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A clinical crossover trial of the effect of manipulative therapy on pain and passive and active range of motion of the painful hip

Mohsen Kazemi, RN, DC, FRCCSS(C), FCCPOR(C), MSc, PhD[1]
Sydney Hubbel Leguard, BHSc (Hons), DC[1]
Sebastian Lilja, BHSc (Hons), DC[1]
Steven Mahaise, BHSc (Hons), DC[1]

Objectives: *This study aims to determine whether manipulative therapy of the hip joint can increase range of motion (ROM) and/or decrease pain in individuals experiencing symptomatic hip pain.*

Methods: *Non-disabled young adults were recruited on campus of a chiropractic college for this randomized crossover study. Subjects' hip active and passive ROM and pain perception were measured. Subjects then received a drop-piece hip manipulation (DPHM) or an alternative treatment, followed by measurement of active and passive ROM and pain.*

Results: *Eight males and 12 females (n=20) between the ages of 21-32 years completed the study. Statistically significant improvements in numeric pain scale (NRS) and passive abduction were observed for the manipulation group when compared to the alternative*

Essai clinique croisé sur l'effet des manipulations sur la douleur et l'amplitude des mouvements actifs et passifs de la hanche douloureuse

Objectifs : *Cette étude vise à déterminer si les manipulations de la hanche peuvent augmenter l'amplitude du mouvement et/ou diminuer la douleur chez les personnes ayant des douleurs à la hanche.*

Méthodologie : *On a recruté de jeunes adultes non handicapés sur le campus d'un collège chiropratique pour participer cette étude croisée à répartition aléatoire. L'amplitude des mouvements actifs et passifs de la hanche et la perception de la douleur ont été mesurées. Les sujets ont ensuite subi des manipulations de la hanche sur une table à sections mobiles qui chutent ou un autre traitement, puis on a mesuré l'amplitude des mouvements actifs et passifs et l'intensité de la douleur.*

Résultats : *Huit hommes et 12 femmes (n=20) âgés de 21 à 32 ans ont participé à l'étude. Des améliorations statistiquement significatives sur l'échelle numérique de la douleur et de l'abduction passive ont été observées dans le groupe ayant eu des manipulations par rapport à l'autre traitement. Aucun changement significatif*

[1] Department of Graduate Studies and Research, Canadian Memorial Chiropractic College

Corresponding author: Mohsen Kazemi, Canadian Memorial Chiropractic College Leslie St. Toronto, ON, Canada, M2H 3J1
Tel: 416-482-2340
e-mail: mkazemi@cmcc.ca

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treatment. No significant change was observed for all other hip ranges.

Conclusions: *DPHM of the symptomatic hip joint in a small sample of young adults resulted in statistically significant improvements in pain and passive abduction when compared to sham manipulation. Due to low sample size, further research is recommended.*

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KEY WORDS: hip joint, pain, ROM, manipulation, symptomatic, drop piece, chiropractic

d'amplitude n'a été observé pour les autres mouvements de la hanche.

Conclusions : *Les manipulations sur table à sections mobiles qui chutent pour traiter la hanche symptomatique sur un petit échantillon de jeunes adultes a permis d'obtenir des améliorations statistiquement significatives de la douleur et de l'abduction passive par rapport à la manipulation fictive. En raison de la faible taille de l'échantillon, des recherches supplémentaires sont recommandées.*

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MOTS CLÉS : articulation de la hanche, douleur, amplitude du mouvement, manipulation, symptomatique, table chiropratique à sections mobiles qui chutent, chiropratique

Introduction

Poor levels of hip joint range of motion (ROM) have been shown to be an indication for future hip replacement surgery.[1] According to the Canadian Joint Replacement Registry (CJRR) there were 47,075 hospitalizations for hip replacements in Canada during the 2012-2013 year. Of the total number of hip replacement cases, 76.5% were due to osteoarthritis (OA).[2] A determinant of both self-reported and observed disability in individuals with hip OA is decreased ROM at the hip joint. Therefore, there may be a positive relationship between optimal hip joint ROM, and hip joint health.[3]

The hip joint is a multiaxial ball and socket synovial joint that connects the lower limb and pelvic girdle by way of the femoral head and the acetabulum.[4] To increase the articular surface area, the acetabulum contains a labrum, which allows nearly half of the femoral head to sit inside it.[4] It is a highly mobile joint, second to only the glenohumeral joint, capable of many movements: flexion-extension, abduction-adduction, internal-external rotation, and circumduction.[4] When the knee is bent, the hip is capable of a high degree of flexion due to a lack of resistance from the hamstring musculature.[4] In extension, fibers from the iliofemoral ligament become taut and greatly limit extension ROM, especially when compared to flexion.[4] The hip joint's range of abduction is far greater than that of adduction, and the action of external rotation (ER) is much more powerful than that of internal rotation (IR).[4]

Though the hip joint's ROM is typically broad, a wide range of pathological conditions can affect the hip joint's ability to move through its full ROM. Of these conditions, two of the most prevalent pathologies affecting hip joint ROM include OA and femoroacetabular impingement (FAI).[5,6] It is widely accepted that individuals with FAI are predisposed to decreased ranges of motion at the hip joint.[6] Clinical findings have shown patients with FAI to have a significantly decreased ROM in flexion, IR at 90-degree flexion, and abduction compared to patients without hip joint pathology.[6] Patients with hip OA have also been found to present with decreased hip ROM, notably in abduction, and internal/external rotation. In addition, a positive relationship exists between the progression of OA and the subsequent decrease in ROM at the hip joint.[5]

Various interventions have been used to facilitate a change in ROM at the hip joint. Currently, traditional static stretching, trunk muscle strengthening protocols, and proprioceptive neuromuscular facilitation (PNF) are some of the interventions used to attempt to increase ROM in individuals with and without hip joint pathologies.[7-10] Additionally, several studies have investigated the effects of hip mobilization on both short and long-term changes in hip

ROM.[11-15] Beselga *et al*.[11] found significant improvements in hip flexion after a single treatment of mobilizations with movement. Hoeksma *et al*.[12] compared a manual therapy program including manipulation and mobilizations to an exercise program and found significantly better outcomes in pain, stiffness, hip function, and hip range of motion after 5 weeks. Mosler *et al*.[13] studied changes in hip range of motion after a 4-week manual therapy program in junior elite male water polo players and found significant improvement in passive IR and ER. Estébanez-De-Miguel *et al*.[14] examined the effects of three treatment sessions of high force long axis distraction mobilization on passive hip ROM when compared to low and medium force long axis distraction mobilization. They found significant improvements in passive flexion, extension, abduction, adduction, IR, and ER in the high force group and no significant changes in the low and medium force groups.[14] Stathopoulos[15] did a systematic review and meta-analysis regarding the efficacy of mobilizations with movement on ROM of various joints and found statistically and clinically significant improvements in ROM consistently for hip pain. Currently, there is limited evidence examining multiple ranges of motion with a single intervention.

Another common and effective treatment used to treat limitations in hip ROM is manipulation.[16] Manipulation involves the use of a high velocity, low-amplitude (HVLA) thrust into a joint with various intents, including the improvement in joint ROM.[16] Manipulation can also include the use of tools to execute the procedure, including an activator or a drop piece. The present study focuses on the use of drop piece manipulation. Although no supporting clinical evidence exists, drop-piece mechanisms have been promoted as a technology for increasing the efficiency of manipulation.[17] One explanation for this claim suggests that the degree of adjustive effort and force may be reduced. This is due to the drop piece decreasing the counter-resistance of both the table and the patient. Another explanation is that the force of the manipulation is enhanced by the counter-reactive force generated across the joint when adjustive thrusts are maintained through the impact of the drop piece.[18] Both of these proposed explanations consider Newton's first law which states that a body is in equilibrium if no force is acting upon it. If at rest it remains so, if in action it persists in motion unless an opposing motion is met. When drop pieces are used, the thrust executed by the practitioner imparts motion to the targeted joint. This joint remains in motion until the end of the drop.[18]

Bergmann and Davis[19] outline the basic procedure for using a drop piece as follows: first, the targeted joint is positioned over the drop section. Then, the drop section is set, and its tension is checked. The tension should be enough to support the patient's weight without dropping, but light enough so only minimal force is needed to overcome the resistance.[20] Finally, contacts are established over the structure to receive the thrust, and a thrust is generated to make the section drop. This procedure is repeated for a total of three times.[19]

The principal author had been using drop piece hip manipulation for his patients in clinical practice and saw significant improvement in their ROM and reduced pain after the manipulation. Since there are no studies that have used this type of manipulation on the hip joint, we decided to investigate drop piece hip long axis manipulation on hip ROM and pain.

Therefore, the purpose of this study was to examine the changes in pain, and passive and active ROM at the hip joint in patients with a hip complaint or limited ROM at the hip following a femoral-acetabular manipulative procedure compared to an alternative femoral-acetabular treatment.

Methods

Design

The study was a randomized crossover design. Student researchers were blinded to the type of intervention provided (drop-piece manipulation or alternative), and the doctor was blinded to the measurements recorded before and after the intervention. The participants were blinded to whether they were in the manipulation or alternative treatment group. Subjects were fitted with sensors compatible with the Optotrak® System on bilateral aspects of the pelvis and distal to the hip joint on the affected side (Figure 1). Subjects were then asked to perform active hip ROM, including flexion, ER, IR, abduction, and adduction while in the supine position and hip extension in the prone position (Figure 2). The researcher then helped the subject to maintain a 90-degree bend at the knee, and passive ROM with overpressure to the point of pain was performed. Passive hip ROM was measured for flexion, ER, IR, abduction, and adduction in the supine position and hip extension in the prone position (Figure 3). ROM data was collected by the student researchers. Each set of ROM was conducted one time before the intervention and one time after the intervention, unless there was an error in measurement with the Optotrak® sensor. If there was an error, the single errored ROM was repeated. The subjects did not warm-up prior to conducting ROM to simulate day to day clinic setting testing.

After the pre-intervention ROM was measured, the principal investigator entered the room and received a sealed opaque envelope with a slip of paper inside stating if the subject was in the control or experimental group. The student researchers then exited the room. The doctor proceeded with a drop-piece hip manipulation or alternative treatment (see manipulation treatment and alternative treatment below), then left the room. The student researchers then re-entered the room and post-intervention ROM was measured. In addition, the doctor resealed the allocation in the envelope and returned it to the assessors who labeled the envelope with '2' to indicate the first intervention had occurred. When the subject returned, at least a week later, to receive the opposite treatment, the same procedure occurred, however, when given the same sealed opaque envelope, the principal investigator performed the opposite treatment which was stated on the cue card inside.

Participants

Participants were included in our study if they were students enrolled at the Canadian Memorial Chiropractic College and if they were experiencing self-reported symptomatic pain or limited ROM at the hip joint. Exclusion criteria included any past hip surgery, knee replacement, acute pain due to trauma, radicular pain, numbness or tingling in the involved lower limb, avascular necrosis of the femoral head, stress fracture of the hip joint, received hip manipulation in the past week, severe arthritis of the hip joint, and full ROM of the hip. Data collection occurred between September 2018 and December 2019 in the Biomechanics Lab of the Canadian Memorial Chiropractic College.

Interventions

Manipulation treatment

The patient was supine with the drop-piece under the affected hip. The tension was set by determining the

Figure 1.
Sensor placement and digitization.

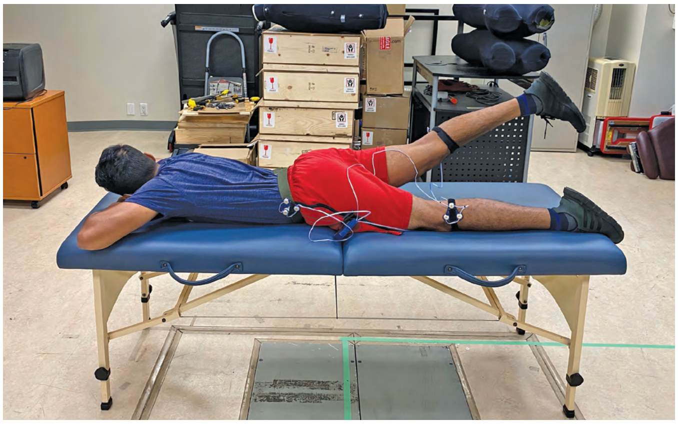

Figure 2.
Active hip extension measurement.

Figure 3.
Passive hip extension measurement

Figure 4.
Manipulation treatment starting point.

Figure 5.
Manipulation treatment end point.

amount necessary for the drop piece to engage under the patient's body weight and then increased by a 1/2 rotation. The doctor took the patient's affected leg with one hand contacting the thigh proximal to the knee while the other hand contacted the leg just proximal to the ankle with 20-30 degrees of hip abduction and 15 to 20 degrees of ER. The doctor initiated a postero-caudal long axis thrust ending in 15 to 20 degrees of hip extension similar to a whip motion, which engaged the drop-piece. (Figures 4 and 5). The doctor repeated the procedure 3 times.

Alternative treatment

The patient was supine with the drop-piece under the affected hip. The tension was set by determining the amount necessary for the drop piece to engage under the patient's body weight and then increased by a 1/2 rotation. The doctor contacted the thigh with a one hand contact on the thigh mid-way between the knee and hip (Figure 6). The doctor initiated a purely anterior to posterior thrust into the table with the other hand, which engaged the drop-piece (Figure 7). The doctor repeated the procedure 3 times.

Outcome measures

Outcome measures included passive/active hip ROM and pain perception. ROM of the hip joint was measured in extension, flexion, abduction, adduction, ER, and IR. External and IR were performed with the knee flexed to 90 degrees. Pain perception was measured by a numeric pain scale (NPS) (1-10) and was measured both before and after the intervention.

Figure 6.
Alternative treatment starting point.

Figure 7.
Alternative treatment end point.

Table 1.
Sample size and effect size estimate[21]

Motion	Side	Rotation	Mean	SE	SD	Diff	Effect size d
Active	left	internal	34.30	3.00	13.42	6.86	0.51
Active	left	external	46.00	2.80	12.52	9.20	0.73
Active	right	internal	36.00	3.20	14.31	7.20	0.50
Active	right	external	46.50	2.50	11.18	9.30	0.83
Passive	left	internal	44.40	3.10	13.86	8.88	0.64
Passive	left	external	45.50	2.20	9.84	9.10	0.92
Passive	right	internal	45.50	3.10	13.86	9.10	0.66
Passive	right	external	54.60	2.80	12.52	10.92	0.87
SE= Standard Error; SD= Standard deviation; Diff= Difference in mean; d= Cohen's d							

Sample size estimate

For a crossover design, the main statistical test was a paired t-test comparing change in hip ROM with the intervention of interest to change in hip ROM without the intervention of interest. Sample size was set at twenty for feasibility reasons. With significance α=0.05, power 1-β=0.80 for a two-sided paired t-test, 20 subjects were found to be sufficient to detect an effect size of d=0.626, as shown below:

$$d=((Z\_(1-\alpha/2)+Z\_(1-\beta)))/\sqrt{n}= (1.96+0.84)/\sqrt{20}=0.626$$

Using data from Aefsky *et al*.[21] for values of both internal and external hip rotation measured in the prone position with both active and passive motion, and considering a change of interest in mean of 20%, the effect sizes ranging from 0.50 to 0.92 were obtained (Table 1). Therefore, the target of 20 subjects were found to be adequate to detect an effect size of 0.62, capturing six of the eight rows (highlighted) in Table 1.[22-23]

Randomization

Randomization occurred by labeling 20 cue cards with either "manipulation treatment" (10 cards) or "alternative treatment" (10 cards). Each card was enclosed and sealed within an opaque envelope. The envelopes were shuffled by hand by the student investigators and then chosen at random to be assigned to each subject. Each subject's assigned subject code was labelled on one envelope, which was stored and then handed to the principal investigator on the day each subject participated in data collection.

Statistical methods

Means with standard deviation, confidence intervals (95%), a paired t-test and effect size estimates were used to analyse the data. A dependent samples t-test was used rather than a two-sample (independent) t-test in order to account for within participant differences. This study received ethics approval from the Canadian Memorial Chiropractic College Research Ethics Board with approval number: 1604A01.

Results

Twenty-one participants with a painful hip were screened for eligibility criteria. All met the eligibility criteria and agreed to participate in the study. One participant dropped out due to personal reasons prior to commencing data collection. Twenty participants completed the study. Participant demographic information are summarized in Table 2.

Table 2.
Participant demographics

	Manipulation	Alternative
No. of participants	10	10
Sex	2 males, 8 females	6 males, 4 females
Age (year)	23-31	21-32
Mean Age (year)	25.4	26.0
Weight (kg)	50.0-90.7	53.1-108.9
Mean Weight (kg)	69.2	77.0
Height (cm)	158.0-180.3	152.4-190.5
Mean Height (cm)	167.6	175.8
kg=kilogram; cm=centimeter		

Table 3.

Range of motion, changes in range of motion and differences between manipulation and alternative treatment - statistical analysis results

			Manipulation change in ROM	Alternative change in ROM	Difference in change (Manipulation –Alternative, bigger positive mean value indicates more change with Manipulation than with Alternative)						
ROM	Active/ Passive	n	Mean ± SD (°)	Mean ± SD (°)	Mean ± SD (°)	95%CI - L	95%CI - U	t-statistic	df	p-value	Effect size
Abduction	Passive	12	10.6 ± 13.2	-1.2 ± 9.0	11.8 ± 11.3	4.6	19.0	3.62	11	0.004*	1.31**
	Active	12	0.4 ± 8.5	-3.8 ± 12.8	4.1 ± 17.0	-6.6	14.9	0.84	11	0.418	0.32^
Adduction	Passive	17	2.4 ± 6.9	-0.4 ± 6.9	2.8 ± 9.5	-2.1	7.7	1.20	16	0.248	0.41^
	Active	17	3.7 ± 5.4	0.2 ± 7.8	3.5 ± 9.5	-1.4	8.3	1.50	16	0.153	0.45^
Extension	Passive	17	3.7 ± 10.0	0.3 ± 9.0	3.4 ± 14.5	-4.0	10.9	0.98	16	0.342	0.38^
	Active	11	5.8 ± 7.9	0.5 ± 9.5	5.3 ± 11.1	-2.2	12.7	1.58	10	0.146	0.56^
Flexion	Passive	20	-0.6 ± 18.7	1.0 ± 16.0	-1.5 ± 27.3	-14.3	11.3	-0.25	19	0.804	-0.09
	Active	20	0.9 ± 18.9	3.6 ± 12.4	-2.6 ± 26.4	-15.0	9.8	-0.44	19	0.664	-0.21
Internal Rotation	Passive	19	1.6 ± 20.7	3.9 ± 13.0	-2.3 ± 25.7	-14.7	10.1	-0.38	18	0.705	-0.18
	Active	19	6.1 ± 12.7	5.1 ± 11.8	1.1 ± 17.9	-7.6	9.7	0.26	18	0.795	0.09
External Rotation	Passive	18	10.5 ± 18.4	2.7 ± 11.3	7.8 ± 24.0	-4.2	19.7	1.38	17	0.187	0.69**
	Active	19	9.4 ± 15.8	1.6 ± 11.2	7.8 ± 20.9	-2.3	17.9	1.63	18	0.121	0.70**

ROM = range of motion; SD= standard deviation; df=differential; p-value< 0.05 significant; effect size: high**> 0.62, moderate^ 0.30-0.61, low <0.29

Passive range of motion

Statistical analysis (Table 3) revealed a statistically significant change in passive abduction (11.8 ± 11.3, p = 0.004) in the manipulation treatment group when compared to the alternative treatment group. No significant change was observed for passive adduction (2.8 ± 9.5, p = 0.248), extension (3.4 ± 14.5, p = 0.342), flexion (-1.5 ± 27.3, p = 0.804), IR (-2.3 ± 25.7, p = 0.705), and ER (7.8 ± 24.0, p = 0.187).

Active range of motion

Statistical analysis (Table 3) revealed no statistically significant change in active abduction (4.1 ± 17.0, p = 0.418), adduction (2.8 ± 9.5, p = 0.248), extension (5.3 ± 11.1, p = 0.146), flexion (-2.6 ± 26.4, p = 0.664), IR (-2.3 ± 25.7, p = 0.705), and ER (7.8 ± 24.0, p = 0.121) in the manipulation group when compared to the alternative treatment.

Numeric pain scale change

Statistical analysis (Table 4) showed significant improvements in numeric pain scale after the manipulation (-1.05 ± 0.81, p<0.0001) and alternative treatments (-0.44 ± 0.89, p=0.0351) when compared to before the treatment. There was a statistically significant improvement in numeric pain scale when the manipulation treatment

Table 4.

Analysis of change in numeric pain scale following manipulation and alternative treatments and the difference in change

	n	Mean ± SD	95%CI - L	95%CI - U	t-statistic	df	p-value	Effect Size
Manipulation	20	-1.05 ± 0.81	0.67	1.43	5.80	19	<0.0001	0.54
Alternative	20	-0.44 ± 0.89	0.03	0.87	2.27	19	0.0351	0.23
Difference in change (manipulation-alternative)	20	-0.60 ± 1.20	-1.16	-0.04	-2.24	19	0.0374	0.71

SD= standard deviation; df=differential; CI= confidence interval; p-value< 0.05 significant

Table 5.
Perceived intervention received by rate of correct guess

	Correct Guess Rate (%)
Initial visit	85
Crossover	75

was compared to the alternative treatment (-0.60 ± 1.20, p=0.0374).

Perceived intervention received

On average, the participants' ability to correctly guess which intervention that was received was 85% and 75% for the initial visit and crossover visit, respectively (Table 5).

Effect size

Calculation of effect sizes (Table 3) revealed large effect sizes for passive abduction (1.31) and ER (0.69), and active ER (0.70). Moderate effect sizes were noted for active abduction (0.32), adduction (0.45), and extension (0.56) as well as passive adduction (0.41) and extension (0.38). For the numeric rating scale results, the effect size comparing change in pain with manipulation to change in pain with sham was 0.71.

Discussion

This study evaluated the effects of femoral-acetabular high velocity low amplitude manipulation with drop piece (HVLA MDP) compared to an alternative femoral-acetabular procedure on pain perception and passive and active ROM at the hip joint in symptomatic students with a hip complaint and/or limited ROM at the hip.

In this study the Optotrak® system was used to measure active and passive hip ROM. Schmidt *et al*. reported all four Optotrak® systems they tested produced high precision, repeatability and accuracy of under 10 µm when the distance between the camera system and rigid body was minimized to within the manufacturer's recommended range.[24] This procedure was used and followed in the current study. However, although all hip ranges of motion were measured in all 20 participants, some data was omitted from statistical analysis due to corruption that was not apparent during the initial measurement and collection. The use of the Optotrak® system involved the use of wired sensors that were strapped to the participants' hips and shanks. As stated previously, for the comfort of the participants, the hip sensor was attached to a belt that was wrapped tightly around the participants' hips. Although there was an intended effort to ensure all sensors were securely fixed to the participants, especially during the motion trials; there were cases the Optotrak® markers still slipped/shifted from their fixed position. In most cases this marker slippage was caused by the participants movement during hip flexion, when the participants thigh would contact the Optotrak® marker itself. In other cases, marker slippage was a result of the sensor straps loosening up during testing. To address these issues: the Optotrak® markers were strapped on a little tighter than usual, tape was sometimes used, and/or the marker was repositioned to prevent any of the participants anatomy from making contact with the markers during testing. Even despite these countermeasures, several trials were omitted because marker slippage was hard to detect during data collection, unless it was obvious to the tester (i.e., tester witnessed the marker fall off or come undone). Sometimes it was not until the visual 3D bone model was applied to the data and successive trials compared to identify a definite marker slippage. Therefore, the data for those trials were omitted, leading to differing sample sizes for the statistical analysis of each ROM, as seen in Table 3. The greatest omission of data occurred for passive (n=12) and active (n=12) abduction as well as active extension (n=11). All ranges except passive and active flexion were affected by this issue.

For the data that was analyzed, as summarized in Table 3, it was found that there was a significant increase in passive abduction in the manipulation treatment in comparison to the alternative treatment.

There are numerous theoretical mechanisms of action for manipulation therapy (MT).[25-27] These theories are based around three major concepts: the biomechanical effects, the muscular reflexogenic effects and the neurophysiological effects.[28] The hip joint is a synovial joint and has synovial folds that are highly innervated and capable of generating pain. Hip synovial folds have been reported to be involved in production of catching, locking and clicking of the joint.[29]

MT is suspected to gap the joint, therefore reducing the impaction on the trapped synovial folds and allowing it to return to its normal position.[27,30] This will allow the joint to regain full or improved ROM.

It has been reported that MT can have hypoalgesic as well as muscle reflex effects.[31-35] The hypoalgesic effects of MT can be attributed to the gate-control theory of pain.[26,28] The joint capsule and surrounding musculature have numerous proprioceptors in the form of muscle spindles and type I and type II afferents.[26,28] With MT, there is a dynamic stretch to the tissue that will cause an increase in afferent discharge from these receptors.[35-37] This increase in afferent input will attenuate the pain sensation at the dorsal horn, thereby creating a hypoalgesic effect.[26] The muscle-reflexogenic effects of MT are believed to occur through the effects on the muscle spindles surrounding the joint. As with the gate-control theory, during the act of the manipulation, there is an increase in the afferent output from the surrounding muscle spindles.[35-37] Directly after MT, the muscle spindles become silent for a short period.[35,37] After this silent period, the spindles return to firing at their appropriate rate, which can cause a relaxation of the surrounding muscles. The hip manipulation in this study was done with 20-30 degrees of hip abduction. This may have increased hip abduction by further stretching of the hip capsule in abduction resetting the muscle spindle, inhibiting the hip adductor groups, releasing of any synovial fold entrapment, gaping the joint and resulting in increased abduction and decreased pain.[24, 26-29, 31-37]

Although statistical significance was found only for passive abduction, the effect sizes appear to show a moderate to high trend towards improvement in ROM following manipulation for active and passive ER (effect size =0.70 and 0.69 respectively). Effect size is a quantitative measure of the magnitude of the experimental effect. The larger the effect size the stronger the relationship between two variables. The higher effect sizes in ER may also have been due to the direction of the manipulation which included 15 to 20 degrees of ER and ending in 15 to 20 degrees of extension. Further investigation using a larger sample size may clarify the effects of manipulation as multiple data sets were omitted due to sensor movement.

Other studies have investigated the effects of manipulation and mobilization of the hip joint on ROM but did not use a drop piece. Stathopoulos *et al*.[15] found statistically significant differences in hip flexion and IR after hip mobilizations with movement as they mobilized the joint in these directions. This differs from results of the current study in which an increase in passive abduction of the hip was observed possibly due to the direction of the MT. Additionally, a case study by Strunk and Hanses[38] used a combination of manipulation, mobilization, and passive stretching with the intent of improving the ROM of 70-year-old patient with an osteoarthritic hip. For manipulation, a gentle prone P-A drop piece technique was used.[38] This differs from our technique, which used a long-axis manipulation combined with a drop piece. After 12 weeks of care, the patient had improved disability scores and a small increase in active IR of the hip.[38] Hoeksma *et al*.[12] compared manual therapy to exercise therapy in the treatment of hip OA. The manual therapy intervention was a traction manipulation, in the limited position of the hip, using a high velocity thrust, similar to our design.[12] They concluded that manual therapy was far superior to exercise therapy in improving hip function in patients with OA.[12] Brantingham *et al*.[39] investigated the short-term effectiveness of full kinematic chain manual and manipulative therapy (MMT) plus exercise compared with targeted hip MMT plus exercise for symptomatic mild to moderate hip OA. The treatment consisted of a targeted hip manipulation, using high-velocity, low-amplitude thrust-type along with pre- and post-treatment stretching of the same hip.[39] They concluded that there was no statistically significant difference between the two groups however, both groups did have improved Western Ontario and McMasters Osteoarthritis Index (WOMAC) scores.[39]

There was a statistically significant improvement in numeric pain scale scores for both the manipulation treatment and the alternative treatment. However, when the two treatments were compared, there was a statistically significant difference in the magnitude of improvement for the manipulation treatment. The decrease in pain perception may be due to the hypoalgesic effects of MT.[26,28] There are no studies evaluating the minimal clinically important change in the NPS for hip pain; however, Child *et al*.[40] concluded that a change of two points (20%) represents a clinically meaningful change in patients with low back pain. As such, although the reduction of pain seen in our study was statistically significant, it may not be clinically significant. Furthermore, our sample included participants from a young healthy student population. Further research is needed to determine if clinically meaningful pain reduction can be achieved in populations with more severe and limiting hip ROM. Regardless, a one-week washout period was used in this study which was reported to be an appropriate length of time for crossover studies in manipulation.[41]

Notably of all the participants undergoing manipulation, only one participant reported a short episode of tingling in their ipsilateral foot during the procedure. No other side effects were reported.

The alternative treatment in the current study involved setting up the participant similarly to the manipulation treatment, however, the alternative used a thrust directly into the drop piece as opposed to the manipulation treatment which used a thrust into the joint, which then engaged the drop piece. In regard to the quality of the alternative procedure as a sham, 85% of participants at the initial visit correctly guessed whether they received the manipulation or alternative treatment and 75% of the participants guessed correctly at the crossover visit indicating the quality of the alternative procedure as a sham to be poor. This may have been influenced by the population used in the study. Due to the fact that all participants included were chiropractic students, some may have been exposed to drop piece hip manipulation during their education and therefore were able to identify whether they received the manipulation treatment or alternative treatment. Since there are no other drop piece mechanism studies that exist, this study establishes a baseline for improving sham procedures involving drop pieces. The procedure could be improved on by excluding chiropractic students and including individuals who have never received manipulation before or by blindfolding the participants so they cannot see what is being done.

Limitations

A reduction in the initial sample size was the result of data collection errors due to movement of the Optotrak® sensors. The equipment available to us included wired sensors that were attached to the participants using a Velcro strap. Unfortunately, in some cases, this resulted in the sensors shifting during data collection. We were able to identify these errors using our re-digitizing protocol after every trial. The data that was found to be corrupt was omitted from the study, which resulted in smaller and differing sample sizes for the statistical analysis of each ROM. As such we were not able to reach the sample size estimate (except for active and passive flexion) we desired which increased the likelihood of type II error.

Furthermore, differences between groups (i.e., sex ratio, weight, and height) have not been accounted for in the statistical analysis. As such, there may have been an unequal distribution of important known or unknown confounding factors between groups. This may have contributed to the differences in outcomes observed between groups.

During the intake no information on participant's diagnosis, duration of symptoms nor outcome measures were collected, which restricts the ability to infer findings to a wider population. For future studies obtaining information on diagnosis, duration and appropriate outcome measures are recommended. One pre- and post-intervention measurement was used to simulate real clinical testing. However, this may have increased the chances of errors in measurement and the potential for unusable data due to corrupt files.

Establishing a convincing alternative sham manipulation was difficult. Subjects in this study were chiropractic students, who may have been familiar with the manipulation used in our study. This led to a high percentage of participants correctly guessing which treatment they received, thus decreasing the quality of blinding, and could have resulted in an overestimation of the treatment effect. Repeating the study with non-chiropractic students and modifying the alternative treatment are recommended.

This study investigated the immediate effect of hip HVLA MDP. Future research investigating both the short- and long-term effects of hip manipulation is recommended.

Conclusions

HVLA MDP of the symptomatic hip joint in young adults (21 to 32 years of age) statistically significantly improved the perception of pain. It may also lead to significant increases in passive hip abduction; however, not achieving the desired estimated sample size for ROM measurement increased type II error in this study. Further research including larger sample size and improved sham procedures are recommended.

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