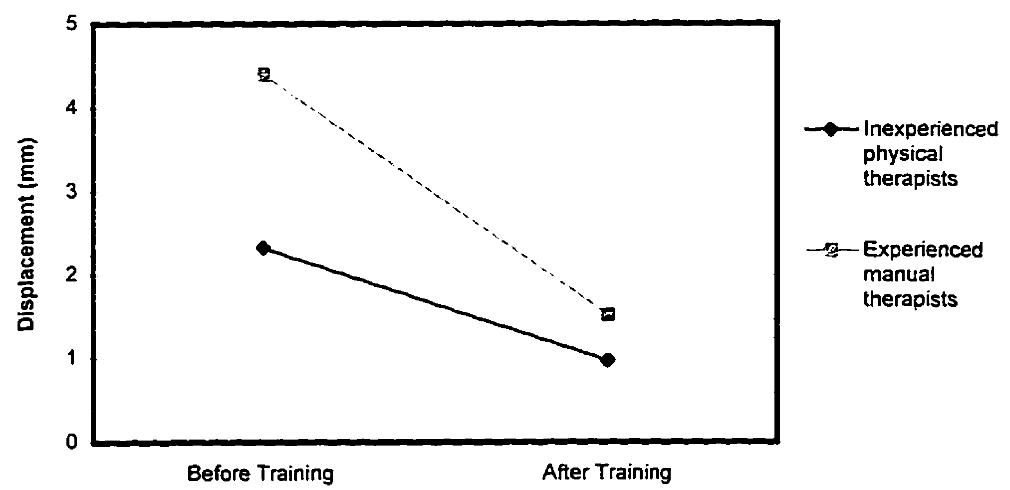


**Figure 4.6.** Means of the absolute error calculated from the actual and the estimated values for the displacement.

**ii) Displacement**

There was a statistically significant difference between the two groups of physical therapists in the absolute error, when estimating the magnitude of displacement that occurred, applying grade II, posteroanterior pressure to a vertebra. The results of the two-way ANOVA for the displacement are demonstrated in Table 4.5 and also show that there was a statistically significant difference between the tests before and after the training. According to the pre-test (Table 4.3) the inexperienced physical therapists' perception was good prior to the training but their error still decreased following the training. The experienced manual therapists improved their poor perception of the magnitude of displacement that occurred following the training. Statistically, both groups reacted similar to the training but the experienced group decreased their error significantly more than the inexperienced, as Figure 4.6 shows.

**Table 4.5.** Results of the two-way ANOVA for the displacement, using the absolute error when subtracting the estimated value from the actual value.

| Source of Variation | SS[1)] | DF[2)] | MS[3)] | f-value | P-Value |
|---|---|---|---|---|---|
| Groups[4)] | 17.2 | 1 | 17.2 | 6.384 | 0.016 |
| Training[5)] | 44.9 | 1 | 44.9 | 16.719 | 0.000 |
| Interaction[6)] | 5.8 | 1 | 5.8 | 2.149 | 0.151 |
| Error | 96.8 | 36 | 2.7 | | |
| Total | 164.7 | 39 | | | |

1) SS = sum of squares
2) DF = degrees of freedom
3) MS = mean squares
4) Groups = Relatively inexperienced physical therapists and experienced manual therapists.
5) Training = pre-training and post-training
6) Interaction = groups x training

**C. Force - Displacement Correlation**

Table 4.6 shows the results of the Pearson's Correlation test and, as expected, there was a very strong correlation between the force and the displacement. Since the spring constant was ten Newtons per millimetre it was expected to see approximately one millimetre displacement for each ten Newtons of force applied. When comparing the mean values for the force and the displacement in Table 4.6, there was an obvious discrepancy, where the force was consistently higher than the expected resultant displacement. This discrepancy, however, remained consistent through the study and is most likely due to friction in the moveable components in the spinal model.

**Table 4.6.** The Pearson's Correlation Coefficient and the mean values for the force and the displacement.

| | Before Training | | | After Training | | |
|---|---|---|---|---|---|---|
| | PCC[1)] | Force[2)] | DP[3)] | PCC | Force | DP |
| Inexp. PT.[4)] | 0.92 | 61.1 | 4.8 | 0.96 | 62.4 | 5.3 |
| Exp. MT.[5)] | 0.96 | 77.1 | 5.8 | 0.94 | 72.1 | 5.9 |

[1)] PCC = Pearson's Correlation Coefficient, between the force and the displacement
[2)] Force = The mean of the actual force values
[3)] DP = The mean of the actual displacement values
[4)] Inexp. PT. = Relatively inexperienced physical therapists
[5)] Exp. MT. = Experienced manual therapists

**D. The Utilisation of Posteroanterior Pressure**

The therapists answered a question on the utilisation of posteroanterior pressure. Although, this was not mentioned in the objectives of the study, it has some value for discussion purposes. Only the seven relatively inexperienced physical therapists who used manual techniques daily answered these questions. They treated approximately five patients each working day by using posteroanterior pressure on the spine. The experienced manual therapists treated approximately four patients a day by using this technique. The descriptive statistics are presented in Table 4.7.

**Table 4.7.** Descriptive statistics on the number of patients the therapists treated by using posteroanterior pressure per day.

| Statistics | Inexp. PT[1)] | Exp. MT[2)] |
|---|---|---|
| Mean | 5.1 | 3.8 |
| Standard Deviation | 4.6 | 2.0 |
| Minimum | 1 | 0 |
| Maximum | 13 | 7 |

[1)] Relatively inexperienced physical therapists
[2)] Experienced manual therapists

# Chapter V

# DISCUSSION

## A. Accuracy of Perception Before Training

A significant difference between the actual and the estimated values was expected for the force and the displacement, under controlled laboratory conditions. A recent study had shown that physical therapists had poor perception when estimating the forces applied and the resultant displacement.[45] The results of the pre-test, in this study, suggest that physical therapists have indeed poor perception of the forces they apply, regardless of experience. However, this was not true for the displacement. The inexperienced group could accurately estimate the magnitude of displacement that occurred whereas the experienced group did not.

It seems logical to compare the results of this study with those from the study by Simmonds *et al.* (1995),[45] since both studies used the same spinal model. Yet, the studies are not entirely comparable because of considerable modifications to the spinal model. The spring constant used in this study was 100 N/cm compared to 222 N/cm in the least of the three stiffness conditions in Simmonds' study. The stiffness levels are, therefore, hardly comparable. Simmonds *et al.* (1995) used a group of experienced manual therapists and also tested for the difference between the actual and the estimated values. Their results show that there was a statistically significant difference between these values for both the force and the displacement. Since Simmonds *et al.* (1995) used only experienced manual therapists, the comparison can only apply to the experienced manual therapists in this study. The results of these two studies are therefore in agreement with each other for both the force and the displacement. It was the inexperienced group that proved to have more accurate estimate for the displacement. It is not clear why there was a difference between these groups in estimating the magnitude of displacement. However, the experienced manual therapists have taken more courses in manual therapy than the inexperienced physical therapists. In these courses the emphasis is generally on detection of abnormalities, stiffness or resistance changes and various end-feels. It is surmised that physical therapists may gradually loose the ability to judge the magnitude of displacement with progressive training in manual therapy due to different emphasis. The inexperienced physical therapists on the other hand may still be able to judge the magnitude of displacement, perhaps because they have not had the opportunity to specialise.

The therapists participating in this study, generally stated that they were not accustomed to thinking about the force they applied when using posteroanterior pressure on the spine. Nor were they used to thinking in terms of millimetres when assessing the displacement of a spinal segment. Physical therapists learn to assess posteroanterior displacement of a spinal segment by grading the motion according to stiffness or resistance. All therapists in this study stated difficulties in determining the magnitude of forces they applied and the ensuing displacement (they found the force harder to estimate).

Although the inexperienced physical therapists were younger (mean age = 25 than the experienced manual therapists (mean age = 43) there was no obvious trend for the younger in either group to be more or less accurate. Also, there was no trend for one gender to be more accurate than the other. However, these factors could be studied more reliably with a larger sample size.

The inexperienced physical therapists tended to underestimate the magnitude of the force they applied, with two exceptions. The experienced manual therapists also underestimated the force with one exception and eight of them overestimated the displacement. This trend is in agreement with the results from the study by Simmonds *et al.* (1995).[45] However, only four of the ten inexperienced physical therapists tended to overestimate the magnitude of displacement.

It was interesting to see that the inexperienced physical therapists applied grade II very close to the middle of the available range. Their mean displacement was 4.8 millimetres, or 0.2 millimetres under the halfway of the available range. The definition of grade II, posteroanterior pressure on the spine did not indicate how far into the range the pressure should be applied. It only informs that grade II is a large amplitude motion within the resistance free portion of the range. However, when the grades are explained in diagrams, grade II is usually shown to reach approximately 50 percent of the total range. There is an obvious discrepancy in the definition of grades of motion as explained in the text book[34] which might influence therapists' decision in positioning grade II. Since there was only one spring with a constant resistance, until the "end-feel" was reached, there was no expectation of "increased resistance".

It may be speculated that the inexperienced group was following the diagrams since their actual mean value of displacement was so close to the mid-range. The experienced group, on average, compressed the spring harder, or one millimetre more than the inexperienced group. It may be surmised that the experienced manual therapists were possibly expecting some resistance as indicated in the definition.

It has been mentioned earlier that although there was a strong correlation between the actual force and the actual displacement, there was a discrepancy between the mean values. It is not known whether the friction in spinal model was consistent through the range or if the surfaces of the brass and/or the aluminium block might have been uneven, possibly causing irregular friction. If that was the case, an increased resistance may have been felt by the more experienced group indicating that they perceived some difference and decided that grade II would go as far as this increased resistance was sensed. However, if there was uneven friction it clearly was not consistently at the same point in the range throughout the experiment (see variability in the raw data, Appendix J). Actually, some of the experienced manual therapists pointed out that they sensed uneven friction in the system which was not always at the same point in the range from one visit to another.

Since the inexperienced group was able to accurately estimate the magnitude of motion that occurred it could be concluded that they had a good perception of grade II. However, this does not tell how close to grade II they were since grade II can be looked at in different ways, according to diagrams and the definition. The experienced group seems to have a different idea of grade II or use other determinants. The unreliability of posteroanterior motion testing, shown by numerous studies[6,22,32] may perhaps be explained by the difference in the decision of positioning each grade.

The results might suggest that physical therapists establish their own criteria of the grading system, in accordance with experience. Mior *et al.* (1990) suggested that experience did not play a role in clinical accuracy and that experienced therapists established their own criteria.[35] However, it is evident that the definition of any test has to be clear and consistent so that all clinicians use the test in the same way. Only then can accurate and reliable testing be expected.

The artificial end-feel of the spinal model consisted of a second set of springs that gave double resistance to the pressure. All the participants, regardless of experience, were able to sense this increased resistance. All therapists positioned grade II within the prescribed end of range, although by increasing the force, they could have exceeded that limit.

Physical therapists use the end-feel of joint to assist with assessment. For them, it is not necessarily the force applied that matter, rather the joint's response to that force applied. However, it would be valuable to know the magnitude of the force applied to a vertebra, since it could facilitate standardisation of the technique.

To have the credibility to work as a physical therapist within the field of musculoskeletal disorders, one is expected to have the ability to perceive the quality of accessory motion. It would be worthy to investigate whether physical therapists can perceive accurately, various stiffness levels in a system like the spinal model. It would also be worthy to investigate the magnitude of the minimum stiffness change, physical therapists can possibly perceive.

**B. Effect of Training on the Accuracy of Perception**

The purpose of the training session in this study was primarily to investigate its effects on the accuracy of the estimates of force and displacement. Although the results of this study did show that inexperienced physical therapists were able to estimate the displacement accurately without any training, it was expected that the therapists in both groups would be inaccurate. Therefore, a training session was used as a method to see if the therapists would be able to improve their estimates.

It was certainly expected that the more experienced and advanced physical therapists would have had more sense of the magnitude of displacement that occurred. However, the results of this study show that the more inexperienced therapists were better in their estimation before the training. This study suggests that the training proved successful for the experienced therapists since their improvement was of a significant level.

Training with direct feedback has been shown to be an effective method of repeating predetermined forces when physical therapy students apply posteroanterior pressure on the lumbar spine.[29] Further, Keating *et al.* (1993) found a significant improvement in the replication of specified forces when training physical therapists by using a bath scale for feedback.[21] These studies also indicate that physical therapists maintain the effects of the training over a period of one week[29] or a month.[21]

The therapists in this study did not perform the post-test immediately after the training, which could have influenced the results. Physical therapists are quite busy, especially those who work in private practice. It was, therefore not manageable for all the therapists to make the five appointments with exactly the same number of days between. This may not have been an issue. Figure 5.1. shows that there was no obvious trend for the therapists with more time between the fourth and the fifth sessions to have a larger absolute error for the force than those who had less time between the two visits, as might have been expected.

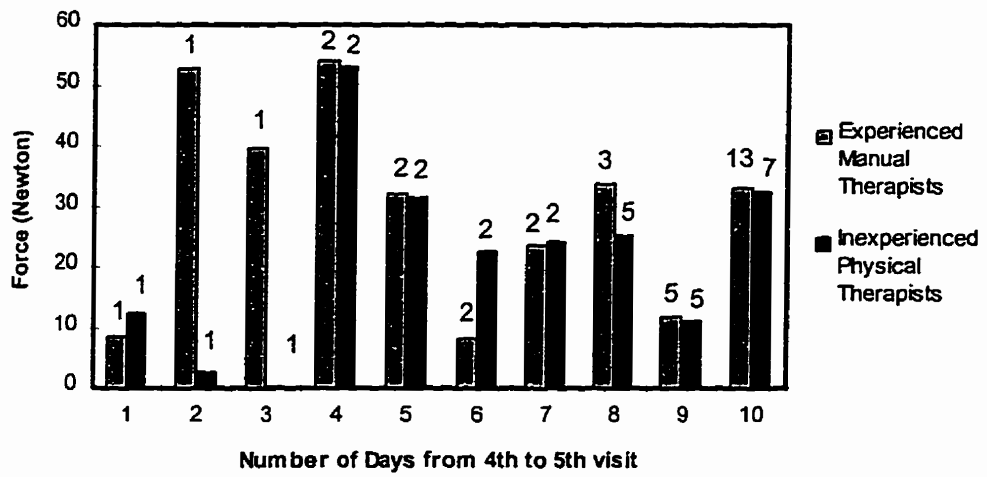


**Figure 5.1.** Absolute error when the actual force value is subtracted from the estimated value. Therapists are ranked in the order of the number of days between the 4th and the 5th visit. This number is written on top of the bars.

Those physical therapists, participating in this study, who treated spinal problems, generally, used posteroanterior pressure for diagnostic and treatment purposes, on a daily basis. Since the physical therapists use posteroanterior motion testing to some extent, it is important that they are able to present their findings in a standardised manner. However, it may be difficult for physical therapists to change their way of teaching and using posteroanterior pressure, since the grading system has been used for years. The knowledge of the spine's responses to posteroanterior pressure has increased significantly during the last decades as a number of studies have shown.[24,25,26,27,28,30,31,43] Considering the results of this study, it is evident that training is a good method of improving the accuracy of perception when estimating the displacement. It should be possible in the near future to integrate the grading system with the present knowledge of the mechanical responses. Experts could decide on the standard magnitude of displacement and the corresponding forces to each grade of motion. This might need to be done for each segment, and further research on gender differences and age is required. When each grade has been standardised, students can use direct feedback to learn and practice these standardised values of force and displacement in order to estimate these values accurately. This would be a reasonable way to improve the communication between therapists and between therapists and other health care professionals.

Although the feedback with a digital oscilloscope used in this study was successful for the displacement, it was not the case for the forces applied. Since the difference between the pre- and post-test approached significance it might be suggested that with more training the accuracy could have increased. Additional study with longer training may answer this important question. Once further research has established how much training would be needed in order to improve the estimation significantly. Obtaining such result may prove to be beneficial in clinical practice.

The limitations of the equipment must be born in mind in deriving conclusions from this study. The spinal model allowed measurements of force and displacement only in the vertical direction, although it can give the therapists an idea of their perception of these factors. The model has linear load deflection relationship and therefore, did not totally simulate the human biological tissue, which limits the generalisation to the clinical situation. Only one vertebra mounted in the spinal model excludes the comparison of the motion occurring at different levels in the spine as is the case in the clinical situation. It is not known if the artificial end-feel in the spinal model simulates normal end-feel in the human lumbar spine. It is not known how much the friction in the system influenced the results. During the training, the target lines on the scope's screen, basically depended on a specified amount of force, whereas the target line for the force at 60 Newton may have given a more reliable feedback. The target line for the displacement may have varied due to friction in the system.

# Chapter VI

# SUMMARY AND CONCLUSION

## A. Summary

The objectives of the study were to determine the accuracy of perception among two groups of physical therapists at different levels of education and experience. This was determined for force and displacement when the therapists applied posteroanterior pressure to a vertebra, before and after a training session. Group differences were also determined. The groups consisted of relatively inexperienced physical therapists and experienced manual therapists.

To conduct the study a spinal model was used that measured the actual forces and corresponding displacement. The therapists estimated these factors. These factors were tested before and after a training session. The main matrix for the outcome measures was obtained from the instrument and the physical therapists for the statistical analysis.

Two-way ANOVAs were used for the inferential statistics, central to the objectives of the study, although using different outcome measures. To determine the accuracy of perception before the training the difference between the actual and the estimated values was used. To determine the effects of training and group differences, the absolute error between the actual and the estimated values was used.

**B. Decision on Research Hypotheses**

1a. There was a statistically significant difference, between the means of the actual forces applied and the estimated values obtained from relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was retained.

1b. There was a statistically significant difference, between the means of the actual forces applied and the estimated values obtained from experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was retained.

1c. There was not a statistically significant difference, between the means of the actual magnitude of displacement that occurred and the estimated values obtained from relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was rejected.

1d. There was a statistically significant difference, between the means of the actual magnitude of displacement that occurred and the estimated values obtained from experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was retained.

2a. There was not a statistically significant difference, between the absolute errors of the force, before and after a training session, among relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was rejected.

2b. There was not a statistically significant difference, between the absolute errors of the force, before and after a training session, among experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was rejected.

2c. There was not a statistically significant difference, between the absolute errors of the magnitude of displacement, among relatively inexperienced physical therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was rejected.

2d. There was a statistically significant difference, between the absolute errors of the magnitude of displacement, among experienced manual therapists, applying grade II posteroanterior pressure to a vertebra.

The hypothesis was retained.

3a. There was not a statistically significant difference, between relatively inexperienced physical therapists and experienced manual therapists estimating the force, when applying grade II posteroanterior pressure to a vertebra, before and after a training session, when using the means of the absolute errors for the statistical analysis.

The hypothesis was rejected.

3b. There was a statistically significant difference, between relatively inexperienced physical therapists and experienced manual therapists, estimating the displacement that occurred when applying grade II posteroanterior pressure to a vertebra, before and after a training session, when using the means of the absolute errors for the statistical analysis.

The hypothesis was retained.

## C. Conclusions

Based on the results of this study, the following conclusions were drawn:

1. It is suggested that relatively inexperienced physical therapists have accurate perception of the magnitude of displacement that occurs in a spinal model when using grade II, posteroanterior pressure on a vertebra. Experienced manual therapists, on the other hand, have poor accuracy of perception of the displacement under same conditions.

   The results suggest that relatively inexperienced physical therapists and experienced manual therapists have poor perception of the magnitude of forces applied to a spinal model when using grade II, posteroanterior pressure on a vertebra.

2. The results of the study indicate that experienced manual therapists improve their accuracy of perception of the magnitude of displacement, following a training session by using direct feedback.

   It may be suggested that physical therapists, regardless of experience might improve their accuracy of perception of the force applied with longer training session than used in the present study.

3. It may be concluded that relatively inexperienced physical therapists have better perception of the forces applied and displacement produced than experienced manual therapists, when using posteroanterior pressure. Further, the relatively inexperienced physical therapists generally respond better to training on the force than the experienced manual therapists.

On the basis of theses conclusions, it can be stated that the spinal model along with a digital oscilloscope can be used as an effective training tool to enhance the accuracy of perception in posteroanterior motion testing and mobilisation of lumbar spine.

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## APPENDICES

# APPENDIX A

## Definitions of common terms

**Definition of a Passive Accessory Intervertebral Motion**

Passive accessory intervertebral motion has been defined by Maitland (1986)[4] as joint movements which cannot be performed voluntarily or in isolation but are a necessary component of normal joint function. The range of accessory movement is small but a full range is required for full range of active and passive motion of a joint. The range of accessory movement is greatest when the muscles acting over the joint are relaxed and the joint is positioned midway between the limits of its different directions of active movements.

Maitland's definition correlates with the one described by Williams and Warwick (1980).[6] Their definition of an accessory movement is all joint surface motions that actively cannot be performed in the absence of resistance.

**Definition of resistance**

Resistance to motion occurs in a normal joint function. Kaltenborn (1985) [2] divides the resistance felt during passive motion into two parts. The "first stop" is at the end of the physiological range of the joint's motion and the "final stop" is referred to as the "end-feel" and the quality of the "end-feel" depends on the joint tested.

Maitland (1977) [5] identifies Kaltenborn's "first stop" as R1 and the "final stop" as R2 for the physiological movement. However, the resistance felt in the accessory movement has different characteristics since it is not the patient's voluntary motion. Authors have not come to a conclusion of a definition of resistance related to accessory motion. However, Lee *et al.* (1990) [3] state that for accessory motion, resistance begins early in the range of motion and increases linearly as the motion continues.

**Definition of stiffness**

Corrigan and Maitland (1983)[1] define stiffness as a loss of accessory movement in association with loss of normal joint movement. They claim that at times, a restriction in the range of accessory movement may be the only relevant clinical finding detectable. The available range is tested with the joint placed in two positions. Firstly, midway between the limits of all active ranges; and secondly, with the joint placed at the limit of any one or all directions of an active movement. Maitland (1986) [4] apparently uses the terms stiffness and resistance interchangeably.

**Definition of Maitland's grades of mobilisation.**

Maitland (1986) [4] provides a detailed description of the types of movements which are divided into four grades for the sake of learning the technique.

<u>Grade I</u> is a small -amplitude movement performed at the beginning of the range.

<u>Grade II</u> is a large-amplitude movement performed within the free range but not moving into any resistance or stiffness.

<u>Grade III</u> is a large-amplitude movement performed up to the limit of the range.

<u>Grade IV</u> is a small-amplitude movement performed at the limit of the range.

Figure 1. explains visually the position and the magnitude of each grade in the range of intervertebral joint motion for normal motion according to Maitland (1986). [4]

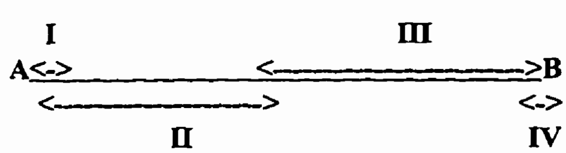


Figure 1. Grades of movement in a normal intervertebral joint. A = Beginning of range of movement. B = End of normal, average range of movement.

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# APPENDIX B

## Questionnaires

**Inexperienced Physical Therapists**

Name:____________________________________________________

Where and when (year and month) did you gain your B.Sc. degree in physical therapy?

__________________________________________________________

What is your field of physical therapy and for how long (months) have you been practising? ________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

__________________________________________

If you treat any spinal problems, please answer the following questions.

How many patients do you treat by using posteroanterior pressure?

A day: _______________________

A week: _______________________

A month: _______________________

On the average, when you use posteroanterior pressure as a treatment method, how many oscillations (approximately) do you use?

For one sequence: __________________________________

How many sequences do you use for one treatment? ____________

Do you use posteroanterior pressure for diagnostic purposes? _____ yes _____ no

In terms of percentages, how important is posteroanterior pressure in your final decision of diagnosis? ________________________________________

How much do you use manual techniques on the spine, including soft tissue treatments?

A day: _________________

A week: _________________

A month: _________________

How much do you use manual techniques on the extremities, including soft tissue treatments?

A day: _________________

A week: _________________

A month: _________________

**Experienced Manual Therapists**

Name:______________________________________________

Where and which year did you gain your B.Sc. degree in physical therapy? ________

______________________________________________

What was your field of physical therapy and for how long did you practice in each field before you started the manual therapy education? ______________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

Which year did you start your manual therapy education?_____________________

Where and which year did you complete your examination or degree in manual therapy?______________________________________________

______________________________________________

For how many years have you been practising manual therapy, including required practice for your examination? ______________________________

For how many years and months have you been practising manual therapy after the completion of examination? ______________________________

How many patients do you treat by using posteroanterior pressure?

A day: ______________________

A week: ______________________

A month: ______________________

On the average, when you use posteroanterior pressure as a treatment method, how many oscillations (approximately) do you use?

For one sequence: ______________________________

How many sequences do you use for one treatment? ______________

Do you use posteroanterior pressure for diagnostic purposes? ______ yes ______ no

In terms of percentages, how important is posteroanterior pressure in your final decision of diagnosis? ______________________________________

How much do you use manual techniques on the spine, including soft tissue treatments?

A day: ________________

A week: ________________

A month: ________________

How much do you use manual techniques on the extremities, including soft tissue treatments?

A day: ________________

A week: ________________

A month: ________________

# APPENDIX C

**Introductory letter**

Dear ______________________________,

Thank you for your interest in participating in the study: Posteroanterior motion test of a lumbar vertebra. A study of accuracy of perception among physical therapists, at two different educational and experience levels, before and after a training session.

Your participation is appreciated and will hopefully lead to further progress in our profession, physical therapy.

Supplied with this letter is a form of consent that I ask you to sign after you have considered your final decision whether to participate in the study. Please, feel free to call me at any time or we can arrange a convenient appointment time.

Thank you for your time and your interest.

Yours truly,

______________________________

Sigrún Vala Björnsdóttir, MSc. PT. candidate
Department of Physical Therapy
University of Alberta
Edmonton, Alberta

# APPENDIX D

## Consent form

A consent form.

---

Title: Posteroanterior motion test of a lumbar vertebra. A study of accuracy of perception among physical therapists, at different educational and experience levels, before and after a training session.

Investigators: Sigrún Vala Björnsdóttir, MSc. PT. candidate, Physical Therapy. Rehab. Med. U of A. Phone & fax: 433-9959
Dr. Kumar S, professor, Physical Therapy. Phone: 492-5983.

Purpose: The purpose of this project is to investigate if the use of a spinal model can improve the perceptual skills of physical therapists, estimating the force applied and the magnitude of displacement, performing posteroanterior pressure on the lumbar spine. You will have to visit Corbett Hall, University of Alberta, Edmonton, five times, with equal intervals, during two weeks period. In the first visit you will be asked to estimate these factors by using Maitland's grade II on the spinal model. The second, third, and fourth visits consist of a practise session, where you will have the opportunity to use the spinal model for approximately 45 minutes and receive feedback on your work. The fifth and the last visit consists of a post-test, where you, again, will be asked to estimate the force applied and the magnitude of the displacement.

Consent:

I, ____________________________________, agree to participate in the above named project. I understand that my participation is voluntary. I may withdraw from the study at any time without consequences to myself. I recognise that I may not necessarily benefit from the study.

I also understand that all results from my work will be treated confidentially. My name will not appear on any of the completed worksheets - only an identifying code number. My name will not be associated with any publications arising from the research as all information will be presented in a summary form.

All questions that I had about the project have been answered to my satisfaction, but I will be free to ask further questions of any investigator at any time - both during visits and between visits at phone & fax number: 433-9959.

______________________________ ____________________

Participant's signature Date

______________________________ ____________________

Principal Investigator's Signature Date

# APPENDIX E

## Description of the spinal model

# SPINAL MODEL

A special spring-resisted housing with an artificial lumbar vertebra on top, was designed at the University of Alberta (Figure A.1). The housing was a round brass block with equal length and diameter of 12.5 cm. At the top end of the brass block a hole was bored 6.5 cm deep and 7.7 cm in diameter. At the base of this hole, five smaller holes, 3 cm deep and 1.5 cm in diameter, were machined for the springs to be positioned. These holes allowed for various combinations of springs to be used, depending on the desired stiffness level.

In this study, one spring was placed in the middle of the housing. That spring was 57 mm in length and had a spring constant of 100 N/cm. Two springs were placed in the outer region of the housing, each of them was 51 mm in length and had a spring constant of 50 N/cm. The depth of the holes for the springs were adjusted so that there would be precisely ten millimetres difference in length between the middle spring and the two outer springs.

An aluminium block was fitted inside the brass block. The aluminium block was 7.7 cm in diameter and 6.5 cm in length and had indentations at the bottom, into which the springs fitted when the aluminium block was placed on top of them. Another aluminium block, 7.7 cm in diameter and 2.5 cm in length with two holes at the base, was positioned on top of the first aluminium block, where two bars from it protruded into the corresponding holes in the top block. A round hole was machined on the top of the second block where the vertebra was firmly fitted.

A linear variable differential transformer (LVDT) was mounted on the side of the brass block and measured the magnitude of the displacement of the vertebra. A thin aluminium bar connected the LVDT to the aluminium block. The whole structure was placed on a wooden board. Underneath the board was a load cell allowing for the applied force to be measured. The load cell was then fixed to another wooden board. This device was then placed on a larger wooden platform on top of a table.

Calibration of the model was conducted prior to the first experiment each day by using a standardised weight of 1.250 pounds for the load cell. The LVDT was calibrated by manually moving the shaft through 0.5 millimetres increments using a Mitutuoyo Digital Calliper. The output were sampled at 50 Hz frequency through a Data Translation 2801 A/D data acquisition board into a computer.

**SPINAL MODEL**

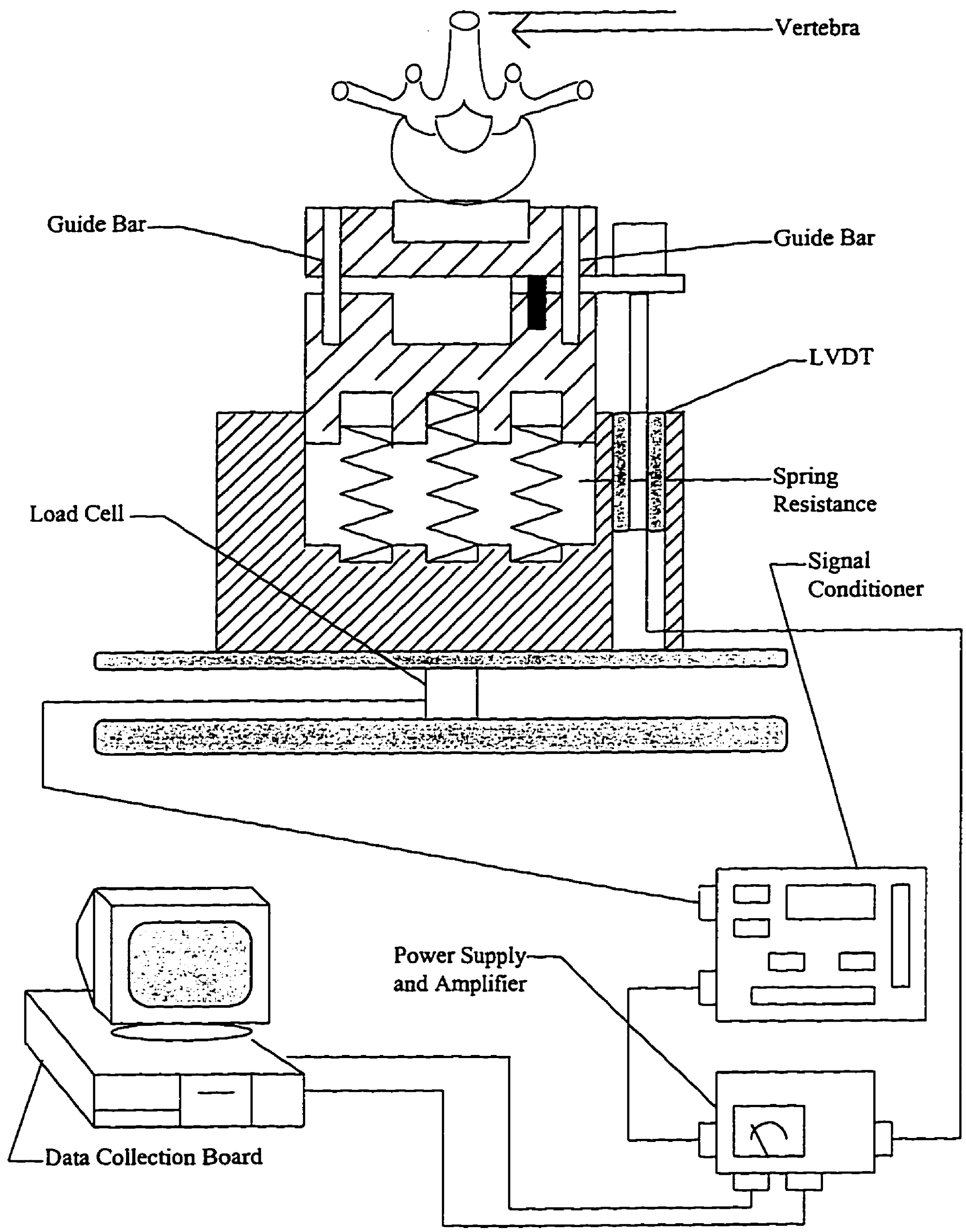


**Figure 1** Schematic of the Spinal Model.

# APPENDIX F

## Description of the digital oscilloscope

## DIGITAL OSCILLOSCOPE

For the training, a digital oscilloscope (Figure A.2) was placed opposite to the therapists and was used to give direct feed-back. Two channels on the oscilloscope were used, one for the force and one for the displacement. The channel for the force was connected to the load cell through the signal conditioner and the channel for the displacement was connected to the LVDT through the amplifier

The two channels on the scope displayed two visible lines on the screen, one for the force and one for the displacement. After each line had been adjusted to its baseline, one at the bottom and one at the middle of the screen, weight corresponding to 60 N was placed on the spinal model, elevating the lines on the screen. White tape was then adhered to the screen, one for each line. The bottom of the tape was placed where the elevated line was and the weight was then removed, bringing the two lines back to its baseline and leaving the tape as "target" lines for grade II mobilisations. When the therapists applied oscillating force to the vertebra the lines moved according to the oscillations, giving them direct feedback on the force they applied on one hand and on the displacement on the other hand.

## Digital Oscilloscope

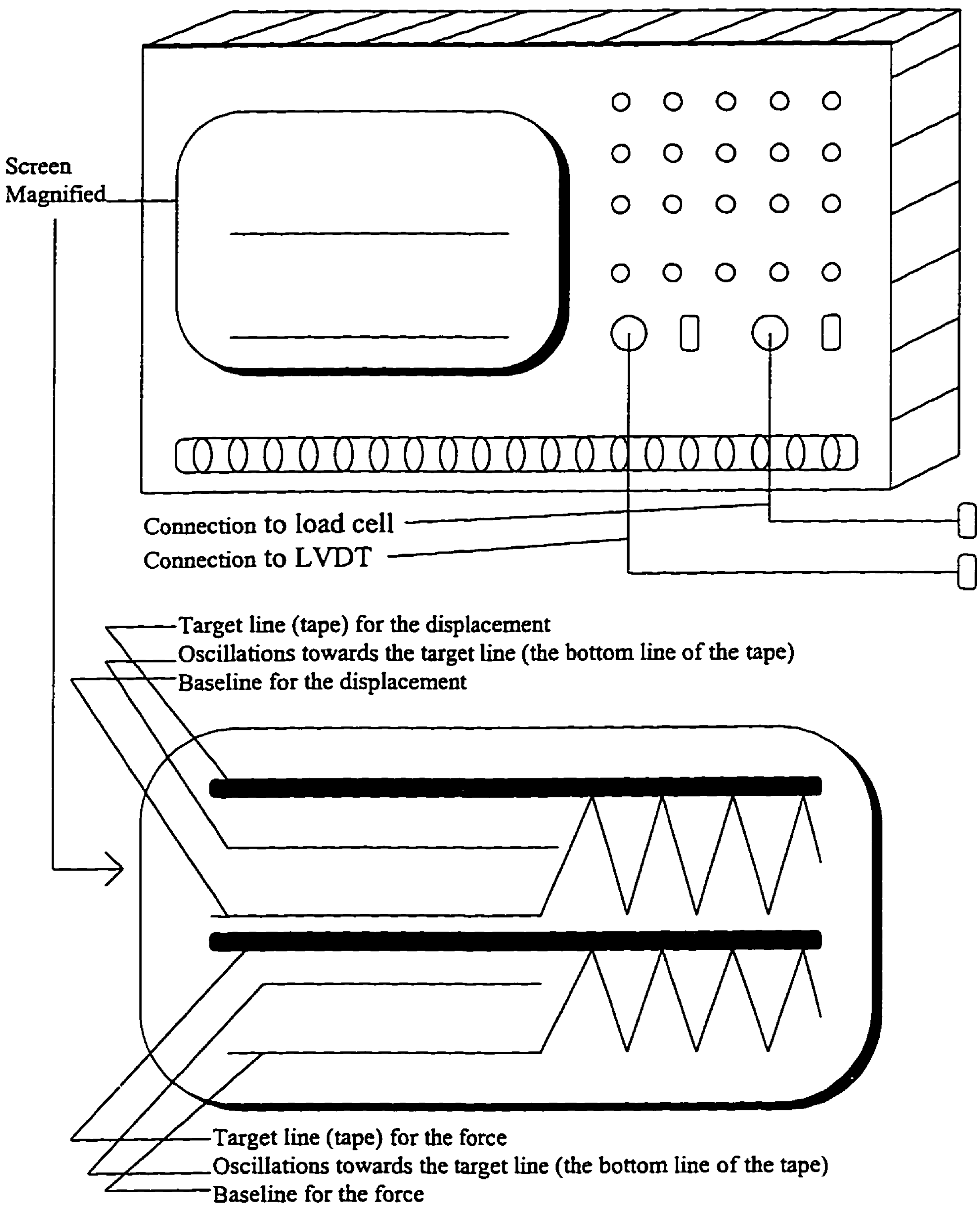


**Figure A.2** Schematic of the Digital Oscilloscope.

# APPENDIX G

## Instructions for the tests

## INSTRUCTIONS FOR THE TESTS

**General information:**

The spinal model has a spring system that assimilates the accessory movements in the lumbar spine, when force is applied in the vertical direction. When force is applied the first set of springs compress, resulting in a certain magnitude of displacement in relation to the amount of force applied. The second set of springs give increased resistance and is, in this study, considered the "end-feel" and full range of accessory motion has been reached.

**Instructions:**

The spinal model is an unfamiliar method for participants and only assimilates the human body. Therefore, participants will have the opportunity to practice and familiarise themselves with the functional behaviour of the spinal model.

Apply 30 oscillations to the spinal model until you reach the "end-feel".

Apply Maitland's grade II, according to definition. When you feel comfortable with grade II, data will be collected over a period of 30 seconds. During the data collection, think about the peak force that you are applying and the magnitude of displacement that occurs.

Immediately after the data collection, estimate the amount of forces you applied and the magnitude of displacement that occurred.

**Definition of Maitland's grades of mobilisation.**

Maitland (1986) provides a detailed description of the types of movements which are divided into four grades for the sake of learning the technique.

<u>Grade I</u> is a small -amplitude movement performed at the beginning of the range.

<u>Grade II</u> is a large-amplitude movement performed within the free range but not moving into any resistance or stiffness.

<u>Grade III</u> is a large-amplitude movement performed up to the limit of the range.

<u>Grade IV</u> is a small-amplitude movement performed at the limit of the range.

The figure below explains visually the position and the magnitude of each grade in the range of intervertebral joint motion for a normal joint according to Maitland (1986).

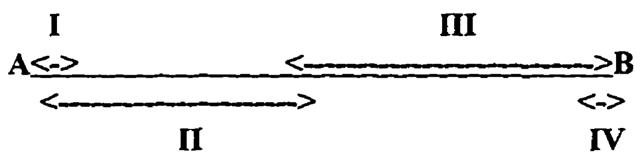


Figure. Grades of movement in a normal intervertebral joint. A = Beginning of range of movement. B = End of normal, average range of movement.

# APPENDIX H

## Instructions for the training

## INSTRUCTIONS FOR THE TRAINING

### 1. FORCE:

Concentrate on the force. Apply 30 oscillations where you reach the "end-feel". At the point where increased resistance is felt the force you apply is approximately 100 N (10 kg, 22-23 pounds).

Apply 30 oscillations that reach the target line on the display. Now you are applying grade II and you are asked to concentrate on the amount of force you are applying while you train to improve your perception for grade II mobilisation with direct feedback.

This process is repeated three times.

### 2. DISPLACEMENT.

Concentrate on the magnitude of displacement. Apply 30 oscillations where you reach the "end-feel". At the point where increased resistance is felt the magnitude of displacement is approximately 10 mm.

Apply 30 oscillations that reach the target line on the display. Now you are applying grade II and you are asked to concentrate on the magnitude of displacement that occurs while you train to improve your perception for grade II mobilisation with direct feedback.

This process is repeated three times.

### 3. FORCE AND DISPLACEMENT.

Now you will have direct feedback on both force and displacement simultaneously.

Apply 30 oscillations where you reach the "end-feel". At the point where increased resistance is felt the force you apply is approximately 100 N (10 kg, 22-23 pounds) and the magnitude of motion is approximately 10 mm.

Apply 30 oscillations that reach the target lines on the display. Now you are applying grade II and you are asked to concentrate on the amount of force and the magnitude of displacement that occurs while you train to improve your perception for grade II mobilisation with direct feedback.

This process is repeated three times.

Repeat sessions one to three.

# APPENDIX I

## Sample size calculations

**Sample size calculations for a two-way ANOVA (2x2 factors)**

$$n_c = \frac{(n^1 - 1)(\mu + 1)}{\#\text{ of cells}} + 1$$

For effect size of .5, study power of .80 and α level of .05

$$n_c = \frac{(17 - 1)(1 + 1)}{4} + 1 = 9$$

$n_c$ is the number of subjects required in each of the four cells in the ANOVA.

$n^1$ is obtained from a standardised table for an effect size of .5, study power of .80 and α level of .05.

μ is the number of comparisons - 1

# APPENDIX J

## Raw data

**Treatment of the raw data**

In order to determine the peaks of force and displacement for each therapist and each test, the data from the computer was processed in the following way. Prior to administering each test, data was collected from the spinal model for 30 seconds at a frequency of 50 Hz, where no force was applied to the vertebra to determine the baseline. This base line for the force and the displacement were used as reference values for the following measurement.

For each oscillation, four to ten highest values, depending on the shape and width of the peaks, were entered into Excel 4.0 software program. The values for each oscillation varied from $\pm$ 0.5 pound. The reference value was subtracted from each of these values. The average of these values from each oscillation obtained was computed. The average of the average peak values for each subject was then calculated arithmetically to represent the raw data for the force and displacement from the spinal model. The number of oscillations generally varied between the therapists from 15 to 40 during the 30 seconds period with exceptions of a few outliers at either end (low end = 5; high end = 65).

# RAW DATA

Raw data for the actual outcome and the estimated values for force and displacement, before and after a training session for the relatively inexperienced physical therapists and the experienced manual therapists.

| Subject | Before Training | | | | After Training | | | |
|---|---|---|---|---|---|---|---|---|
| | Force (Newton) | | Displacement (mm) | | Force (Newton) | | Displacement (mm) | |
| | Actual | Esti-mated | Actual | Esti-mated | Actual | Esti-mated | Actual | Esti-mated |
| Inexp.[1] 1 | 42.79 | 8.90 | 3.9 | 5 | 56.93 | 44.48 | 4.7 | 5 |
| Inexp. 2 | 47.99 | 13.34 | 3.5 | 5 | 47.15 | 14.72 | 3.4 | 5 |
| Inexp. 3 | 76.77 | 2.22 | 6.1 | 3 | 60.85 | 35.58 | 4.8 | 4 |
| Inexp. 4 | 61.38 | 88.96 | 5.2 | 5 | 71.48 | 40.00 | 6.4 | 5 |
| Inexp. 5 | 76.02 | 66.72 | 5.5 | 3 | 64.67 | 53.38 | 5.6 | 6 |
| Inexp. 6 | 75.88 | 8.90 | 5.5 | 5 | 89.40 | 66.72 | 7.6 | 7 |
| Inexp. 7 | 100.21 | 34.34 | 7.5 | 5 | 53.73 | 29.43 | 4.4 | 5 |
| Inexp. 8 | 45.46 | 8.90 | 2.7 | 10 | 60.49 | 60.00 | 5.7 | 4 |
| Inexp. 9 | 35.76 | 44.48 | 2.5 | 5 | 46.21 | 48.93 | 4.2 | 5 |
| Inexp. 10 | 48.71 | 7.36 | 5.1 | 3 | 72.68 | 19.62 | 6.5 | 5 |
| Exp.[2] 1 | 42.08 | 9.81 | 3.3 | 10 | 58.49 | 50.00 | 4.2 | 5 |
| Exp. 2 | 118.63 | 13.34 | 8.6 | 6 | 76.77 | 44.48 | 6.3 | 3 |
| Exp. 3 | 52.00 | 44.48 | 3.6 | 10 | 36.30 | 44.48 | 3.0 | 5 |
| Exp. 4 | 89.81 | 88.96 | 7.4 | 10 | 108.49 | 68.67 | 8.6 | 7 |
| Exp. 5 | 82.91 | 88.96 | 5.2 | 7 | 56.31 | 44.48 | 5.0 | 5 |
| Exp. 6 | 62.81 | 24.53 | 5.0 | 10 | 76.33 | 22.24 | 7.0 | 10 |
| Exp. 7 | 60.23 | 22.24 | 5.1 | 10 | 79.62 | 26.69 | 6.5 | 8 |
| Exp. 8 | 113.47 | 44.48 | 8.9 | 10 | 82.78 | 49.05 | 5.8 | 5 |
| Exp. 9 | 59.38 | 22.24 | 3.7 | 12 | 77.66 | 44.48 | 6.4 | 5 |
| Exp. 10 | 89.45 | 22.24 | 7.6 | 3 | 68.05 | 44.48 | 6.2 | 7 |

[1] Relatively inexperienced physical therapists

[2] Experienced manual therapists