A CLINICAL EVALUATION OF HIP JOINT FUNCTIONAL ABILITY AFTER SACROILIAC JOINT MANIPULATION IN PATIENTS WITH SACROILIAC JOINT SYNDROME

ABSTRACT

Objective: To determine the effect of sacroiliac joint manipulation on hip joint functional ability in patients with sacroiliac syndrome.

Design: This study was a crossover clinical experiment.

Setting: Durban Institute of Technology Chiropractic clinic.

Participants: Sixty volunteers from Durban and its surrounding areas.

Interventions: Treatment A: Motion palpation of the sacroiliac joints, and a sacroiliac joint manipulation. Treatment B: Motion palpation of the sacroiliac joints.

Main Outcome Measures: Objective measurements: Active hip joint ranges of motion were assessed using an Inclinometer, pressure threshold of the Piriformis muscle was measured using an Algometer, and hip joint proprioception was assessed by measuring joint position sense of the hip joint using an Inclinometer. Subjective measurements: Numerical pain rating scale-101 (NRS-101), and the Revised Oswestry Low back pain and Disability Questionnaire to see the effect of sacroiliac joint manipulation on sacroiliac syndrome.

Results: Sacroiliac joint manipulation had a significant effect on sacroiliac syndrome and hip joint range of motion. Manipulation also improved hip joint proprioception, however the improvement was immediate and not sustained. The effect of manipulation on Piriformis muscle pressure threshold was beneficial but not significantly so.

Conclusions: It is was suggested by the researcher that sacroiliac joint manipulation be used for sacroiliac syndrome and in the prevention of hip joint pathologies occurring due to erroneous muscle contraction, decreased hip joint range of motion and/or decreased hip joint proprioception.

Key Indexing Terms: Hip Joint Functional Ability, Manipulation, Motion Palpation, Pressure Threshold, Proprioception, Range of Motion, Sacroiliac Syndrome.

INTRODUCTION

At least 80 percent of the population suffers from low back pain at some time during their lives (Manga et al., 1993: 221). At the time of any given survey it is estimated that the number of people actually suffering from low back pain ranges from 5 to 30 percent (Manga et al., 1993: 221). The differential diagnosis of back and leg pain should include sacroiliac joint disease (Hendler et al., 1995: 169). According to Schwarzer et al. (1995: 36) the prevalence of sacroiliac joint pain appears to range from 13%-30%, thus making the sacroiliac joint a significant source of pain in patients with chronic low back pain.

Sacroiliac syndrome is well-defined and usually presents with pain over the sacroiliac joint in the region of the posterior superior iliac spine, with possible referral to the buttock, groin, and leg (Kirkaldy-Willis et al., 1992: 123). Hendler et al. (1995:171) state that the ligaments become taut, and the reflex muscle spasm and pain is intense, severe, and continuous. Harrison et al. (1997: 614) found that most patients with sacroiliac syndrome seem to present with spastic or hyperactive muscles which leads to increased pain and inflammation. Because of the close proximity of the Piriformis muscle to the sacroiliac joint (Moore and Dalley, 1999: 551), the Piriformis muscle is very likely to be in a hypertonic state in sacroiliac syndrome.

In a study by Cibulka et al. (1998: 1009-1015), results showed a correlation between sacroiliac joint dysfunction and unilateral hip rotation asymmetry. In a study by Bisset (2003), results indicated that a sacroiliac manipulation has an effect on hip rotation on the side of sacroiliac syndrome, with a statistically significant increase in hip active and passive internal rotation. However, he recommended that further studies in this regard should contain a placebo group and more manipulations should be administered and the effects on hip rotation noted.

The muscles responsible for movements of the hip (Moore and Dalley, 1999: 533, 534, 540, 551, 563, 613) have an overlapping innervation with the hip joint (L2 to S1) (Palastanga et al., 1989: 440) and sacroiliac joint (L2 to S3) (Bernard and Cassidy, 1991: 2112 and Ombregt et al., 1999: 691). Due to the facilitation of the neuronal pool at the level of the involved hypertonic muscle associated with sacroiliac syndrome (Korr, 1975 as cited in Leach, 1994: 98), proprioceptors could be facilitated erratically thus decreasing hip joint proprioception. However, Bernard and Cassidy (1991: 2126) hypothesize that manipulation forcefully stretches hypertonic muscles against their muscle spindles, thus leading the researcher to hypothesize that, with sacroiliac manipulation, proprioceptors could be stimulated thus resetting hip joint proprioception.

Objectives

In light of the above, the aim of this clinical investigation was to determine the effect of sacroiliac joint manipulation on hip joint functional ability[1] in patients with sacroiliac syndrome by means of subjective and objective clinical findings, thus facilitating in providing information with regards to the treatment and rehabilitation of the hip.

- The first objective was to determine the effect of sacroiliac joint manipulation on sacroiliac syndrome in terms of the subjective clinical findings.

[1] Hip joint functional ability was defined in this study as an assessment of Piriformis muscle pressure threshold, active hip joint range of motion, and hip joint proprioception. Limitations in terms of data collected was as a result of the fact that patients could not participate in this study if they had a hip pathology, therefore excluding them from being able to supply subjective data.

The first hypothesis was that sacroiliac joint manipulation would improve sacroiliac syndrome indicated by favourable subjective clinical findings.

- The second objective was to determine the effect of sacroiliac joint manipulation on hip joint functional ability in terms of the objective clinical findings.

  The second hypothesis was that sacroiliac joint manipulation would improve hip joint functional ability indicated by favourable objective clinical findings.

- The third objective was to compare the subjective and objective clinical findings of the group receiving manipulation to the sacroiliac joint versus the control group before and after the crossover.

  The third hypothesis was that the group receiving manipulation to the sacroiliac joint would compare favourably to the control group indicated by an improvement in subjective and objective clinical findings. It was hypothesized that the subjective and objective clinical findings of the control group would either stay the same or get worse.

METHODS

Subjects and Examiners

A non-probability, convenience sampling technique was used. A sample size of sixty patients suffering from sacroiliac joint syndrome was used.

Thirty males and thirty females were randomly divided into two groups of thirty, by means of drawing either A or B from a hat. Each group contained 15 males and 15 females. For the first half of the study group A received treatment by means of a sacroiliac joint manipulation, and group B acted as a control group. A crossover then occurred and group B received treatment and group A acted as a control group for the remaining half of the study.

The evaluations were done by a nominated evaluator, and all treatment was done by the researcher in order to:

a) standardize evaluation and treatment

b) ensure that there was a blinding process to exclude experimental bias (Mouton, 1996: 141-160)

Screening Phase

Inclusion criteria

- In order to increase group homogeneity patients were required to have a numerical pain rating scale-101 (NRS-101) reading of 50 or more in order to be included.
- Patients between the ages of 25-45 were included. Brandt (2002) found little radiographic evidence of osteoarthritis in patients below the age of 45 years.
- Only English speaking patients were included as English is the researcher's first language and helped to reduce possible linguistic confusion between participants and the researcher.
- Patients had to have sacroiliac joint syndrome. A diagnosis of sacroiliac joint syndrome was made if all of the following were found:
    1. Pain felt over the sacroiliac joint, with possible referral to the groin, trochanter, and buttock (Riggien 2003)
    2. Sacroiliac joint was tender to palpation (McCullach et al. 1997: 180-181)
    3. The pain was aggravated by 2 of the following 4 provocation tests: Gaenslen's, Patrick's Faber, Yeomann's (also called Erichson's), and Posterior Shear tests (Riggien 2003) (McCullach et al. 1997: 180-181)
    4. Other apparent causes of the patient's sacroiliac joint pain were not present e.g. infection (Riggien 2003 and McCullach et al. 1997: 180-181)

- Patients were only accepted once they had undergone a full case history, revised physical examination, lumbar regional examination, hip regional examination and had read and signed the informed consent form.

- After the initial consultation, patients were required to attend seven follow-up visits.

Exclusion criteria

- If any of the following contra-indications to manipulation were present then the patient was excluded from the study: (Gatterman 1990)
  1. Disc herniations with increasing signs and symptoms of neurological deficit
  2. Abdominal aortic aneurysm
  3. Lumbar spine tumours
  4. Lumbar spine infections
  5. Lumbar spine traumatic injuries
  6. Cauda equina syndrome
  7. Spondylolisthesis

- Any patients who began taking medication (e.g. anti-inflammatories or analgesics) for their low back pain (Poul et al. 1993) or began receiving treatment for their low back pain, during the course of the study, were excluded (Haldeman 1992). Patients who had had previous lower back surgery were also excluded.
- Patients suffering from any hip pathologies including instability were excluded. Hip pathologies were ruled out subjectively by a history of groin pain, and objectively by means of a basic hip examination including Quadrant scouring test, Patrick's Faber test, and decreased or painful internal rotation of the hip (Magee, 1992).
- All patients who did not meet the inclusion criteria were replaced.

Intervention

Treatment A: Motion palpation of the sacroiliac joints, and a sacroiliac joint manipulation.

Treatment B: Motion palpation of the sacroiliac joints.

Only one side was chosen to be evaluated and treated. This was decided by taking the following into consideration:

- The side that was symptomatic for the patient
- The side on which the provocation tests for sacroiliac syndrome were positive
- The side on which the sacroiliac joint was restricted

The intervention was conducted as indicated by the table below.

Week	Visit	Group A	Group B
1	1	Case history, Physical, Lumbar regional, Clinical evaluation and Treatment A	Case history, Physical, Lumbar regional, Clinical evaluation and Treatment B
	2	Inclinometer (including JPS) and algometer readings and Treatment A	Inclinometer (including JPS) and algometer readings and Treatment B
2	3	Treatment A	Treatment B
	4	Clinical evaluation **CROSSOVER** Treatment B	Clinical evaluation **CROSSOVER** Treatment A
3	5	Inclinometer (including JPS) and algometer readings and Treatment B	Inclinometer (including JPS) and algometer readings and Treatment A
	6	Treatment B	Treatment A
4	7	Clinical evaluation	Clinical evaluation

<u>A clinical evaluation included:</u>

- Completing the numerical pain rating scale-101 (NRS-101) in order to measure pain intensity.
- Undergoing active hip range of motion testing using an Inclinometer. This was done pre- and post- treatment.

- Measuring pressure threshold over the Piriformis muscle using an Algometer. This was done pre- and post- treatment.
- Completing the Revised Oswestry Low back pain and Disability Questionnaire in order to indicate the effect of low back pain on your ability to manage everyday life.
- Undergoing hip rotation range of motion testing using an Inclinometer in order to measure joint position sense (JPS) and thus proprioception of the hip joint. This was done pre- and post- treatment.

Hip joint proprioception was assessed by means of measuring joint position sense of the hip joint pre- and post- treatment using an Inclinometer. In a study conducted by Deshpande et al. (2003) to determine the reliability and validity of ankle proprioceptive measures, results showed that joint position sense was a reliable tool for measuring proprioception, and that active movement was a reliable method for measuring joint position sense.

Statistical Analysis

Baseline comparisons between the categorical baseline variables and the group to which the participant was assigned were done using Fisher's exact test. Continuous baseline variables that were not normally distributed were compared between groups using a non-parametric Wilcoxon Mann-Whitney test. Continuous normally distributed baseline data were compared using the two sample t-test. The differences obtained in each of the periods of the cross-over design were analysed using a repeated measures analysis of variance (ANOVA). To determine the effect of certain baseline variables on the treatment, a repeated measures ANOVA was done with the baseline variables included as covariates.

RESULTS

Numerical Pain Rating Scale:

Sacroiliac manipulation provided significant pain relief to the patients. The syndrome also improved without manipulation (during motion palpation), but to a lesser extent than with manipulation. The pain measurement continued to improve over time, with the lowest value recorded after both treatments (manipulation and motion palpation) were given. See Table 1 in appendices.

Revised Oswestry Low Back Pain and Disability Questionnaire:

Sacroiliac manipulation made a significant change to the rating on the Revised Oswestry low back pain and disability questionnaire. The syndrome also improved during the control treatment (motion palpation), but to a lesser extent than during the manipulation. The readings at the final visit were lower than the readings at the first visit, indicating that the patients continued to improve over time. See Table 2 in appendices.

Hip Joint Range of Motion:

There was an increase in all hip ranges of motion immediately after the first manipulation, and a slight decrease or no change immediately after motion palpation in most cases. This indicates that sacroiliac manipulation had a significant immediate effect on hip range of motion. In most cases however, the value before the second manipulation was lower than the value immediately after the first manipulation, but after the second manipulation this value went higher than the value immediately after the first manipulation. The second manipulation thus provided additional benefit to the patients. For all ranges of motion the value after three manipulations was higher than the value before the first manipulation, as opposed to a slight decrease seen for most ranges of motion in the control (motion palpation) group. It can thus be said that sacroiliac manipulation increases hip joint range of motion in patients suffering from sacroiliac syndrome. See Table 3 to Table 8 in appendices.

Hip Joint Proprioception:

The mean value immediately after the first manipulation was closer to normal than the mean value immediately before manipulation. The mean value immediately after the first motion palpation was further from normal than immediately before motion palpation, indicating that sacroiliac manipulation had beneficial immediate effects on hip proprioception. However, this improvement was not sustained, since the mean value before the second manipulation was further from normal than the mean value immediately after the first manipulation, and the mean value after three manipulations was even further from normal than the value before the first manipulation for 10º internal and 20º internal rotation. See Table 9 to Table 12 in appendices.

Pressure Threshold of the Piriformis Muscle:

The mean algometer readings did not show a large change during either treatment (manipulation or motion palpation). The sustained effect was larger than the effect immediately after the treatment. An increase in the algometer readings was shown over a longer time in both treatments (manipulation and motion palpation). The readings at the final visit were higher than the readings at the first visit, indicating that the patients continued to improve over time. See Table 13 in appendices.

DISCUSSION

Numerical Pain Rating Scale (NRS):

A large decrease in pain was observed when the manipulation was done and a smaller decrease in pain was observed when the control was done. This is in congruence with the literature (Kirkaldy-Willis and Burton, 1992: 249 and Cassidy and Mierau, 1992: 223) that indicates a decrease in pain is expected post manipulation or after a course of manipulative treatments.

Revised Oswestry Low Back Pain and Disability Questionnaire:

As for the NRS, there was a larger decrease in the rating when the manipulation was done than when the control (motion palpation) was done. This is expected post manipulation or after a course of manipulative treatments (Kirkaldy-Willis and Burton, 1992: 249 and Cassidy and Mierau, 1992: 223).

Hip Joint Range of Motion:

Possible reasons for the increase in hip range of motion seen with sacroiliac manipulation are as follows and are supported by Mellin (1988: 669):

- Sacroiliac syndrome may cause restrictions in hip mobility because of a decrease in general physical activity. Thus, with sacroiliac manipulation providing pain relief, the physical activity of the patient may increase thus increasing the mobility of the hip.
- Sacroiliac syndrome, through neurological reflexes, may cause spasm of the muscles in close proximity to the sacroiliac joint (Harrison et al., 1997: 614 and Hendler et al., 1995: 171). This spasm could restrict hip joint range of motion. Sacroiliac manipulation elicits reflexes which have the potential to reduce hypertonicity (spasm) (Korr, 1975 as cited in Leach, 1994: 99 and Kirkaldy-Willis and Burton, 1992: 250), thus increasing the flexibility and contractile ability of these muscles with a subsequent increase in hip joint range of motion.

Hip Joint Proprioception:

Due to the facilitation of the neuronal pool at the level of the involved hypertonic muscle associated with sacroiliac syndrome (Korr, 1975 as cited in Leach, 1994: 98-99), proprioceptors could be facilitated erratically thus decreasing hip joint proprioception. However, Bernard and Cassidy (1991: 2126) hypothesize that manipulation forcefully stretches hypertonic muscles against their muscle spindles. Therefore, with sacroiliac manipulation, proprioceptors could be stimulated thus resetting hip joint proprioception resulting in the improvement seen above.

As can be seen from the above, the effect of manipulation on joint position sense, and thus proprioception, is immediate with no sustained effects. This is expected as the effects of manipulation on proprioception are neurological and thus immediate. Therefore, it is suggested by the researcher that proprioceptive activity needs to be facilitated over the long term and between adjustments e.g. using a wobble board.

Pressure Threshold of the Piriformis Muscle:

Sacroiliac manipulation seems to be able to elicit reflexes which have the potential to reduce hypertonicity (spasm) in the surrounding muscles like the Piriformis muscle (Korr, 1975 as cited in Leach, 1994: 99 and Kirkaldy-Willis and Burton, 1992: 250). This could possibly increase the pressure threshold of the Piriformis muscle. The reflex would be an immediate neurological effect; however, the decrease in muscle spasm is more likely a physiological effect which may take time to occur, especially in cases of chronic sacroiliac syndrome as was the case in the majority of patients in this study. This could be the reason why the sustained effect was larger than the effect immediately after treatment.

CONCLUSION

Sacroiliac joint manipulation had a significant effect on sacroiliac syndrome and hip joint range of motion. Manipulation also improved hip joint proprioception, however the improvement was immediate and not sustained. It was suggested that other proprioceptive exercises be performed between manipulations. The effect of manipulation on Piriformis muscle pressure threshold was beneficial but not significantly so. It is therefore suggested by the researcher that sacroiliac joint manipulation be used for sacroiliac syndrome as well as in the prevention of hip joint pathologies occurring due to erroneous muscle contraction, decreased hip joint range of motion and/or decreased hip joint proprioception.

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APPENDICES

Numerical Pain Rating Scale:

Table1: Pain (NRS)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	45.62	10.09	25.00	45.00	75.00
Pre-manipulation	45.58	11.31	15.00	45.00	73.00
Post-manipulation	31.37	17.41	0.00	30.00	63.00
Pre-control	40.62	14.85	0.00	44.00	75.00
Post-control	38.28	18.31	0.00	40.00	75.00

Revised Oswestry Low Back Pain and Disability Questionnaire:

Table 2: Revised Oswestry low back pain and disability questionnaire

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	14.65	6.16	0.00	14.50	31.00
Pre-manipulation	13.95	6.45	0.00	14.00	29.00
Post manipulation	8.55	7.32	0.00	6.50	35.00
Pre-control	12.42	6.85	0.00	12.00	31.00
Post control	11.35	7.54	0.00	11.50	29.00

Hip Joint Range of Motion:

Table 3: Flexion (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	96.87	15.23	42.00	101.50	119.00
Immediately pre-manipulation	96.37	15.01	42.00	100.00	119.00
Immediately post-manipulation	100.25	14.20	41.00	102.00	126.00
Visit after manipulation – pre	99.50	13.93	44.00	99.50	132.00
Visit after manipulation – post	102.48	14.16	58.00	101.00	135.00
Long after manipulation*	101.10	14.73	40.00	104.00	135.00
Immediately pre-control	98.82	14.18	40.00	102.00	122.00
Immediately post-control	98.47	14.57	42.00	101.50	130.00
Visit after control – pre	97.72	12.73	43.00	99.00	123.00
Visit after control – post	96.97	12.98	45.00	98.00	125.00
Long after control*	99.73	12.60	63.00	102.00	120.00

* These measurements were taken at the beginning of the following cross-over period.

Table 4: Extension (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	23.13	7.57	6.00	24.00	40.00
Immediately pre-manipulation	23.28	7.81	6.00	24.00	40.00
Immediately post-manipulation	26.63	6.57	11.00	27.50	42.00
Visit after manipulation – pre	26.85	9.64	10.00	27.00	80.00
Visit after manipulation – post	28.55	6.75	12.00	29.00	49.00
Long after manipulation*	27.85	7.57	10.00	29.00	42.00
Immediately pre-control	24.52	8.09	10.00	24.00	42.00
Immediately post-control	25.12	7.08	11.00	24.00	40.00
Visit after control – pre	24.20	6.99	10.00	24.00	39.00
Visit after control – post	25.37	6.77	11.00	27.00	40.00
Long after control*	24.13	6.89	7.00	24.00	37.00

* These measurements were taken at the beginning of the following cross-over period.

Table 5: Abduction (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	71.18	13.84	35.00	72.50	93.00
Immediately pre-manipulation	69.37	13.65	30.00	72.00	89.00
Immediately post-manipulation	74.73	12.34	38.00	77.00	97.00
Visit after manipulation – pre	73.03	12.38	38.00	76.00	93.00
Visit after manipulation – post	75.75	12.01	45.00	78.00	102.00
Long after manipulation*	73.72	15.23	17.00	75.50	99.00
Immediately pre-control	72.83	13.24	47.00	75.00	99.00
Immediately post-control	72.33	13.66	46.00	75.00	98.00
Visit after control – pre	71.37	13.13	40.00	71.50	92.00
Visit after control – post	71.38	13.06	36.00	71.00	94.00
Long after control*	71.95	14.67	30.00	73.50	97.00

* These measurements were taken at the beginning of the following cross-over period.

Table 6: Adduction (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	9.43	3.90	3.00	9.00	22.00
Immediately pre-manipulation	9.27	3.64	3.00	9.00	22.00
Immediately post-manipulation	10.42	3.53	5.00	10.00	22.00
Visit after manipulation – pre	10.23	3.85	5.00	10.00	22.00
Visit after manipulation – post	11.28	3.72	4.00	11.00	21.00
Long after manipulation*	10.92	3.67	4.00	10.00	22.00
Immediately pre-control	10.00	3.71	4.00	10.00	20.00
Immediately post-control	10.07	3.63	3.00	10.00	18.00
Visit after control – pre	9.72	3.48	4.00	10.00	18.00
Visit after control – post	9.92	3.67	3.00	10.00	18.00
Long after control*	9.85	3.61	4.00	10.00	20.00

* These measurements were taken at the beginning of the following cross-over period.

Table 7: Internal rotation (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	42.88	9.41	27.00	42.00	66.00
Immediately pre-manipulation	41.42	9.88	26.00	38.50	66.00
Immediately post-manipulation	43.88	10.58	23.00	40.50	69.00
Visit after manipulation – pre	43.05	10.72	24.00	40.50	69.00
Visit after manipulation – post	45.60	11.55	23.00	42.50	74.00
Long after manipulation*	45.68	11.22	20.00	45.50	74.00
Immediately pre-control	44.05	10.87	20.00	44.00	74.00
Immediately post-control	44.00	10.54	24.00	43.00	69.00
Visit after control – pre	42.17	10.20	22.00	40.00	65.00
Visit after control – post	42.18	11.27	23.00	40.00	68.00
Long after control*	43.23	10.76	24.00	43.50	70.00

* These measurements were taken at the beginning of the following cross-over period.

Table 8: External rotation (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	43.18	9.21	13.00	44.50	68.00
Immediately pre-manipulation	42.82	9.65	13.00	42.50	68.00
Immediately post-manipulation	45.55	8.90	20.00	46.00	69.00
Visit after manipulation – pre	43.70	9.55	25.00	45.50	68.00
Visit after manipulation – post	46.10	9.31	18.00	48.00	68.00
Long after manipulation*	44.42	9.17	21.00	46.00	68.00
Immediately pre-control	43.27	8.53	21.00	44.50	68.00
Immediately post-control	43.27	8.22	23.00	45.00	65.00
Visit after control – pre	43.98	8.27	24.00	45.50	60.00
Visit after control – post	42.80	8.35	22.00	45.00	59.00
Long after control*	43.32	8.93	20.00	44.00	68.00

* These measurements were taken at the beginning of the following cross-over period.

Hip Joint Proprioception:

Table 9: 10º internal rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-1.60	2.01	-7.00	-1.50	2.00
Immediately pre-manipulation	-1.70	2.09	-7.00	-1.00	2.00
Immediately post–manipulation	-1.27	2.15	-6.00	-1.00	5.00
Second manipulation – pre	-1.93	2.45	-8.00	-2.00	2.00
Second manipulation - post	-1.52	1.88	-6.00	-1.00	2.00
Long after manipulation*	-1.75	2.25	-9.00	-2.00	2.00
Immediately pre-control	-1.75	2.43	-9.00	-2.00	2.00
Immediately post control	-1.80	2.21	-8.00	-2.00	2.00
Second control – pre	-1.70	2.42	-8.00	-2.00	5.00
Second control - post	-2.00	2.11	-7.00	-2.00	2.00
Long after control*	-1.60	2.07	-7.00	-1.50	3.00

* These measurements were taken at the beginning of the following cross-over period.

Table 10: 10º external rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-1.48	2.79	-8.00	-1.50	4.00
Immediately pre-manipulation	-1.90	2.50	-8.00	-2.00	2.00
Immediately post–manipulation	-1.43	2.23	-7.00	-1.00	4.00
Second manipulation – pre	-1.75	2.29	-9.00	-2.00	2.00
Second manipulation - post	-1.87	2.75	-15.00	-1.00	3.00
Long after manipulation*	-1.67	2.36	-8.00	-1.50	4.00
Immediately pre-control	-1.30	2.57	-8.00	-1.00	4.00
Immediately post control	-1.47	2.21	-7.00	-1.00	3.00
Second control – pre	-1.67	2.45	-12.00	-1.00	2.00
Second control - post	-1.87	2.75	-15.00	-1.00	3.00
Long after control*	-1.75	1.99	-7.00	-2.00	2.00

* These measurements were taken at the beginning of the following cross-over period.

Table 11: 20º Internal rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-0.78	2.71	-6.00	-1.00	5.00
Immediately pre-manipulation	-1.00	2.52	-6.00	0.00	5.00
Immediately post–manipulation	-0.33	2.90	-7.00	0.00	10.00
Second manipulation – pre	-1.20	2.50	-8.00	-1.00	4.00
Second manipulation - post	-1.02	2.51	-6.00	0.00	5.00
Long after manipulation*	-1.53	3.41	-19.00	-1.00	3.00
Immediately pre-control	-1.10	3.71	-19.00	-0.50	5.00
Immediately post control	-1.37	2.60	-8.00	0.00	3.00
Second control – pre	-1.30	2.53	-8.00	-1.00	8.00
Second control - post	-1.25	2.21	-8.00	-1.50	4.00
Long after control*	-0.53	2.25	-5.00	0.00	3.00

* These measurements were taken at the beginning of the following cross-over period.

Table 12: 20º external rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-0.73	3.04	-9.00	0.00	5.00
Immediately pre-manipulation	-0.92	2.58	-9.00	0.00	4.00
Immediately post–manipulation	-0.53	2.15	-7.00	0.00	6.00
Second manipulation – pre	-0.83	2.95	-13.00	0.00	4.00
Second manipulation - post	-1.12	2.99	-10.00	0.00	4.00
Long after manipulation*	-0.72	2.69	-15.00	0.00	4.00
Immediately pre-control	-0.65	3.12	-15.00	0.00	5.00
Immediately post control	-0.90	2.69	-8.00	0.00	4.00
Second control – pre	-1.15	2.97	-12.00	0.00	4.00
Second control - post	-1.15	2.63	-8.00	0.00	4.00
Long after control*	-0.85	1.90	-7.00	0.00	3.00

* These measurements were taken at the beginning of the following cross-over period.

Pressure Threshold of the Piriformis Muscle:

Table 13: Algometer readings (kg/cm^2)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	6.16	2.69	1.50	5.80	10.00
Immediately pre-manipulation	6.50	2.64	2.40	5.80	10.00
Immediately post –manipulation	6.67	2.59	2.40	6.20	10.00
Second manipulation - pre	6.69	2.69	2.80	6.55	10.00
Second manipulation - post	6.77	2.73	2.70	6.50	10.00
Long after manipulation*	7.11	2.72	2.50	6.50	10.00
Immediately pre-control	6.37	2.83	1.50	6.00	10.00
Immediately post control	6.38	2.86	1.30	5.75	10.00
Second control – pre	6.43	2.73	1.40	5.55	10.00
Second control – post	6.40	2.75	1.40	5.50	10.00
Long after control*	7.02	2.62	3.10	7.40	10.00

* These measurements were taken at the beginning of the following cross-over period.