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Commentary

An interdisciplinary clinic in rural Tanzania – observations on chiropractic care in a developing nation

Joe Lemire, DC, MSc, FCCS(C)¹ Brian Budgell, DC, PhD²



Joe Lemire, DC, MSc, FCCS(C)

It appears that a great many chiropractors and chiropractic institutions are involved in health care initiatives in developing countries. Developing nations present extraordinary opportunities to do good, but also



Brian Budgell, DC, PhD

Il semble qu'un nombre important de chiropraticiens et d'institutions chiropratiques participent à des initiatives de soins médicaux dans des pays en développement. Ces pays offrent beaucoup d'occasions pour des actions

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Conflict of interest: B. Budgell is a director and president of the executive committee of Global Peace Network, the Canadian NGO which is partowner of the Kanyama Village Dispensary. © JCCA 2016 carry risks, for practitioners and organizations, which may not be obvious prior to actual local engagement. This paper describes the guiding principles under which one international collaboration has evolved in rural Tanzania, a so-called 'low resource' setting where the majority of families subsist in extreme poverty. Several challenges to effective care are also identified.

(JCCA. 2016;60(2):131-136)

KEY WORDS: chiropractic, Tanzania, international development, outreach

Introduction

While most chiropractors and virtually all accredited undergraduate chiropractic programs are located in wealthier nations, an increasing number of chiropractic practitioners and students seek clinical experiences in developing nations. For instance, at a recent meeting of the directors of clinics of North American chiropractic colleges, 10 of 17 clinic directors present reported that their students take part in humanitarian chiropractic missions in developing nations (Survey by Dr. Lemire at the ACC-RAC Clinic Directors Meeting, March 14, 2013, positives, mais comportent aussi pour les praticiens et les organisations des risques qui ne sont pas toujours évidents avant l'engagement sur le terrain. Cet article décrit les principes directeurs sur lesquels a évolué une initiative collaborative internationale en Tanzanie rurale, un environnement décrit comme faible en ressources, où la majorité des familles subsiste dans une extrême pauvreté. L'article cerne en outre plusieurs défis à relever pour offrir des soins efficaces.

(JCCA. 2016;60(2):131-136)

MOTS CLÉS : chiropratique, Tanzanie, développement international, aide

Washington, DC, USA). Out of the 10 colleges, 3 indicated that they did not support their students' endeavors in international humanitarian missions. Unfortunately, the opportunities available appear to cover a broad spectrum ranging from frankly entrepreneurial exercises which exploit vulnerable populations and naive students, to programs which seek to meet the standards of education and clinical care seen in the most highly regulated environments. This paper describes an evolving interdisciplinary outpatient clinic in rural Tanzania, the Kanyama Village Dispensary. The Kanyama Village Dispensary (seen in



Figure 1 The Kanyama Village Dispensary.

Figure 1), operates under a memorandum of association between Global Peace Network (GPN), a registered Canadian charity (www.globalpeacenetwork.ca), the Tanzania Home Economics Association (TAHEA), a Tanzanian community-based organization, and the Magu District Council, the level of government responsible for overseeing health care within the district in which the clinic is located. GPN, which founded the clinic, conducts programs in Tanzania and Nicaragua, and subscribes to the principle that international programs should be legal, ethical and effective. This paper describes how the Kanyama Village Dispensary models these values.

Legality

Historically, international non-governmental organizations (NGOs) in Tanzania have, in the words of one Canadian development officer, 'gone where the government was not and done what the government could not do (personal communication, 2012).' This approach may have been justified at a time when the government was largely absent from rural health care. However, governance in an independent Tanzania has evolved considerably and it is no longer possible, practical or responsible for NGOs to 'fly under the radar.' In Tanzania, regulations require the registration of health care facilities, setting requirements for physical facilities, such as floor space and segregation of rooms, and stipulating which types of services may be offered according to the facility classification. Health professionals are also regulated, although at the time of the establishment of the Kanyama Village Dispensary in 2013, there were no chiropractors registered to practice in Tanzania, nor had specific legislation been contemplated. Thus, the first chiropractor registered to practice in Tanzania, a Canadian Chiropractor, Dr. Andrew Wilson, DC, was registered under the legislation for practitioners of 'traditional medicine.' Four chiropractic practitioners have subsequently been registered under the same legislation, and a physiotherapist was permitted to practice without registration as no specific legislation governed physiotherapy at the time she was at the dispensary. Within this context, general liability insurance for the facility provides a measure of protection to patients and practitioners.

Once the practitioner has received a letter of invitation from the District Executive Director to provide volunteer clinical services, he or she can apply for registration. The process of registration is undertaken by the District Council on behalf of the volunteers; in essence there is no cost to the volunteers for this process.

Within the Tanzanian health care system, a dispensary, such as the one described herein, is an outpatient facility designed to serve a catchment area of 6 to 10 thousand people. In most instances, it is the patient's first point of contact with the public health care system, although some communities also have so-called 'health outposts' staffed by local people who have been given some rudimentary training in first aid and triage.¹ The Kanyama Village Dispensary was designed to exceed the space requirements for a dispensary, with a view to evolving into a health center, the next highest classification of health care facility. As a registered facility, the Kanyama Village Dispensary normally has a staff of two nurses and two 'clinical assistants' provided by the District Medical Officer. A clinical assistant is a person who has completed a 2-year diploma program following high school, and may have undergone some further specialized training.¹ Clinical assistants are normally referred to as 'Doctor' and have much the same scope of practice as medical doctors in Canada. To put this into perspective, in Magu District there are 3 medical doctors (MDs) serving a population of approximately 300,000. As a registered facility, the Kanyama Village Dispensary is also entitled to an allotment of essential medicines distributed from a national supply centre. However, the distribution of medicines is problematic throughout Tanzania and after two years of operation the Kanyama Village Dispensary has still not received its allotment. Consequently, the District Medical Officer has redistributed some medications from the District hospital, and supplementary supplies are brought from Canada with visiting volunteers. No license is required to import donated medications and donated medications are dispensed by on-site medical staff.

In general, the volunteers at the Kanyama Village Dispensary attend to musculoskeletal complaints Monday to Friday in a dedicated on-site rehabilitation building. Clinic records for the year ending July 31, 2015 show that more than 70% of patients present with chronic low back pain and about 25% with neck pain. These statistics are congruent with the 2010 Global Burden of Disease Report, which revealed that among non-communicable diseases, diabetes and musculoskeletal disorders such as low back pain and neck pain increased the most between 1990 and 2010 in most regions of the world.²

In the process of diagnosing and treating musculoskeletal disorders, the chiropractors have to rule out tropical diseases such as malaria, amoebiasis and schistosomiasis, as well as common communicable diseases such as HIV and tuberculosis. Being registered as practitioners of 'traditional medicine', the chiropractors have no limitations on their scope of practice, and could legally recommend or provide drugs and treat patients with non-musculoskeletal conditions. However, the practice at the Kanyama Village Dispensary is to refer non-musculoskeletal complaints to the medical staff on site. Any drugs available in Tanzania can be purchased over-the-counter without a prescription. The practice at the Kanyama Village Dispensary is to refer patients to our medical staff for provision of drugs.

Ethical Considerations

The population served by the Kanyama Village Dispensary includes many people who live in extreme poverty - defined by the World Bank as living on less than \$1.25 USD per day.³ In theory, Tanzania has a national insurance program in which families may enroll for the equivalent of approximately \$10 dollars per year. This exceeds the ability of most local families to pay. Children under the age of 5 and adults over 60 years are supposed to receive free health care. However, front line facilities (mostly dispensaries) often have insufficient medications or diagnostic supplies^{4,5}, so that patients are referred out to private pharmacies and labs. Since drugs and commercial laboratory services are beyond the means of most Tanzanians, the net effect of all of these factors is that many people in rural communities do not have access to registered health services at all.^{6,7} Thus, all care provided by volunteers at the dispensary is offered free of charge. Additionally, no charge is rendered for the use of malaria rapid diagnostic kits or urinalysis multistix donated through GPN. Furthermore, with the understanding and cooperation of the District Medical Officer, the medical staff routinely waives charges for any service to patients who might have difficulty paying.

A minority of people in the catchment area of the dispensary have a primary school education and illiteracy is the norm. Few are sufficiently fluent in English to allow an unaided interview in English, and for many even the national language, Kiswahili, is not spoken well. Patient interviews are conducted through interpreters, including clinic medical staff. Record keeping for patients receiv-

ing treatment from volunteers meets the same standards as those required for practice in Canada. Hence, in addition to demographic data and health history, patients provide a history of their current complaint, leading to a recorded diagnosis and management plan. As is the practice throughout Magu District, written informed consent is not acquired since most patients are illiterate. Interestingly, the most current national guidelines for clinical practice do not make reference to informed consent.8 Furthermore, most patients do not have a sufficient understanding of human biology, health and disease to weigh treatment options, which are relatively limited to start with. Most people in the community regard witch-craft as an important cause of disease or even the unifying cause of disease.9 In this environment, patient-directed care and informed consent as implemented in more developed nations are meaningless, and so practitioners take on the somewhat conflicted roles of both clinician and patient advocate.

Unlike some models, the program at Kanyama Village Dispensary does not charge a fee to volunteers. Volunteer practitioners are expected to make a commitment of 3 months, as it is felt that shorter stays disrupt rather than contribute to the program. To date, room and board, local transportation, and economy return airfare have been provided by GPN. In the most recent instance, this was assisted by a scholarship from the Student Canadian Chiropractic Association. Additionally, in July of 2015, the dispensary received two volunteer chiropractic students and a professor from the University of Québec at Trois-Rivières (UQTR). These volunteers paid their own expenses for their one-month stay, which was planned as a pilot exercise for placing future students at the dispensary and other health care facilities in Tanzania. The two visiting students were closely supervised by their professor and were required to maintain the same clinical standards of practice as they would have during a clinical supervised placement at the UQTR's Outpatient Student Clinic. The clinical placement in Tanzania was counted towards partial fulfillment of course requirements of their final year at UQTR.

Effectiveness

With local variability, musculoskeletal disorders now rival or exceed more high profile diseases such as malaria, tuberculosis and HIV/AIDS, as causes of days lost to disability and loss of productivity in East Africa.² In 1990,



Figure 2.

Kanyama Village Dispensary Patient Visits. October 2013 – September 2015. Bi-directional arrows indicate times when Canadian volunteers have been on-site.

low back pain ranked number 12 out of the top 25 causes for disability and reached number seven in 2010.² Sadly, musculoskeletal specialists are almost absent from Tanzania and in 2014 the World Confederation of Physiotherapists listed only 40 physiotherapists for the approximately 40 million people in Tanzania.¹⁰ Currently, volunteers at the Kanyama Village Dispensary appear to be the only registered chiropractors in the country. Public rehabilitation facilities are absent from Magu District. Hence, patients suffering musculoskeletal trauma or stroke, for example, have historically only received acute care before discharge.

Figure 2 maps patient visits to the clinic since it was first staffed by Magu District health workers in 2013. Initial patient numbers were very low, largely due to the virtual absence of medicines and diagnostic tests. This situation is not uncharacteristic of Tanzania in general.¹

When Canadian volunteers have been on site (bi-directional arrows in Figure 2) from July to September 2014, January to March 2015, and most recently at the beginning of July 2015, a rapid increase in the number of patients seeking musculoskeletal care can be observed. Interestingly, there were also coincident and sharp increases in patients seeking medical care for non-musculoskeletal complaints (data not yet available for medical care from July to September, 2015). The increase in 'medical' patients may be attributed to referrals from the rehabilitation staff to the medical staff, and also possibly due to the increased attractiveness of visiting practitioners to local patients, due to both perceived and real expertise.

Challenges

The model of the not-for-profit, remote, interdisciplinary clinic faces a number of important interwoven challenges. The intermittent provision of rehabilitation services, as implemented to date, conflicts with the concept of rehabilitation, which often requires continuous care over weeks or months. On the other hand, it is challenging to recruit and fund volunteers, particularly considering the distance of the clinic from Canada, and even its remoteness in Tanzania. A mechanism which is being explored to overcome these difficulties is to have the clinic, and related facilities in the referral chain, function as external clinics for accredited educational programs in Canada and elsewhere. Ultimately, however, sustainability and scalability can only come from the provision of adequately trained local practitioners.

Lessons Learned

While we have no statistics to refer to, the common knowledge among development workers in Tanzania is that the average project fails, often quickly and quite spectacularly. The Kanyama Village Dispensary has weathered its own crises and its relative longevity appears to be due partly to local partnerships and local intelligence. More specifically, the input of the Magu District Council and the Tanzania Home Economics Association has been invaluable in navigating the several layers of bureaucracy which can either facilitate or defeat philanthropic initiatives. It has also been important to temper North America enthusiasm and to learn patience. Things almost invariably take longer than anticipated to achieve, but often for very good reasons. For example, our Tanzanian colleagues normally contract malaria at least once each year, which means that work often falls behind schedule. During the rainy seasons, transportation becomes quite problematic and unpredictable, and at any time of the year electrical and communications systems often fail. In circumstances which might be quite frustrating, we remind ourselves that if things worked as well as they do in North America, there would be no need for us in Tanzania. We are also encouraged by seeing improvements in the well-being of our community with each passing year - in other words, we observe that philanthropy, by and large, works.

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Effect of two consecutive spinal manipulations in a single session on myofascial pain pressure sensitivity: a randomized controlled trial

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Objective: To investigate the summative effect of two consecutive spinal manipulative therapy (SMT) interventions within the same session on the pain pressure sensitivity of neurosegmentally linked myofascial tissues.

Methods: 26 participants were recruited and assessed for the presence of a clinically identifiable myofascial trigger point in the right infraspinatus muscle. Participants were randomly assigned to test or control group. Test group received two consecutive real cervical SMT interventions to C5-C6 segment while controls received one real SMT followed by one validated sham SMT intervention to C5-C6 segment. Participants received the two consecutive SMT interventions 30 minutes apart. Pain pressure threshold (PPT) readings were recorded at pre-SMT1 and 5, 10, 15, 20 and 25 minutes post-SMT1 and post-SMT2. PPT readings were normalized to pre-SMT1 values and averaged. Objectif : Étudier l'effet sommatif de deux interventions consécutives de manipulation vertébrale (MV) dans la même session sur la sensibilité à la pression douloureuse des tissus myofasciaux liés par des neurosegments.

Méthodologie : 26 participants ont été recrutés, chez qui on a étudié la présence d'un point de déclenchement myofascial cliniquement identifiable dans le muscle infraépineux droit. Les participants ont été répartis au hasard au groupe expérimental ou au groupe témoin. Le groupe expérimental a subi deux interventions consécutives réelles de MV cervicales au niveau de C5-C6, tandis que le groupe témoin a subi une MV réelle suivie d'une manipulation factice confirmée, au niveau de C5-C6. Les participants ont subi les deux interventions consécutives de MV à un intervalle de 30 minutes. Les seuils de pression douloureuse (PPT) ont été enregistrés avant les MV-1 et 5, 10, 15, 20 et 25 minutes après la MV-1 et après la MV-2. Les PPT ont été normalisés et ramenés à la moyenne, sur les valeurs pré-MV-1.

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Corresponding author: Michelle A. Laframboise Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, Canada e-mail: michelle.laframboise@gmail.com © JCCA 2016 Results: Repeated measures ANOVA demonstrated a significant main effect of SMT intervention [F(1,24)=8.60, p<0.05] but not group [F(1.24)=0.01](p=0.91). Post-hoc comparisons demonstrated a statistically significant (p<0.05) increase in SMT2 versus SMT1 (18%) in the test group but not in controls (4%) (p=0.82).

Conclusions: Two consecutive SMT interventions evoke significant decreases in mechanical pressure sensitivity (increased PPT) within neurosegmentally linked myofascial tissues. The antinociceptive effects of SMT may be summative and governed by a doseresponse relationship in myofascial tissues.

(JCCA. 2016;60(2):137-145)

KEY WORDS: chiropractic, spinal manipulation, myofascial pain, pressure thresholds

Introduction

Chronic musculoskeletal diseases rank amongst the leading burdens of illness on the Canadian economy¹. Myofascial pain (MPS) is the most common form of musculoskeletal pain and is characterized by chronic regional pain associated with the clinical manifestation of myofascial trigger points (MTrP) within the affected muscles². Its prevalence in the general Canadian population has been reported as high as $20\%^3$ and up to $85\%^4$ in the elderly (>65 years) population segment. MTrP are recognized as palpable hyperirritable nodules located within taut bands of skeletal muscle⁵. Given that the ratio of over-65 to under-65 population is expected to double in Canada by 2050⁶, chronic MPS is poised to become one of the greatest challenges to Canada's health delivery system. For this reason, advancing cost-effective therapies for the management of MPS is important to the sustainability of our health delivery system.

Spinal manipulative therapy (SMT) is a cost-effective and commonly employed therapeutic modality used in the clinical setting for the treatment and management of chronic pain of myofascial origin.^{7,8} SMT is characRésultats : Les mesures répétées ANOVA ont montré un effet principal significatif de l'intervention MV [F (1,24) = 8,60, p < 0,05], mais pas du groupe [F (1,24)= 0,01] (p = 0,91). Des comparaisons subséquentes ont montré une augmentation statistiquement significative (p < 0,05) dans MV-2 par rapport au MV-1 (18 %) chez le groupe expérimental, mais pas chez le groupe témoin (4 %) (p = 0,82).

Conclusions : Deux interventions consécutives de MV évoquent une diminution significative de la sensibilité à la pression mécanique (augmentation de la PPT) dans les tissus myofasciaux liés par des neurosegments. Les effets antinociceptifs de la MV peuvent être sommatifs et régis par une relation de « réponse à la dose » dans les tissus myofasciaux.

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MOTS CLÉS : chiropratique, manipulation vertébrale, douleur myofasciale, seuils de pression

terized by the application of a high-velocity, low amplitude manual thrust to the joints of the spine. Despite the widespread use of SMT in the rehabilitation setting, its physiologic mechanisms and dose-response effect in the treatment of myofascial pain are poorly understood.

A limited number of studies have been published addressing the dose-response physiologic effect(s) of SMT. A dose-dependent reduction in the frequency and intensity of cervicogenic headache has been reported with SMT for up to 8 treatments.⁹ Similarly, increasing the frequency of chiropractic treatments from one to four sessions per week over a four week period has also been shown to reduce pain and disability outcomes in a dose-dependent manner within a chronic low back pain population.¹⁰

The body of research investigating the mechanisms of SMT has also consistently shown that SMT evokes regional physiologic effects. Significant decreases in regional paraspinal muscle tenderness have been observed post-SMT¹¹ and more recent research has suggested that these antinociceptive effects may be mediated via neurosegmental mechanisms⁷. A neurosegmental mechanism refers to an effect following an intervention delivered to a specific intersegmental functional spinal unit on a tissue innervated by its corresponding spinal nerve root, an example of this would be an intervention delivered to the C5-C6 functional spinal segment having an effect on the infraspinatus muscle, which is innervated by the suprascapular nerve (origins of the C5 and C6 spinal nerve roots).²⁹ Very few studies to date, however, have explored the summative (dose-response) antinociceptive effect of SMT. In particular, no studies have investigated the summative antinociceptive effect of two consecutive SMT interventions in myofascial tissues using a randomized controlled design.

The purpose of this study is to investigate the summative effect of two consecutive SMT interventions within the same session on the pain pressure sensitivity (PPT) in neurosegmentally linked myofascial tissues. We set out to test the hypothesis that two consecutive SMT interventions applied to the C5 spinal segment evokes greater increases in PPT at a MTrP site within a neurosegmentally linked muscle (infraspinatus, C5-C6) as compared to a single SMT intervention. The findings of this study will provide insight into the temporal summative effect(s) of two consecutive SMT interventions and inform future research investigating the summative and dose-response relationship of SMT for therapeutic applications in the management of MPS.

Methods

This randomized controlled intervention study was approved by the Ethics Board at the Canadian Memorial Chiropractic College and the University of Guelph and was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki, 2000) for experiments with humans. This manuscript conforms with the consort guidelines for reporting randomized trials (http://www.consort-statement.org/). All participants provided written informed consent prior to participating and none of the participants withdrew from the study.

A power analysis using previously published data determined that a sample size of 13 participants per group (n=26) was needed to provide 90 percent power to detect an effect size of d=1.33 standard deviation at an alpha of 0.05 using a two-tailed test for significance.¹² A total of 26 prospective participants were recruited via convenience sampling from the Canadian Memorial Chiropractic Col-

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lege (CMCC, Toronto, Ontario, Canada) student population. Participants were either male or female between the ages of 21-40 years from the CMCC main campus and/or campus clinic. Each prospective participant was assessed for eligibility by completing a confidential health history questionnaire and undergoing a brief physical assessment conducted by the primary investigator, a licensed chiropractor in the Province of Ontario, Canada.

All patients were screened for current/recent episodes of neck pain. The primary inclusion criterion was the presence of a clinically identifiable MTrP locus (experimental unit) within the right infraspinatus muscle. The diagnostic features of a MTrP used in this study have been previously reported and include a palpable hyperirritable nodule located within a taut band of skeletal muscle, pain recognition on palpation of the trigger point, pain referral to the lateral aspect of the affected shoulder and/ or local twitch response in the muscle¹³. To improve the reliability of detection, we only accepted clinically identifiable MTrP loci with a baseline PPT value less than 35 N (Newtons).¹⁴

A computer generated random allocation sequence was used to randomize qualifying participants into two groups. Each group received two SMT interventions (SMT1, SMT2) 30 minutes apart. The test group received two real cervical spinal manipulative therapy interventions (rcSMT) while controls received one rcSMT and then one sham cervical spinal manipulative therapy intervention (scSMT). The statistician held the randomization scheme and, in order to ensure concealment, the statistician was not involved in the experiment. The individual group allocations were printed by the research assistant and placed into blank white opaque numbered envelopes. The assessing clinician was blinded but the treating clinician was exposed to allocation codes. The same research assistant was responsible for recording all PPT values during the course of the study and was also blinded to the participants' group status.

One licensed clinician with over 34 years of clinical experience in SMT provided all cervical spine interventions to the participants. All testing was conducted at the Canadian Memorial Chiropractic College (CMCC) main campus clinic in Toronto, Ontario, Canada. The treating clinician was responsible for administering all SMT interventions (real and sham). The assessing clinician was responsible for performing the history and physical assessment on all prospective participants and for clinically identifying MTrP within the infraspinatus muscle. The assessing clinician was blinded to participants' group allocation while the treating clinician was not.

The primary outcome used to quantify the pressure sensitivity at the infraspinatus MTrP site was the pressure pain threshold (PPT) measure. A Chatillon DFE Series Force Gauge (AMETEK TCI, Florida, USA) with a gauge tip contact area of 285mm² (19x15mm) was used for all PPT recordings. For this study, we defined the PPT as the magnitude of force (Newtons) applied to the MTrP locus at the infraspinatus muscle which elicited the onset of a self-reported deep dull achy pain, local discomfort and/ or referred pain down the posterior lateral aspect of the ipsilateral arm. To quantify the pressure sensitivity of the infraspinatus MTrP, the algometer tip was placed perpendicular to the skin surface and a progressively increasing force was applied by the force gauge at a constant rate of 5N/s¹⁵ until the participant verbally indicated the onset of the local and/or referred deep, dull, or achy sensation in the area of the infraspinatus. The maximum reading on the force gauge at that point was recorded as the raw PPT reading. Three consecutive raw PPT readings were taken from the MTrP point locus at each measurement and the average of the three raw PPT readings was used as the raw PPT measure for analysis. All raw PPT values for each time point were normalized to baseline (pre-SMT1) during the analysis to allow for between subject comparisons.

Participants were asked to lay prone while the assessing clinician identified a MTrP in the infraspinatus muscle. The MTrP locus was identified and marked with a non-toxic marker directly on the skin to allow for easy identification and consistency throughout the study. All PPT readings were taken from the right side. Prior to the SMT1 intervention, participants were trained to consistently identify the PPT threshold using the contralateral infraspinatus MTrP. Baseline (pre-SMT1) PPT values were taken with the pressure gauge by the assessing clinician from the right infraspinatus. The assessing clinician was not present in the room while the treating clinician performed the SMT intervention to the cervical spine.

After the baseline PPT values were recorded, participants were asked by the assessing clinician to lie supine on the chiropractic table with the head resting on the drop headpiece which is designed to increase acceleration of the thrust during the cervical manipulative procedure. The participants that were assigned to the test group received each of the two rcSMT interventions 30 minutes apart with PPT measurements taken every 5 minutes (5, 10, 15, 20 and 25 minutes) after each of the rcSMT interventions. The rcSMT was performed by manually contacting the C5-C6 segment. The participant's head was supported by the treating clinician's forearm while the contact hand of the treating clinician contacted the C5-C6 spinal segment. A thrust maneuver was then applied to the C5-C6 segment with the supportive hand resting on the zygoma of the participant. A rotational inferior drop thrust maneuver was delivered with a high velocity low amplitude thrust. The head and neck was then returned to the neutral position.¹⁹ Immediately after the first rcSMT (SMT1) intervention, test participants were placed in the prone position for PPT measurements at 5-minute intervals (5, 10, 15, 20 and 25 minutes). A second rcSMT (SMT2) was then performed 5 minutes after the last PPT reading (ie., 25 minutes post-SMT1) and participants once again assumed the prone position for PPT measurements at 5-minute intervals (5, 10, 15, 20 and 25 min) for up to 25 minutes post-SMT2.

In contrast to the test group, controls received a rcSMT intervention first (SMT1) and scSMT intervention second (SMT2). The sham SMT intervention used in this study has been previously validated¹⁶ and involves an identical preloading of the cervical spine tissues as the rcSMT protocol. In the scSMT intervention, however, the participant's head is supported by the treating clinician's forearm, which rests directly on the headpiece. The treating clinician thrusts downward into the headpiece with the supporting arm to produce the sensation of a rapid manual thrust to the neck, however, no thrust is made by the contact hand and no segmental cSMT is applied to the C5-C6 segments. In order to assess for group bias, at the end of the study all participants were asked which intervention they believed they received.

All raw PPT measures were normalized to baseline (pre-SMT1) values prior to statistical analysis. The dependent variable was the mean normalized PPT which was calculated for each 25-minute epoch post-SMT intervention (SMT1 and SMT2) for each intervention group (test and control). We tested for equality of variance using Brown Forsythe test. A repeated measures two-way

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Group	Height (m)	Weight (kg)	Age (yr)	BMI (kg/m²)	Male:Female
Control	1.74 (0.10)	75.05 (11.86)	25.08 (2.22)	23.93 (2.00)	9:4
Test	1.77 (0.09)	77.77 (20.53)	24.77 (1.69)	24.59 (4.72)	6:7
P-value	0.534	0.682	0.694	0.647	

Table 1.Demographic profile of participants (n=26) in this study.Data presented as mean (SD).SD=standard deviation

Table 2.Average normalized (to baseline pre-SMT1)pain pressure threshold (PPT) readingsat the right infraspinatus muscle at each time pointafter SMT interventions (SMT1, SMT2)on both test and control groups.Data expressed as mean (SD).

		Control	Test
	SMT 1		
	5	1.28 (0.20)	1.20 (0.27)
MT1	10	1.42 (0.44)	1.30 (0.42)
Post-S	15	1.45 (0.48)	1.45 (0.54)
Min F	20	1.52 (0.63)	1.48 (0.50)
	25	1.53 (0.57)	1.42 (0.36)
	SMT 2		
Min Post-SMT2	5	1.48 (0.47)	1.55 (0.49)
	10	1.54 (0.68)	1.63 (0.54)
	15	1.51 (0.71)	1.63 (0.61)
	20	1.51 (0.53)	1.61 (0.56)
	25	1.46 (0.56)	1.64 (0.62)

ANOVA was performed using SMT intervention (SMT1, SMT2) and group (test, control) as the independent factors and normalized PPT as the dependent variable. Post-hoc comparisons of SMT interventions for each group were performed using the Bonferroni test. Multiple t-tests were used to compare baseline demographics between groups. Statistical analysis was performed with SPSS Statistical Software (Version 11.0, SPSS Ins., Chicago, USA). Level of significance was set at 0.05.

Results

A total of 26 participants (13 test, 13 control, mean age 24.9 ± 1.9 yr) were analyzed and no one withdrew from the study nor was excluded from the analysis. No statistical differences in baseline demographics including height, weight, age and BMI were observed between groups (Table 1).

The average normalized PPT reading after each SMT intervention (SMT1, SMT2) at each time point for each group is listed in Table 2. Brown Forsythe test did not reveal any differences in the variance between groups (p=0.21). The results of the two-way ANOVA demonstrated a significant main effect of SMT intervention [F(1,24)=8.60, p<0.05] but not group [F(1.24)=0.01] (p=0.91). SMT intervention*group interaction approached significance [F(1,24)=3.10](p=0.09). Post-hoc individual comparisons demonstrated statistically significant increases in SMT2 versus SMT1 in the test group [-0.24, CI - 0.41, -0.07](p<0.05) but not controls [-0.06, CI - 0.23, 0.11](p=0.82). Our data also demonstrates a significant 18% increase in PPT after SMT2 in the test group



Figure 1.

Normalized mean(SEM) pain pressure threshold (PPT) reading over the 25-minute recording period following each intervention (SMT1, SMT2) for each group (test, control). Common lettering denotes significant difference (alpha = 0.05). SEM = standard error of mean; SMT = spinal manipulative therapy; PPT = pain pressure threshold.

while controls demonstrate a 4% increase in PPT after the SMT2 intervention (Figure 1).

Subjects were asked what group (test,control) they thought they were assigned to. Our results demonstrate a specificity of 85% and sensitivity of 77% for participants correctly guessing their group assignment.

Discussion

The results of this study support our hypothesis that two consecutive, SMT interventions evoke greater decreases in mechanical pressure sensitivity within neurosegmentally linked myofascial tissues versus a single SMT intervention. Our data shows a statistically significant increase in PPT from SMT1 to SMT2 in the test group; in contrast, no difference was observed from SMT1 to SMT2 in controls. Test participants demonstrated an average of 18% increase in PPT after SMT2 compared with only a 4% increase in controls, who received a rcSMT followed by a scSMT intervention. These collective observations suggest that the effects of two SMT interventions are summative (temporal summation) and support the hypothesis that a dose-response relationship may exist between SMT and its antinociceptive effect in myofascial tissues.

A significant body of research has previously demonstrated regional changes in mechanical pressure sensitivity (PPT) after spinal manipulation in both healthy and clinical cohorts. SMT applied to the spine has been shown to evoke significant reductions in local mechanical pressure sensitivity in both asymptomatics^{7;17;18} as well as a chronic neck pain population¹⁹⁻²¹. In contrast, only two studies have failed to demonstrate changes in local pressure sensitivity after an SMT intervention. One of these findings was reported in the lumbar spine after lumbar SMT in healthy asymptomatics²², while another study reported no difference in mechanical pressure sensitivity in the low back, gluteal and sacroiliac regions following lumbosacral SMT in a chronic low back pain group²³. Two additional studies reported similar decreases in mechanical pressure sensitivity in the extremities after cervical SMT; bilateral decreases in PPT were measured at the lateral epicondyles of asymptomatics²⁴ as well as patients with lateral epicondylalgia²⁵ post-cervical SMT. Similarly, regional decreases in PPT have also been observed in cranial structures including the masseter and temporalis muscles²⁶ of asymptomatics as well as over the sphenoid bone in chronic neck pain patients²⁷ after SMT to the atlanto-occipital joint.

Despite the extensive research studying the effects of SMT, very little research to date has been done to investigate the dose-response effects of SMT. Two studies have examined dose response effects of multiple session SMT protocols in chronic LBP patients. The first demonstrated a positive clinically important effect for the number of chiropractic treatments on chronic low back pain intensity and disability outcomes after 4 weeks of treatment¹⁰ while a follow-up study examining the effect of four different treatment doses and found a mild dose-response effect to the total number of SMT treatments, peaking at 12 treatments; this study employed outcomes of pain intensity, functional disability and medication use⁹. Positive dose-response effects have also been reported after a sixweek course of cervical SMT in a chronic cervicogenic headache cohort.28

In contrast to the existing literature examining the dose-response of SMT in multiple sessions, our study is the first to examine the summative effect of consecutive SMT within a single session. Our findings show that two

SMT interventions lead to greater reductions in mechanical pressure sensitivity (temporal summation), adding evidence to support the hypothesis that a dose-response relationship may exist between SMT and antinociceptive effects in myofascial tissues.

Consistent with much of the existing research in this area, the primary outcome measure in this study was the PPT. The PPT was defined in our study as the least amount of force applied perpendicularly to the MTrP site in which the subject experienced a change from pressure sensation to a dull ache.²⁹ Pressure algometry has been experimentally validated as a reliable technique for quantifying MTrP sensitivity; extensive research exists to validate its high inter and intra-examiner reliability³⁰⁻³⁴ and studies have demonstrated that the PPT measure is strongly correlated to pain perception³².

The results of this study should be interpreted in light of several limitations. The primary consideration is the potential for subject group bias given that each participant had previous experience with cSMT which may have enabled them to identify their assigned intervention group. At the completion of the trials, we asked all participants which group they felt they were in. In spite of the fact that we employed a previously validated sham SMT procedure¹⁹; our results show a specificity of 85% and sensitivity of 77% for participants guessing their group assignment. Over the course of this study, however, we recorded 33 PPT readings from each of the 26 participants, for a total of 858 PPT readings. The mean coefficient of variation for all PPT readings was 0.05, suggesting that subject bias likely did not meaningfully impact our primary outcome measure.

Another limitation is the potential for modulating the sensitivity of a MTrP over time with repetitive pressure testing. We recorded three PPT measurements from the infraspinatus MTrP at each of the 5 time intervals post-SMT1 and SMT2, respectively, for a total of 30 readings over a one-hour period. However, previous research reports that repeated pressure algometry to a MTrP site over a one-hour duration does not impact the PPT reading.²⁹

We observed significant increases in the mean normalized PPT after the second test SMT intervention (SMT2); however, the clinical significance of these differences is unknown. The minimally clinically important difference (MCID) of pressure algometry in myofascial tissues has not been established. Fuentes³⁴ estimated that a clinically relevant change in the lumbar paraspinals of healthy volunteers would approximate 114 kPa; this pressure represents a raw difference of 33N from baseline in our study, given that our algometer probe head area measured 285mm². In contrast, Walton suggests a clinically relevant range of 50-220 kPa, the equivalent of 14-63N in our study. The average raw PPT increase from baseline in the test group was 19.0N (60kPa) while the maximum recorded increase from baseline was 54.1N (189kPa). Only 2 of 13 test participants (15%) demonstrated PPT changes above Fuentes' 33N (114kPa) threshold. In contrast, 7 of 13 (54%) participants fell above Walton's minimum threshold of 14N (50kPa) and the average raw difference in our study was 19.0N. These collective observations suggest that the decrease in myofascial pressure sensitivity observed in our study post SMT2 for test subjects may not have been clinically meaningful, however, more research is needed to establish reliable MCID thresholds for use in the evaluation of myofascial trigger points.

Our study demonstrates that two, consecutive SMT interventions reduces pain pressure sensitivity in neurosegmentally linked myofascial tissues in young healthy subjects. Future research should advance this line of inquiry by investigating the effects of multiple (>2) SMT interventions on pressure sensitivity in myofascial tissues to assess for saturation effects of treatment. Furthermore, we only assessed PPT changes for up to 25 minutes post-intervention in this study; future studies should investigate the duration of antinociceptive response in myofascial tissues with increasing SMT exposures in order to assess whether multiple SMT interventions enhance effect duration. In addition, the effects of multiple SMT interventions in non-segmentally linked tissues should be evaluated to assess for non-segmental (systemic) effects.

Our findings show that two SMT interventions enhance the antinociceptive effect (temporal summation) in myofascial tissues when compared to only one. These findings also support the hypothesis that a dose-response relationship exists between SMT and the antinociceptive effects in myofascial tissues and informs future research investigating the therapeutic applications of SMT in the management of myofascial pain.

Conflicts of interest

The authors of this study report no conflicts of interest. This study was not externally funded.

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The reliability of lumbar motion palpation using continuous analysis and confidence ratings: choosing a relevant index of agreement

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Introduction: Most studies show motion palpation unreliable. This study's primary objective was assessing its reliability using a continuous measure methods, most-fixated level paradigm, stratified by examiners' confidence; and the secondary objective was comparing various indices of examiner agreement.

Methods: Thirty-four minimally symptomatic participants were palpated in side posture by two experienced examiners. Interexaminer differences in identifying the most-fixated level and degree of examiner confidence were recorded. Indices of agreement were: Intraclass correlation coefficient, Mean and Median Examiner Absolute Examiner Differences, Root-Mean-Square Error and Bland-Altman Limits of Agreement. Introduction : La plupart des études montrent que la palpation dynamique n'est pas fiable. L'objectif principal de cette étude était d'évaluer sa fiabilité en utilisant des méthodes de mesure continue, le paradigme du niveau intervertébral le plus fixé, empreint du degré d'incertitude des examinateurs; et l>objectif secondaire était de comparer divers indices de concordance des examinateurs.

Méthodologie : Trente-quatre participants minimalement symptomatiques ont été palpés en position couchée par deux examinateurs expérimentés. Les différences, dans la capacité de désigner le niveau intervertébral le plus fixé, entre les examinateurs et le degré d'incertitude de ces derniers ont été enregistrés. La liste suivante constitue les indices de concordance : le coefficient de corrélation intraclasse, la moyenne et la médiane des examinateurs, les différences absolues entre les examinateurs, et les limites de concordance selon Bland-Altman.

Résultats : Trois des quatre indices de fiabilité (à

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Disclosure: This research project was internally funded by the institution. The authors have no commercial conflicts of interests to report in relation to the project. © JCCA 2016 Results: Three of four reliability indices (excluding intraclass correlation) suggested on average examiners agreed on the most fixated motion segment, and agreement increased with confidence. Statistical measures of data dispersion were low. The analyses of subgroups were "fragile" due to small sample size.

Discussion: Although subject homogeneity lowered ICC levels, the other reliability measures were not similarly impacted. Continuous measures statistical analysis demonstrates examiner agreement in situations where discrete analysis with kappa may not.

Conclusion: Continuous analysis for the lumbar mostfixated level is reliable. Future studies will need a larger sample size to properly analyze subgroups based on examiner confidence.

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KEY WORDS: chiropractic, motion palpation, lumbar, reliability, continuous analysis, confidence rating

l'exception de la corrélation intraclasse) ont suggéré qu'en moyenne les examinateurs concordent sur le niveau intervertébral le plus fixé en palpation dynamique; la concordance augmente avec le niveau de certitude. Les mesures statistiques de dispersion étaient faibles. Les analyses des sous-groupes n'étaient pas fiables en raison de la petite taille des échantillons.

Discussion : Bien que l'homogénéité des sujets réduise les niveaux du CCI, cela n'affecte pas pour autant les autres mesures de fiabilité. Les analyses statistiques des mesures continues révèlent une concordance entre les examinateurs dans des circonstances où une analyse discrète avec l'indice de concordance kappa en serait incapable.

Conclusion : L'analyse continue du niveau intervertébral le plus fixé est fiable. Les études futures auront besoin d'un plus grand échantillon afin d'analyser correctement les sous-groupes en fonction du niveau de certitude des examinateurs.

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MOTS CLÉS : chiropratique, palpation dynamique, lombaire, fiabilité, analyse continue, degré d'incertitude

Introduction

Motion palpation (MP) of the spine and sacroiliac joints is an assessment tool that is integral to most manual therapy practitioners and is taught within the core curriculum of virtually every chiropractic college. Most studies show MP to be unreliable, with concordance not much above chance levels.¹⁻⁴ Possible explanations for the general poor interexaminer reliability of MP have involved variation in procedure⁵, poor interexaminer spinal level localization leading to possible misreported discrepancies^{6,7}, incorrect spinal landmarks⁸⁻¹⁰, and variations in patient anatomy¹¹. Moreover, few previous studies allowed examiners to identify different degrees of fixation; this most likely lowered reported levels of agreement since it was not reasonable to expect agreement where one or both examiners did not find the subject especially fixated.

Despite the reported low reliability of spinal MP, the authors were able to develop an alternative study design

that ultimately demonstrated higher degrees of interexaminer reliability in the thoracic¹² and cervical¹³ spines. Rather than having the examiners in their study rate individual spinal levels as fixated or non-fixated, the examiners were asked to identify the location within a defined spinal range that was the "most-fixated" (in this paper the term "most-fixated" characterizes a vertebra that is perceived by the examiner to exhibit more resistance to movement with palpatory pressure than other vertebrae in a defined range). In addition, the examiners were asked to state whether they were "confident" or "not-confident" in their finding, so as to allow analysis of subject subgroups that were stratified by the degree of examiner confidence. The primary goal of the present study was the adoption of this "most-fixated" level paradigm to study the interexaminer reliability of motion palpation of the lumbar spine. The secondary goal was to explore the properties of various indices of examiner agreement.

Methods

This study was approved by the Institutional Review Board of the Palmer College of Chiropractic, and all subjects provided written informed consent. The subjects constituted a convenience sample of 35 chiropractic college students who were either asymptomatic or had low back/leg pain ≤ 2 on a 0-10 pain scale. The eligibility criteria excluded subjects who had received manual therapy in the lumbar spine or sacroiliac joints on the day of the study. The pre-established number of subjects to be used in this study was based upon the work of Eliasziw et al.¹⁴; the sample size required at the 5% significance level with 80% power is approximately 35 subjects. It is reasonable to consider an intraclass correlation (ICC) value of 0.60 to be minimally acceptable for inter-examiner reliability, based on a scale by which reliability is judged "poor" for values less than 0.40, "fair" between 0.40 and 0.59, "good" between 0.60 and 0.74, and "excellent" for values between 0.75 and 1.00¹⁵. Although these verbal pegs for ICC values are arbitrary, according to Cicchetti¹⁵ they are widely accepted by biostatisticians. The two examiners in this study were both licensed and experienced chiropractors (one 30 years, the other 10 years of experience) who routinely utilize MP. The subjects did not speak to the examiners during the examination; the examiners were situated on opposite ends of the research laboratory, masked as to each other's examination findings. Two

research assistants escorted subjects through the experiment, ensuring that the examiners alternated in assessing them to prevent order effects, and recorded the data.

Subjects were first asked to lie prone on a treatment bench. One of the examiners then placed skin marks using a water-soluble pen at the putative locations of the vertebra prominens (VP), S2, and T12. The same examiner measured the distance from VP to S2, as a proxy for subject height, to be used subsequently in the analysis of data subsets. For the examiners to perform MP, the subjects were positioned with the left side up, with the left upper hip and knee flexed, as if to receive a manipulative procedure commonly called a "pull move".¹⁶ Other studies have used a similar method to assess lumbar motion.¹⁷⁻²⁰ The examiner then applied overpressure at the tested spinal level using the distal aspect of his right middle finger (see Figure 1). While doing so, he used his left hand to apply anteroposterior pressure to the subject's crossed arms, and his right thigh to traction and apply posteroanterior pressure to the subject's left thigh. The examiners successively assessed each of the spinous processes (SPs) of the lumbar spine. After identifying the most-fixated spinal level, each examiner measured its distance to the S2 pen mark, and the data were recorded by a research assistant (Figure 2). The examiner also stated whether he was "confident" or "not confident" in his finding. Although there was some variation in the amount of time



Figure 1. Motion palpation of the lumbar spine.



Figure 2. Localizing the most-fixated level.

between examinations, at least 5 minutes elapsed between palpatory procedures by the two examiners.

Examiner agreement was assessed by determining the difference in the measured distances of the most-fixated segment from the reference mark at S2. Interexaminer reliability was calculated using the following 4 statistical functions: (a) Intraclass Correlation Coefficient (ICC); (b) Mean Absolute Examiner Differences (MeanAED); (c) Median Absolute Examiner Differences (MedianAED); and Bland-Altman Limits of Agreement (LOA). These statistical functions were calculated for the entire dataset as well as for various subsets based on gender, VP-S2 distance (a surrogate for height), age, and degree of examiner confidence. Mean Absolute Deviation (MAD/ mean) and Median Absolute Deviation (MAD/median) were calculated to assess the degree of data dispersion. To illustrate the impact of high subject homogeneity on ICC, the authors constructed and analyzed a hypothetical dataset in which the examiner differences were mathematically identical to those seen in the actual dataset for each of the 34 study subjects, but in which the findings of the most-fixated segment were deliberately distributed more evenly over the lumbar spine (Figure 5).

Results

Of 35 subjects recruited, 34 fit the inclusion criteria (19 females, 54.3%); one subject reported back pain 4/10 and

was thus excluded. The mean age was 25.4 (s=3.4) years; and mean VP-S2 distance was 48.1 (s=4.6) cm. The mean pain level was 0.5 (s=0.7) on a 0-10 numeric pain scale. The distance from S2 to the most-fixated segment ranged from 1.0 to 15.0cm (mean=6.9cm, s=3.0), for 68 assessments, 2 assessments for each of 34 participants. Among 68 assessments, in 2 cases the distance to S2 was <2 cm, suggesting the examiner may have identified the sacrum as the most-fixated level. Under the heuristic assumption that this range included 5 brackets spanning L1 to L5; and assuming an average lumbar spine length of some 20 cm²¹, which corresponds to 4 cm/level; the finding of fixation was usually in the lower lumbar spine with L3 being the most commonly found most-fixated level (Figure 3). One of the examiners did not share the conviction of the other examiner in the utility of the palpatory procedure, but opined that this did not impact his effort to attempt detecting the most-fixated lumbar segment. The less confident palpator scored 12/34 (35%) assessments as "not confident" whereas the more confident palpator scored 7/34 (21%) as "not confident". In analyzing the data, we combined the subset in which one examiner lacked confidence (n=11) with the subset in which both lacked confidence (n=4), because not doing so would have left subsets that were too small to meaningfully analyze. ICC (2,1), MeanAED, MedianAED, MAD/mean, and MAD/median values are reported in Table 1; and Bland-Altman LOA in

Table 1.
Data Summary – ICC, MeanAED, MAD/mean, MedianAED, MAD/Median,

All distances in cm	ICC (2,1)	MeanAED	MAD/mean	MedianAED	MAD/median
All subjects (34)	0.39 (0.06, 0.64)	2.6	1.7	2.5	1.8
Both confident (19)	0.09 (-0.40, 0.52)	2.4	1.6	2.3	1.8
≥1 Ex. not confident (15)	0.51 (-0.05, 0.80)	2.9	1.7	3.2	1.8
Males (15)	0.50 (-0.02, 0.80)	2.7	1.6	2.7	1.3
Females (19)	0.19 (-0.29, 0.58)	2.7	1.7	2.7	1.8
Shorter (17), M=44.3	0.13 (-0.40 ,0.58)	2.7	1.7	3.2	1.7
Taller (17), M=51.8	0.45 (0.00, 0.76)	2.4	1.7	2.2	1.7
Younger (17), M=23.2yr	0.21 (-0.34, 0.64)	2.4	1.8	2.1	1.6
Older (17), M=27.7yr	0.47 (0.03, 0.76)	2.8	1.6	2.5	1.4

Abbreviations: M=Mean; MeanAED=Mean Examiner Difference; MedianAED=Median Examiner Difference; MAD/mean=Mean Absolute Deviation; MAD/median=Median Absolute Deviation; ICC=Intraclass Correlation Coefficient; Ex=examiner; yr=years.

Table 2. For the entire dataset (n=34) the Shapiro-Wilk statistic was used to verify normality at the 95% threshold, with W=0.98. The distribution of all subsets was also normal.

For the n=34 sample as a whole, ICC(2,1)=0.39, which would be judged "poor" according to commonly-cited cutoffs for qualitative ratings corresponding to ICC values.¹⁵ Although ICC values in Table 1 did not suggest a relation between examiner confidence and interexaminer agreement; male gender, greater VP-S2 distance (i.e., being "taller"), and age (i.e., being "older") were directly related to higher ICC values. In the hypothetical dataset (Figure 5) in which the examiner differences were mathematically identical to those seen in the actual dataset (Figure 3), but in which the findings of the most-fixated segment were deliberately distributed more evenly over the lumbar spine, ICC rose from 0.39 ("poor") to 0.70 (i.e., "good"). Therefore, ICC in this study was (misleadingly) lowered by the homogeneity of the subjects, with the most-fixated level mostly in the lower lumbar spine.

MeanAED values ranged from 2.4-2.9 cm and MedianAED from 2.1 to 3.2 cm among the subsets. These values were all well under 4.0cm, the vertical height of a typical lumbar vertebra²¹, suggesting the examiners agreed on average in identifying the most-fixated level, or at least the motion segment containing it. Although for the full dataset interexaminer agreement based on ICC calculations had been judged "poor", the MeanAED and MedianAED values of 2.6cm and 2.5cm respectively for the full dataset suggested otherwise. Since their values increased to 2.9cm and 3.2cm respectively if at least one examiner lacked confidence, it may be said that less confidence was associated with less examiner agreement. There was higher interexaminer agreement in the younger and taller subsets, but there was no gender effect. MAD/mean and MAD/median, measures of data dispersion, were quite uniform among all datasets, ranging from 1.6 to 1.8cm for MAD/mean and 1.4 to 1.8cm for MAD/median. Since these values were <2cm, it may be said that the *variability* of interexaminer differences was low, less than half the height of a lumbar vertebra. Stated otherwise, examiner distances from the average most fixated level were small and formed a tight distribution around these average examiner differences (Figure 6).

The Bland-Altman Limits of Agreement (LOA) analysis also suggested high interexaminer agreement on the most-fixated level, with higher agreement (smaller LOAs and smaller SDs) when the examiners were both confident; and also when the subjects were male, taller, and/ or younger. These findings are quite consistent with the MeanAED and MedianAED results, save for the impact of gender, which was negligible in these latter. For the full dataset, the 95% LOA = -7.05, 6.05cm; SD=3.34cm; and fixed bias = 0.50cm. Figure 4 is the Bland-Altman

			v	0				
Sample sizes as in Table 1				95% CI		689	68% CI	
	Bias	SE	SD	Lower limit	Higher limit	Lower limit	Higher limit	
All	0.50	0.57	3.34	-7.05	6.05	-3.53	3.03	
Both confident ≥1 Ex. not confident	0.30 0.76	0.73 0.94	3.19 3.63	-5.94 -6.35	6.54 7.87	-2.97 -3.17	3.27 3.93	
Male Female	0.41 0.58	0.86 0.79	3.34 3.43	-6.15 -6.14	6.96 7.30	-3.07 -3.07	3.48 3.65	
Shorter, M=44.3 Taller, M=51.8	0.07 0.94	0.87 0.76	3.59 3.13	-6.96 -5.19	7.10 7.06	-3.48 -2.60	3.55 3.53	
Younger, M=23.2yr Older, M=27.7yr	0.04 0.99	0.82 0.80	3.29 3.40	-6.49 -5.68	6.41 7.66	-3.25 -2.84	3.20 3.83	
Abbreviations: SE=standard error of mean; Standard Deviation=SD; CI=confidence interval								

Table 2.Bland-Altman Limits of Agreement.



Figure 3. *Most-fixated lumbar levels*.

L5 L4 L3 L2 L1 Figure 5.





Hypothetical dataset, heterogeneous subjects.



plot and histogram of examiner differences; the scatter plot and histogram of examiner differences; the scatter ed they formed a normal distribution, consistent with the Shapiro-Wilk results. There was a trend for more confidence to result in smaller SDs, reflecting greater examiner agreement: in the n=19 subgroup when both examiners were confident, the SD decreased from 3.34cm to 3.19cm, whereas in the n=15 subgroup where one or both of the examiners lacked confidence the SD increased to 3.63cm.

The square root of the mean squared error (MSE) yields root-mean-square error (RMSE), another measure of examiner accuracy. In this study, combined RMSE=3.3mm.

Discussion

Most MP studies asked examiners to rate each tested level as fixated or not, then used kappa to calculate the reliability. Although the kappa statistic is used to assess examiner agreement reported as discrete data, the palpation findings recorded as continuous data in this study were amenable to being analyzed using the ICC statistical function, as well as other indices of agreement for continuous data. Judging agreement by *how near* the examiners' findings were to one another may be a more sensitive and clinically relevant method of determining agreement than assessing agreement at each spinal level examined. It may capture the essence of how MP is usually done in a typical clinical setting: the palpator generally examines a relevant spinal region looking for the most-fixated place(s).

Previous studies that required each rater to find the subjects fixated or not at each spinal level put a very stringent demand on the examiners, in that they were required to identify all fixations as if they were of the same severity. When many of the subjects in a study are minimally symptomatic, they may not have clinically relevant fixations to identify in the first place. Allowing examiners to rate their level of confidence in their findings enabled this study to explore whether examiners' agreement depends to some extent upon their degree of confidence. The objective of this study was to assess the interexaminer reliability of lumbar MP by (a) defining agreement as relative proximity to each other's findings as to the most-fixated level; and (b) taking into account the examiners' confidence in their palpation findings. In an annotated review of MP(1) that included 48 MP studies, only Potter et al.22 used a most-fixated segment paradigm and continuous analysis similar to the present study, and also

used ICC to calculate interexaminer agreement. Since their study was an *intra-examiner* study and furthermore used other findings in addition to MP to assess agreement, the results cannot be compared with the results of the present study.

According to Bruton et al.23, the physiotherapy and medical literature alike show little consistency in the use of reliability indices for continuous data. In a systematic review of the methods used to assess interexaminer reliability in continuous measures studies, Zaki et al.24 reported that the ICC index was the most popular method used from 2007-9, with 25/42 (60%) of the included studies having used it. In a related systematic review, Zaki et al.25 also reported that the most frequently used index of agreement in concurrent validity studies was the Bland-Altman LOA method, having been used in 178/210 (85%) of included studies; ICC was the 4th most frequently used among the 5 methods tabulated, used in only 7% of the studies. Bland and Altman themselves²⁶ took the position that the LOA agreement method can be used for either interexaminer reliability or inter-instrument agreement studies.

Although the power analysis supported enrolling approximately 35 subjects in order to have confidence in our reliability estimates, an even larger number would have been required to have similar confidence in analyzing subsets of the data that were stratified by gender, age, and VP-S2 distance. To mitigate this effect, for the purposes of analysis we combined the subset in which one examiner lacked confidence (n=11) with the subset in which both lacked confidence (n=4). When a sample size is small, the results of the analysis can be altered considerably by shifting a very small number of data points from one clinical result to another. Walsh²⁷ has described a Fragility Index: "the minimum number of patients whose status would have to change from a nonevent to an event to turn a statistically significant result to a nonsignificant result." As an example using the present study's results, if the 2 examiners had agreed exactly on subject 13, rather than disagreed by 7.1cm (the largest disagreement in the study for a single data point), the ICC(2,1) value for the entire dataset would have increased from the reported 0.39 to 0.46. This increase would have changed the interpretation of the reliability from "poor" to "fair." Conversely, if the 2 examiners had disagreed on subject 31 by 3.2cm (the largest disagreement in the small subset where neither

examiner was confident), the ICC(2,1) for this n=4 subset would have decreased from 0.75 to 0.31, therefore from "excellent" to "poor."

For the n=34 full dataset, the calculated ICC(2,1)=0.39, which would be judged "poor" according to commonly-cited cutoffs for qualitative ratings corresponding to ICC values: interexaminer reliability is judged "poor" for values less than .40, "fair" between .40 and .59, "good" between .60 and .74, and "excellent" for values between" .75 and 1.0 (15). The fragility of the data among the subsets suggests caution in interpreting these results. That stated, the ICC calculations suggest there was higher interexaminer reliability in palpating males, older subjects, and subjects with a greater VP-S2 distance (essentially taller subjects, since VP-S2 distance was a proxy measure for height). Interexaminer reliability was lower when both examiners were confident compared with when at least one lacked confidence. These ICC results differed from those obtained in our prior thoracic motion palpation study¹² in which shared examiner confidence was clearly associated with increased interexaminer reliability, and our prior cervical study¹³ in which re-analysis of the published data also shows higher agreement with more examiner confidence. Since MeanAED, MedianAED, and LOA all showed higher confidence associated with higher examiner agreement, the authors hypothesized that the ICC results, being the outlier among the 4 indices of examiner agreement, were misleading.

Despite its popularity in interexaminer reliability studies, ICC suffers from the limitation that its value decreases when subject variability is relatively low; i.e., the subjects are relatively homogeneous.28 This results from the fact that ICC is a ratio of the variance within subjects to the total variance (the sum of within and between subject variance). When within subjects variance is small, ICC levels are misleadingly low even when the examiners tend to agree. In the present study, with a preponderance of findings at L3 and the most-fixated level usually toward the lower lumbar spine (as seen in Figure 3), ICC values may have been diminished for reasons other than examiner disagreement. To clarify this point, the authors constructed a hypothetical dataset in which the examiner differences were mathematically identical to those seen in the actual dataset for each of the 34 study subjects, but in which the findings of the most-fixated segment were deliberately distributed more evenly over the lumbar spine (see Figure 5). In this hypothetical dataset, the ICC was 0.70 (i.e., "good") despite examiner differences being equal, subject for subject, to those seen in the more homogeneous actual dataset (Figure 3) where ICC=0.39 (i.e., "poor"). This study's ICC calculation inverts a situation that is frequently discussed: sometimes a finding is found to be statistically significant, but clinically irrelevant. In our study, the ICC value statistically suggested "poor" agreement, even though examiners agreed on the most-fixated level most of the time, based on the other 3 indices of agreement used in this study.

To present the results of the present study in a more clinically meaningful way, and to mitigate against the impact of subject homogeneity, the authors also calculated values for Mean and Median Absolute Examiner Differences, which are measures of examiner agreement that are robust in relation to subject homogeneity. MeanAED is the simple average of the absolute values of the examiner differences, and MedianAED the median value of such differences. For any given value of Mean or Median Absolute Examiner Differences, the population of examiner differences may exhibit large, modest, or low variability. The root mean squared error (RMSE) (the square root of the summed squared errors, divided by the sample size), was calculated in conjunction with MeanAED and MedianAED. Because RMSE, unlike these other calculations, involves squaring errors, the level of agreement diminishes rapidly when the examiner differences are large. Therefore it is a more conservative estimate of examiner agreement. The more similar the examiners' ratings, the more RMSE approaches MeanAED and MedianAED. In the present study the RMSE of 3.3cm, corresponding to 83% of a thoracic spinal level, is thus a more conservative estimate of examiner agreement than the MeanAED of 2.6cm and the MedianAED of 2.5cm.

Mean/MAD and Median/MAD were calculated to determine the dispersion of examiner differences. Calculating MAD/mean involves (a) calculating the mean of absolute examiner differences, (b) subtracting this value from each difference and converting to an absolute value; and (c) calculating the mean of this derived set of values. Calculating MAD/median²⁹ involves (a) identifying the median value of absolute examiner differences, (b) subtracting this value from each difference and converting to an absolute value; and (c) calculating the median of this derived set of values. Since Mean/MAD and Median/ MAD values are in the same units as those of the variables being characterized, their values can be very easily understood relative to the clinical situation at hand.

Measures of dispersion tell us how spread out the data values are. The simplest measure of dispersion is range (the difference between the maximum and minimum values), but it is very impacted by extreme minimum or maximum values. Consequently, range is not robust to outliers. SD and variance, although very widely used, are not robust either, since a data point very distant from the others can substantially increase their values. The MAD/ mean function is less sensitive to outliers, and MAD/ median is not sensitive at all. Median is preferred to mean calculations^{29,30} because median analysis (a) is less sensitive to outliers at the far left and right tails of the distribution of examiner differences; and (b) it facilitates the detection and exclusion of such outliers (depending on a subjective judgment for threshold). Unlike the other measures of dispersion, the value of MAD/median has not *already* been altered by these outliers at the extremes of the distribution. In the present study, using the "conservative" threshold of 3 (meaning data points larger than the median $\pm 3^*$ MADe/median be removed) or even the "poorly conservative" threshold of 2 (30), no data points qualified as outliers.

For the total dataset, MeanAED and MedianAED were 2.6 and 2.5cm respectively (in a normal distribution, the mean and median tend to be close), corresponding to about 65% of one lumbar level, given the length of an average lumbar vertebra is 4cm.²¹ The fact that these values increased to about 3.0cm when at least one examiner was not confident suggests that examiner confidence tended to increase reliability. This was in spite of the fact that ICC calculations had not demonstrated that effect, presumably due to subject homogeneity. With MedianAED for the full dataset=2.5cm and MAD/median=1.8cm, it may be deduced that 50% of examiner differences were ≤1.8cm distant from 2.5cm. Figure 6 represents these relationships. It shows that the overall range of examiner differences was 0.0-7.1cm, and that the MedianAED was 2.5cm. It also shows that that 50% of examiner differences were 0.75-4.25cm; and that 79.4% of examiner differences were below 4.25cm, which is only slightly greater than the average lumbar vertebral height of 4.0cm.

The Bland-Altman calculation of limits of agreement (LOA)^{26,31} is yet another measure of examiner agreement

that, like mean and median analysis, is not impacted by subject homogeneity. LOA plots per-subject examiner differences vs. examiner means. A horizontal line is added to reflect fixed bias (intersecting the Y axis at the Grand Mean of examiner differences). Two more horizontal lines are added to show 95% confidence intervals (1.96*SD of examiner differences). LOA analysis depends on the assumption of a constant mean and SD throughout the range of measurements, and a normal distribution of examiner differences. Inspection of the scatter plot and histogram of examiner differences validated these assumptions for this study's data. Since the LOA are derived after having squared examiner differences, they will generally suggest lower levels of examiner agreement then absolute indices of agreement, which do not involve squaring differences; they are thus more conservative. Like these other absolute indices, the LOA are in the same units as the variables being measured, and are thus can be easily interpreted in clinical terms. In this study, for the full dataset, the LOA = -7.05, 6.05 cm, with SD=3.34cm. This may be interpreted as follows: 68% of examiners' findings for the most-fixated segment were ≤ 3.34 cm apart, which is equivalent to 83.5% of the height of one lumbar vertebra. Thus the examiners had a 68% chance of agreeing on the most-fixated level, or at least the motion segment (consisting of 2 vertebra) including it. They had a 95% chance of being \leq 6.68cm apart, equivalent to 1.67 vertebral heights, equivalent to agreeing at least on the motion segment that included the most-fixated level. Among the subsets analyzed, the most important observation was that higher examiner confidence was associated with greater interexaminer reliability, consistent with the mean and median analyses, but not the ICC results.

It is instructive to relate these findings to the practice of motion palpation. In all likelihood abject segmental specificity on a putative site of care is not required, since an intervention would generally address a motion segment consisting of 2 vertebrae. Christensen³² considered motion palpators to agree when their findings were ± 1 spinal segment; as did Harlick³³ in a study of the accuracy of static spinal palpation. More likely than not, the examiners in this study identified the same or adjacent vertebrae as the most-fixated. To take the reasoning one step further, an adjacent vertebra is itself included within yet another motion segment, so addressing a given vertebra will have an impact not only on the 2 immediate neigh-



Figure 7. Spinal interventions perpetrate primary, secondary and tertiary spheres of influence. Largest impact is on the primary contacted vertebra, with smaller impacts on the secondary adjacent vertebra, and tertiary impact on the twice-removed segments.

boring vertebrae, but on 2 other vertebrae once removed from the given motion segment, most likely a smaller (damped) impact. Figure 7 models the impact of an intervention on a single vertebra. The intervention's largest sphere of influence is hypothetically on the immediately adjacent vertebrae, with a smaller sphere of influence on those once-removed.

For MP to be clinically useful, it must not only be found reliable but also valid. Few studies have reported on the content validity (i.e., have defined a reference standard) for motion palpation. Najm³⁴ found only 5 that satisfied the inclusion criteria in a 2003 systematic review showing equivocal validity. In 3 of the studies the palpators examined a mannequin which featured variable and controllable segmental stiffness; the other 2 studies used pain as a reference standard. At least one additional study could have been included, in which masked palpators examining the sacroiliac joint were unable to identify known cases of ankylosing spondylitis as fixated.³⁵ Another study was published at a later date³⁶, in which masked palpators were able to detect fixation at congenital block vertebrae. The relevance of using mannequins to simulate in vivo spinal stiffness remains to be seen, and the presence of pain at spinal segments is at best a surrogate measure for spinal stiffness. On the other hand, deploying subjects with acquired or congenital joint fusions comprises an excellent vehicle for studying the content validity of MP.

Study limitations

Since the integrity of reliability studies depends on the independence of the examiners' observations, there is always a risk that the first palpatory procedure is to some degree a clinical intervention, enough so to impact upon the second palpatory procedure. Allowing at least 5 minutes to elapse between observations, and alternating the order of examiners, was expected to ensure as much as possible the independence of observations and reduce the risk of fixed bias. This study did not include an intra-examiner reliability module. The sample size was underpowered for the analysis of subgroups. A power analysis was performed to justify the sample size for ICC analysis, but not for LOA analysis. This reinforces the need for a priori sample size estimates for all possible between group comparisons and not just on the main question. The appropriate sample size for LOA analysis depends on the accuracy sought for the 95% confidence intervals around the limits, which is given by the formula $+/-1.96 \operatorname{root}(3/n)$ s (where s is the SD of the differences between measurements, and n = sample size (38). In our study, the 95% confidence interval around the limits was approximately ±2cm; this would most likely be judged relatively large by Bland, who suggests a sample size of 100 to achieve a tighter confidence interval around the limits.³⁷ The subjects were relatively homogeneous in the levels most commonly found the most-fixated, depressing ICC values, but not the other measures of interexaminer agreement (MeanAED, MedianAED, and LOA). The fact that examiner 1 did not share the conviction examiner 2 had in the palpatory procedure may have impacted the analysis of confidence. Lack of confidence in an examiner's rating of the most-fixated motion segment might have resulted from either not finding any motion segment significantly fixated, or alternatively due to having found multiple segments significantly but indistinguishably fixated. Subjects were palpated unilaterally, left side up only. The subjects in the study were relatively young and healthy; the results obtained may have been different in another study population with different characteristics.

Conclusions

Although subject homogeneity in this study, with most fixations detected in the lower lumbar spine, apparently depressed the ICC index of interexaminer agreement, the other 3 indices used in this study did in fact suggest the examiners on average tended to identify the same vertebral level or motion segment as the most-fixated. These more robust measures suggested examiner confidence, and to a lesser extent subject demographic factors, impacted on examiner agreement. Using a continuous measures methodology may be more practical for detecting examiner agreement than using level-by-level discrete analysis. The authors would suggest the most-fixated level paradigm best captures the operational definition of motion palpation as it is usually done, and is thus more clinically relevant than level-by-level analysis of agreement. Our results raise the possibility that the present inventory of reliability studies performed in the manual therapy professions, by having used mostly discrete study designs (certainly for MP) may have underestimated clinically relevant examiner agreement, thereby unduly discouraging further research and clinician interest in such research. Moreover, depending solely on ICC calculations to assess interexaminer agreement may result in flawed conclusions, when the subject population is relatively homogeneous. Greater reliance on variance-insensitive statistical functions would mitigate against that possibility. Future studies designed to analyze subsets of the data should use enough subjects to result in credible conclusions.

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The use of spinal manipulation to treat an acute on field athletic injury: a case report

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This case describes the utilization of spinal manipulative therapy for an acute athletic injury during a Taekwondo competition. During the tournament, an athlete had a sudden, non-traumatic, ballistic movement of the cervical spine. This resulted in the patient having a locked cervical spine with limited active motion in all directions. The attending chiropractor assessed the athlete, and deemed manipulation was appropriate. After the manipulation, the athlete's range of motion was returned and was able to finish the match. Spinal manipulation has multiple positive outcomes for an athlete with an acute injury including the increase of range of motion, decrease in pain and the relaxation of hypertonic muscles. However, there should be some caution when utilizing manipulation during an event. In the article the authors propose four criteria that should be met before utilizing manipulation for an acute, in competition, athletic injury. These include the lack of red flags, limited time for the intervention, preexisting doctor-patient relationship and the athlete has

Ce cas décrit l'utilisation de la thérapie de manipulation vertébrale pour une blessure aiguë subie lors d'une compétition de taekwondo. Pendant le tournoi, un athlète a fait un mouvement brusque, balistique, mais non traumatique de la colonne cervicale. Résultat : une colonne cervicale bloquée, limitant les mouvements dans tous les sens. Le chiropraticien soignant a évalué l'athlète et jugé qu'une manipulation était appropriée. Après la manipulation, l'athlète a retrouvé l'amplitude de ses mouvements et a pu terminer le match. La manipulation vertébrale donne souvent des résultats positifs pour un athlète victime d'une blessure aiguë, notamment l'augmentation de l'amplitude des mouvements, la diminution de la douleur et la relaxation des muscles hypertoniques. Toutefois, on devrait être prudent pendant une manipulation lors d'un événement. Les auteurs proposent dans cet article quatre critères qui doivent être remplis avant de procéder à une manipulation suite à une blessure sportive aiguë lors d'une compétition. Ceux-ci comprennent l'absence de risques incontournables, la contrainte du temps pour l'intervention, une relation déjà établie entre médecin

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experience receiving spinal manipulation. Clinicians should be aware that manipulation may be an effective tool to treat an acute in competition athletic injury. The criteria set out in the article may help a practitioner decide if manipulation is a good option for them.

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KEY WORDS: chiropractic, spinal manipulation, athlete, competition, sideline

et patient, et l'expérience préalable de l'athlète à subir une manipulation vertébrale. Les cliniciens doivent être conscients que la manipulation peut être un outil efficace pour traiter une blessure sportive aiguë lors d'une compétition. Les critères énoncés dans l'article peuvent aider un praticien à décider si la manipulation est une bonne option dans le cas qui se présente.

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MOTS CLÉS : chiropratique, manipulation vertébrale, athlète, compétition, ligne de touche

Introduction

Spinal manipulative therapy (SMT) is a treatment modality that has been utilized for centuries with written explanations dating as far back as 460–385 BCE by Hippocrates.¹ There are numerous theoretical mechanisms of action for SMT.²⁻⁴ These theories are based around three major concepts: the biomechanical effects, the muscular reflexogenic effects and the neurophysiological effects.¹ In addition, SMT also appears to have systemic effects on the body.⁵ SMT have been demonstrated to be effective for the treatment of numerous conditions; research has consistently demonstrated its effectiveness for neck and low back pain.^{6,7} It has also been shown that SMT may have positive effects on pain and injury in the extremities.^{8,9} However, with this knowledge, there is limited evidence of the use of SMT during a sporting event to treat an acute injury.

Taekwondo is a martial art originating from Korea. Currently it is practiced throughout the world and has been an Olympic sport since 2000. Taekwondo competition is divided into two different categories: Poomsae (patterns) and sparring. At the highest levels sparring contests consist of three two-minute rounds with a one minute rest period between. Points are accrued through landing punches to the trunk or kicks to the trunk and head. If an injury is sustained during the competition the referee must suspend the match to allow the athlete's doctor to treat the issue. If the athlete cannot return to the match within one minute; the opposing athlete is declared the winner.¹⁰

The goal of this case study is to demonstrate the utilization of SMT during competition and to discuss the times when it may be appropriate.

Case presentation

During a national level Taekwondo match, one of the competitors had a sudden, quick, non-traumatic neck movement and experienced locking in the cervical spine. There was no blow delivered to the head or fall to the mat that would have elicited an immediate change in her cervical range of motion (ROM). She was immediately attended to by her chiropractor who was working in the role of medical responder during the competition. Taekwondo matches have a strict one-minute time limit for the medical responder to assess, provide any treatment and decide if the athlete can continue the match. The chiropractor had witnessed the mechanism of injury and completed an abbreviated history around the complaint. The chiropractor had also had previous encounters with the patient and knew of their medical history. The chiropractor then assessed the athlete for any red flags (referral pain, headaches, dizziness, visual disturbances, and unusual acute and sharp pain) and found a decreased ROM through visual estimation, hypertonic cervical para-spinal musculature bilaterally and restricted cervical segments with point tenderness reproducing the athlete's chief complaint. Based on the mechanism of injury, the lack of red flags, the previous doctor/ patient relationship with the fighter and the assessment results, the chiropractor completed a standing cervical spine manipulation upon the athlete's verbal consent. Due to the previous doctor/patient interactions the athlete was informed of the risks associated with spinal manipulation. The patient had previously signed an informed consent six months prior for a similar neck complaint. This was treated with SMT, in addition to other treatment modalities, to



Figure 1: Gate-Control Theory (Adapted from Dickenson, 2002²⁸)

which the patient had responded positively. After the manipulation, the fighter's ROM was immediately improved compared to pre-manipulation ranges, and she was able to continue and successfully complete the match. After the match, the chiropractor assessed the athlete further to ensure their safety. The athlete reported no pain after the completion of the match and continued to compete on the same day. After the encounter, the chiropractor recorded the entire encounter, which included the competition number, the time and date, mechanism of injury, physical findings and treatment rendered.

Discussion

In this case, the athlete experienced an immediate reduction in her cervical ROM after a sudden, ballistic, non-traumatic movement. The athlete most likely suffered from an entrapped cervical facet meniscoid. One of the older biomechanical theories behind the mechanism of SMT is the release of intra-articular meniscoids, synovial folds or plicas.^{3,11} Intra-articular meniscoids have been found in the majority (86%) of the cervical spine facet joints.¹² Previous literature has described three types of synovial folds that include type I, which are adipose tissue and crescent shaped, type II which are elliptical shaped and project into the facet joint and type III which are made of fibrous tissue and are ragged shaped.¹³ Additionally, it has previously been demonstrated that the synovial folds contain nociceptive fibres which allow them to be pain generators.¹⁴ In addition to the nociceptors, cervical spine facet joints contain type I, type II and type III mechanoreceptors.¹⁵ During cervical spine movement, the facets

will move relative to one another. The facet's motion will take the intra-articular meniscoid to the extreme ranges of motion. As the facets return to their neutral position, the meniscoid can remain trapped in the peripheries of the joint cavity. Pain will then result due to pressure and irritation applied to the trapped meniscoid.³ SMT is suspected to gap the facets, therefore reducing the impaction on the trapped meniscoid and allowing it to return to its normal position.³ This will allow the joint to regain full range of motion. Due to the absence of a traumatic event, the quick cervical motion and decreased range of motion, it is the authors' belief that this is the explanation for the effectiveness of SMT during the case presented. However, other differential diagnoses could include a facet joint irritation or a strain to the surrounding musculature.

There are other theoretical models where SMT may be beneficial in treating acute injuries in athletes during competition. Other effects of SMT beyond that of restoring range of motion can include hypoalgesic effects as well as muscle reflex effects.¹⁵⁻¹⁹ The hypoalgesic effects of SMT can be attributed to the gate-control theory of pain.^{2,4} The facet joint capsule and surrounding musculature have numerous proprioceptors in the form of muscle spindles and type I and type II afferents.^{2,4} With SMT, there is a dynamic stretch to the tissue that will cause an increase in afferent discharge from these receptors.¹⁹⁻²¹ This increase in afferent input will attenuate the pain sensation at the dorsal horn, thereby creating a hypoalgesic effect.² (Figure 1) The muscle-reflexogenic effects of SMT are believed to occur through the effects on the muscle spindles surrounding the joint. As with the gate-control theory,

Table 1:Criteria for an on Acute Injury, On FieldSpinal Manipulation

- Rule out red flags
- Limited time for intervention
- · Pre-existing doctor-patient relationship
- Patient is familiar with spinal manipulation of the injured area
- The rules surrounding informed consent have been satisfied

during the act of the spinal manipulation, there is an increase in the afferent output from the surrounding muscle spindles.¹⁹⁻²¹ Directly after SMT, the muscle spindles become silent for a short period.^{19,21} After this silent period, the spindles return to firing at their appropriate rate, which can cause a relaxation of the surrounding muscles.

While there are possible benefits to utilizing SMT for acute injuries during a sporting event, it should be used sparingly. In the authors' opinion, if the medical practitioner decides to utilize SMT the following criteria should be met (Table 1): the practitioner has assessed for any red flags, there is limited time for the intervention, there is a pre-existing relationship between patient and practitioner, the patient is familiar with spinal manipulation, and the rules surrounding informed consent have been satisfied. These recommendations will allow the doctor assess the patient and deliver a treatment in a circumstance where the patient is informed of the associated risks.

As a medical practitioner, the primary goal would be to do no harm, therefore, ruling out red flags would be a priority when assessing a patient with or without the intent of using SMT. A good red-flag screen for the cervical spine would include utilizing the Canadian C-Spine Rules.^{22,23} These rules were originally designed to screen if a patient would require a radiograph, however, they can help to recognize if there is a traumatic incident or if there are concerning signs and symptoms. A dangerous mechanism, which applies to sporting events, is defined as either a fall from greater than 3 feet, an axial load to the head, or a bicycle accident.^{22,23} Other tests which can be used to rule out potentially severe injuries include the

Table 2:Grading of Neck Pain(Adapted from Guzman, 200924)

Grade	Symptoms
1	Neck pain with little or no interference with daily activities
2	Neck pain that limits daily activities
3	Neck pain accompanied by radiculopathy (pain, weakness and/or numbness in the arm
4	Neck pain with serious pathology, such as tumor, fracture, infection, systemic disease

absence of midline cervical spine tenderness, absence of parathesias in the extremities and the ability of the patient to actively rotate their head 45° in both directions.^{22,23} It is important to be aware of the grading of neck pain and if the diagnosis is grade 3 neck pain (Table 2) or higher this would require additional assessment with removal from the competition.²⁴ If the athlete is presenting with a complaint in another area besides the cervical spine, other red flags should be considered. For example, red flags for low back spinal fractures include older age, prolonged steroid use, severe trauma and contusion or abrasion at the location.²⁵ In addition to the red flags, a chiropractor would also need to assess for the possibility of a concussion as they can occur with impulsive forces transmitted to the head.²⁶ In the case of a concussion, there needs to be an immediate assessment for any cervical spine injuries as well as observations for any more serious pathologies such as intra-cranial bleeds.26 The chiropractor will assess for those changes during the on field assessment including looking for changes in memory, mood and communication. Utilization of the Maddocks Score allows for a quick assessment of these aspects. This test allows for quick assessment of the athletes' orientation to time, location and ability to communicate. It is five questions asking if the athlete knows where they are, the time in the competition, who scored last, what was the last team they played and if the team won the last game.²⁶

After assessing for red flags, the amount of time available for intervention would have an impact on the practitioner's decision to utilize SMT. Certain sports have limited time periods to assess the athlete and make a decision to continue the match (Taekwondo) while other sports can force a team to compete short-handed if the assessment takes a prolonged period of time (soccer). In these time-limited scenarios, SMT may be the only practical option available to the practitioner to treat the athlete in order for the athlete to continue to compete. However, in situations where immediate return is not necessary, the practitioner should bring the athlete to the side of the field for further assessment. At this point, they can utilize the treatment options which they feel will be most effective for the patient's presenting compliant and preferences. If the chiropractor is unsure or concerned about the use of SMT other treatment options can include the use of soft tissue techniques (such as ART®, cross-friction, or instrumented assisted soft tissue techniques), acupuncture or other physical modalities to help return the athlete to sport.

Finally, before a practitioner utilizes SMT on the field, the patient should have a familiarity with both the chiropractor and receiving SMT. This familiarity must include the athlete's past medical history, relevant family history, previous response to treatment (including SMT) and allows for comparison of the current complaint to previous episodes. This information will allow the chiropractor to abbreviate their history to focus on the current complaint. Additionally, the chiropractor can assess if this is a re-occurring condition or a new complaint, which, in the case of the latter, they should be more cautious with before proceeding with on field care. Also, previous research has demonstrated that there is a variable muscle activity response when the spine is manipulated.²⁷ Therefore, if an athlete has never had a spinal manipulation, receiving their first manipulation on the field may have unexpected side effects.

Another key aspect of the necessity of a pre-existing relationship between the practitioner and the athlete is based around the issues involving informed consent. For the patient to receive SMT, they must be fully informed of the risks associated with the treatment. A previous doctor/ patient relationship ensures that the patient is aware of these risks and can properly consent to the treatment. This previous relationship will allow the chiropractor to have standardized written consent from the patient as well. It is important that the chiropractor completes a new informed consent form with the patient periodically to ensure that the patient is still aware of the risks associated with the treatment. Even with a previous history of spinal manipulation of the injured area and a doctor/patient relationship, a verbal consent to provide SMT on the field with brief explanation is still necessary and prudent. However, if no previous relationship has been established, there may not be adequate time to inform the patient, and, under these circumstances, SMT should not be delivered.

Summary

This case demonstrates the use of SMT for an acute injury during a sporting event. SMT can have the ability to decrease pain, increase range of motion and decrease muscle spasm. While it may have its benefits, SMT should be used sparingly for on-field treatment. For SMT to be utilized, there needs to be a limited time to treat, the absence of any red flags, and, finally, the athlete needs to be comfortable and familiar with the proposed manipulation, have a pre-existing relationship with the practitioner and consent to the treatment.

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Conservative management of posterior ankle impingement: a case report

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Objective: To describe the pain and functional improvements of a patient with posterior ankle impingement following a treatment plan incorporating soft tissue therapy, chiropractic adjustment and a progressive rehabilitation program.

Clinical Features: A 37-year- old male presented with posterolateral ankle pain exacerbated by plantar flexion two weeks after sustaining an inversion ankle sprain. Oedema was present and the patient was describing a sensation of instability while walking. The initial diagnosis of lateral ankle sprain was found to be complicated by a posterior ankle impingement caused by a tenosynovitis of the flexor hallucis longus sheath suspected during the physical examination and confirmed by MRI. Objectif : Présenter l'histoire de cas, notamment la progression de la douleur et le retour aux activités fonctionnelles, chez un patient présentant un accrochage postérieur de la cheville. L'article présente ces données en lien avec un plan de traitement incorporant le traitement des tissus mous, l'ajustement chiropratique et un programme de réadaptation progressive.

Caractéristiques cliniques : Un homme âgé de 37 ans présentant une douleur à la cheville postéro-latérale exacerbée par une flexion plantaire deux semaines après avoir subi une entorse de la cheville en inversion. Le patient souffrait d'un œdème et se plaignait d'une sensation d'instabilité lorsqu'il marchait. Le diagnostic initial d'une entorse de la cheville en inversion a été modifié suite à l'examen physique. L'entorse est compliquée par un accrochage postérieur de la cheville relié à une ténosynovite de la gaine du muscle long fléchisseur de l'hallux. Cette trouvaille mise en évidence à l'examen physique fut confirmée par une IRM.

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Disclaimers: None Sources of funding: None Patient consent was obtained for the use of clinical information and imaging with respect to this case report. © JCCA 2016 Intervention and Outcome: *The patient was treated over a 14-week period. Soft tissue therapy, a rehabilitation program and cortisone injection were used to treat this condition. A precise description of the rehabilitation program that contains open kinetic chain, closed kinetic chain, proprioception, and conditioning exercises prescribed to the patient is given. After the treatment plan, the patient returned to play pain free and had no daily living restrictions.*

Summary: A protocol including rest, soft tissue therapy, open and closed kinetic chain exercises, sportspecific exercises and cortisone injection appeared to facilitate complete recovery of this patient's posterior ankle impingement.

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KEY WORDS: chiropractic, ankle, posterior impingement

Introduction

Ankle sprains are one of the most common sports-related injuries.^{1,2} Although most inversion ankle sprains resolve completely, chronic residual ankle symptoms such as pain, swelling, giving-way sensation and limited range of motion may continue to persist chronically in approximately 10% of the cases.3 Differential diagnoses of chronic ankle pain should include osteochondral injury, instability, malunion/non-union/stress fracture, bone bruise, osteoarthritis, tarsal tunnel syndrome and impingement syndromes.^{4,5} Impingement syndromes are defined as painful mechanical limitation of full ankle range of motion due to the entrapment of an osseous or soft-tissue abnormality.⁶ Different types of impingement can occur in the ankle; classification is dependent on anatomical location at the ankle joint. The two main types are anterior and posterior impingement. From those types, subcategories can be made: anterior, anterolateral, anteromedial, posterior and posteromedial impingement.⁶

Posterior impingement is the result of compression of the talus and surrounding soft tissues between the tibia and the posterior aspect of the calcaneus. This occurs Intervention et résultats : Le patient a été traité pendant une période de 14 semaines. Le traitement des tissus mous, un programme de réadaptation et l'injection de cortisone ont été utilisés pour traiter cette condition. Une description précise du programme de réadaptation (exercices cinétiques en chaîne ouverte et fermée, exercices proprioceptifs ainsi que de conditionnement physique), est présentée. Après le traitement, le patient est retourné au jeu sans douleur et sans aucune contrainte dans ses activités quotidiennes.

Résumé : Un protocole comprenant du repos, le traitement des tissus mous, des exercices cinétiques en chaîne ouverte et fermée, des exercices particuliers pour la discipline sportive et l'injection de cortisone semble avoir facilité une guérison complète de l'accrochage postérieur de la cheville de ce patient.

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MOTS CLÉS : chiropratique, cheville, coincement postérieur

mainly with repeated or forced plantarflexion of the ankle.^{4,6} It is most commonly seen in ballet dancers^{7,8}, soccer players^{7,9}, jumping athletes¹⁰, downhill runners⁷ and kicking athletes^{7,9}. The repetitive plantarflexion motion of the ankle during sport and the increased stresses placed on the posterior aspect of the ankle are believed to be the causes of impingement syndrome.⁷ Further, it often occurs as the consequence of an acute injury such as an ankle sprain or a fracture and subsequent repetitive stress. Occasionally, abnormal structures such as an os trigonum can increase the risk of developing symptoms of posterior ankle impingement.¹¹

This article presents a case of posterior ankle impingement of a 37-year old recreational level athlete where a rehabilitation protocol was used for the conservative management. The patient consented to release all information in regards to his case for publication.

Case Presentation

A 37-year-old physically active male presented with a two-week history of left lateral ankle pain. The patient attributed this injury to spraining his ankle playing dek hockey (five versus five hockey with boards, played on foot). The mechanism of injury of the original ankle injury was a trip and fall while running forward creating a hyper-plantarflexion and inversion injury of the left ankle. The patient was unable to finish the game due to an inability to weight bear on the left ankle. Pain was originally located at the anterolateral aspect of the left lateral malleolus, but slowly shifted to the posterolateral aspect of the same malleolus over the following month. Weight bearing reportedly increased the pain to an 8/10 on the numeric pain rating scale (NPRS). No immobilization period occurred as the patient did not seek treatment initially. Prior to this incident, the patient reported playing dek hockey five times per week year round.

At the time of initial visit, the patient reported a sharp pain at the anterolateral and posterolateral aspect of his left ankle while walking. Weight bearing activity reportedly elicited pain that was rated 6/10 in intensity on the NPRS. The patient reported no previous history of foot or ankle trauma, did not report the use of any medications or neutraceuticals at the time of injury, and was a non-smoker and non-drinker. The patient was employed as a worker in a baseball bat factory, which required long hours of standing. Abstaining from weight bearing in the 48-hour period following the injury was not possible due to his work requirements. There were no constitutional signs or symptoms and a systems review was unremarkable.

Visual inspection showed residual oedema around the left lateral malleolus. During gait analysis, a limp was found caused by the left ankle; the patient would decrease time spent in the left stance phase and left plantar flexion motion was decreased during push-off. A bilateral lower extremities neurological examination was performed and was unremarkable (motor strength, L4-S1 reflexes and sensory testing). A lower extremity peripheral vascular examination was unremarkable (normal pedal and tibialis posterior pulses and normal venous return). There was pain on palpation on both sides of the Achilles tendon as well as over the anterior talofibular and calcaneofibular ligaments. Further, pain was elicited at the anterior talocrural joint line. Muscle palpation revealed tenderness of the left flexor hallucis longus, gastrocnemius and tibialis posterior. Active and passive ankle range of motion were actively and passively decreased in plantarflexion and dorsiflexion on the left side compared to right. Passive hyper-plantarflexion provoked pain at the posterolat-



Figure 1.

The hyperplantarflexion test consists of forcing the foot into maximal plantarflexion. If there is a presence of a bony structure or soft tissue in the posterior aspect of the ankle, it can impact between the tibia and the calcaneus, leading to a sharp pain.

eral aspect of the ankle. The patient could not keep a steady balance with left unipedal stance and demonstrated an increase of upper body sway. Orthopedic examination was negative for the following tests on the left side: squeeze test, anterior and posterior drawer test and dorsi-flexion/compression test. The hyperplantarflexion test was positive, provoking pain at the posterior aspect of the left ankle (Figure 1). A diagnosis of grade two lateral left ankle sprain with a possible posterior ankle impingement syndrome (PAIS) was made after the initial visit to the chiropractor. Differential diagnosis included osteochondral lesion, fracture and retrocalcaneal bursitis.

Intervention and outcome

Treatment commenced two weeks after the initial injury occurred and included soft tissue therapy (Active Release Technique[®] and instrument assisted soft tissue mobilization) on the gastrocnemius, soleus, flexor digitorum longus, flexor hallucis longus, tibialis posterior, tibialis anterior and fibularis muscles, as well as a plan of rehabilitation exercises. High velocity mobilizations of the talocrural and tibiotalar joints were avoided for the first month of treatment as pain provocation was elicited. The



Figure 2.

MRI images of the left ankle and hindfoot. A: Axial proton density, fat-saturated TSE image (TR 3460, TE 32). B: Sagittal fat-saturated T2weighted image (TR 4000, TE 30). On both images, the red asterisk (*) indicate the flexor hallucis longus tendon surrounded by a large area of hyperintense signal (yellow arrows) representing fluid in the tendon sheet. The FHL tendon itself is normal and demonstrates low signal intensity on all sequences. The flexor digitorum longus tendon is identified by the yellow number sign (#).

primary goal of conservative management was to restore range of motion and strength through a rehabilitation program. The frequency of care was once per week for three weeks and a reassessment would occur after such time.

Tables 1 through 4 provide an overview of the patient's progression through a plan of rehabilitation exercises. Non-weight bearing open kinetic chain exercises were followed by closed kinetic chain exercises. The goal of this progression was to improve static stabilization of the affected ankle. Dynamic stabilization was later implemented to optimise dynamic ankle stability to prevent recurrence of injury.^{12,13} We monitored the patient's progression with short video recordings of functional tasks (static unipedal stance, different landings and agility maneuvers).

The rehabilitation program started with non weight bearing exercises and progressed to balance as well as isometric strengthening exercises. During phase 2 of the rehabilitation program (Table 2), the clinician reassessed the patient's condition. Progression had been made in regards to range of motion and pain. However, the patient still perceived pain of 4/10 intensity during passive plantarflexion and had pain on both sides of the Achilles tendon during weight bearing and palpation. He was still unable to run due to pain. The patient was sent for an MRI of his left ankle (Figure 2). Signs of inflammation in the flexor hallucis longus sheath and osteochondral lesions of the anterior talar dome were viewed on the MRI. Based on those results and the case presentation indicating posterior ankle pain, a diagnosis of posterior ankle impingement caused by tenosynovitis of the flexor hallucis longus (FHL) sheath was confirmed. During the intervention period, treatment was focused on the diagnosis of PAIS, however the practitioner kept in mind the presence of osteochondral lesions of the anterior talar dome. Following this new diagnosis, the patient was seen for treatment once every two weeks for ten weeks.

While working through the rehabilitation program (end of phase 2b in Table 2), an ultrasound of the patient's left ankle was performed. Pain was still elicited in plantarflexion and was graded as 4/10 on the NPRS, the ultrasound was prescribed to evaluate the posterior structures of his left ankle. An intraarticular hyperechogenic mass with a bony appearance measuring 0.6 x 0.4 cm was found in the retrocalcaneal region. Synovitis surrounding the bony fragment and the flexor hallucis longus was also viewed

Table 1.Phase 1 of the rehabilitation program and patient progression: inflammation reduction.

Timeline	Goal	Exercises description	Pictures
Phase 1 Weeks 1-2	 Oedema control Pain free ROM (avoidance of plantar flexion: neutral ankle position) Return to activities of daily living 	 <u>Open kinetic chain (OKC):</u> ABC's with injured ankle (in the air) Progression to ABC's with thera-band (resistance in 4 directions; inversion, eversion, flexion, extension) <u>Closed kinetic chain (CKC)</u> Bipedal isometric holds: forefoot on a step (5x10sec to 10x10sec to 5x 30 sec to 3x 1 min) Bipedal ½ squat (60 degrees, 4x5 squats to 4x15) Balance on a dynadisc (bipedal) alternate eyes opened/ closed, 3x 1 min *complete plantarflexion was avoided until phase 3 	Bipedal isometric hold
Patient progression	 No oedema Orthopedic testing: all negative (ROM pain free, except active an 	except for posterior impingement during h d passive plantarflexion (NPRS score: 6/10	yperplantarflexion)

on the ultrasound. This bony fragment could correspond to an os trigonum. Interestingly, this bony structure was not identified on the prior MRI. Following the results of the ultrasound, the patient received an ultrasound guided Triamcinolone (synthetic glucocorticoid corticosteroid) injection in the retrocalcaneal region of the ankle where the bony fragment was found. The NPRS pain score went from 4/10 prior to injection to 2/10 after the injection during hyperplantar flexion. The decrease of pain allowed the patient to progress through the rehabilitation program. Plyometric exercises were then introduced into the rehabilitation program.

To the author's knowledge, there are no return to play guidelines for PAIS in the current body of literature. In this case, the return to play protocol was based on literature regarding return to play in athletes following ankle injuries and ankle sprain.¹⁴⁻¹⁵ After regaining pain free range of motion of the left ankle, normal strength and normal ankle stability, the patient went over a sport specific rehabilitation program (Table 3). The patient returned progressively to dek hockey by the end of phase four of the rehabilitation program. At that time, the clinician evaluated that the patient was ready to go back to play as he could run, land, cut and turn on the affected ankle without any pain and felt mentally ready.

Discussion

There are several described etiologies for PAIS. These etiologies include soft tissues or bony structures between the distal aspect of the tibia and the superior aspect of the calcaneus.^{4,6,16} Examples of structures that can be compressed and can cause the development of symptoms are: an os trigonum¹⁷, a prominent posterolateral process of the talus⁴, an enlarged posterior process of the calcaneus⁷, the posterior intermalleolar ligament¹⁸, soft-tissue impingement¹⁹, anomalous muscles²⁰, loose bodies, fractures of the ossicle or talar process, calcified inflammatory tissue, a low-lying flexor hallucis longus muscle belly and thickening of the capsule^{7,8}. Other contributing factors for the development of the condition should also be considered even if they are not currently evidence based: inadequate rehabilitation following previous ankle injury,

Table 2.Phase 2 of the rehabilitation program and patient progression: stability improvement.

Timeline	Goal	Exercises description	Pictures
Phase 2a Weeks 3-4	 Improvement of static ankle stability Improvement of dynamic ankle stability Partial ankle dorsiflexion was begun (5 degree) 	 CKC: Unipedal isometric holds (5x10sec to 10x10sec) Alternate bipedal and unipedal squat/ stable surface (60 degrees, 4x5 sec to 4x15 sec) Balance on a dynadisc (injured ankle) alternate eyes open / eyes closed, 3x1min 	Unipedal isometric hold Unipedal isometric hold Balance on Dynadisc
Patient progression	 ROM pain free, except passive p Unable to run MRI confirmed diagnosis of post 	lantarflexion (NPRS: 4/10) erior ankle impingement caused by tenosy	ynovitis of FHL sheath
Phase 2b Weeks 5-6	 Improvement of static ankle stability Improvement of dynamic ankle stability 	 CKC: Lunge (injured side static on the ground) Multiple directions (front, side, back) 2x (4x each direction) Bipedal Squat on dynadisc Bilateral Lunge (eyes open / eyes closed) Progression from (2x 10 eyes opened and 1x10 eyes closed) to (3x10 eyes closed) 	Bipedal squat
Patient progression	 Pain with passive plantar flexion Subjective improvement in ankle Patient was able to do all exercise 	at end range only (NPRS score: 4/10) e stability (unipedal stance, video analysis) es without discomfort and pain)

Table 3.

Phase 3 of the rehabilitation program and patient progression: increasing load and movement.

Timeline	Goal	Exercises description	Pictures
Phase 3 Weeks 7-10	 Increasing ankle load tolerance Progression to 10° of ankle dorsiflexion Introduction to plyometrics 	 CKC with dynamic stabilization: 2 legged front jump → Landing on one leg (2 x 1 min) 2 legged jump → 90° turn in the air → Landing on 1 leg (both sides) (2x 1 min) Front Jump on 1 leg (2x10 rep) Side jump on 1 leg (2x10 each leg) 	Side jump on one leg
		 Rope jumping (5x 1 min) Walk/run intervals on treadmill (alternate one day : rope jump, other day running program) total : 4 days/ week Side step up and down (3x 1min) 	Side step up and down
		 CKC: Unipedal stance with other leg theraband swings (multiple destabilisations with thera band swings, 4x 1min) Lunge with isometric abduction (thera-band) (3x8 each leg, thera band always on the forward leg) 	Unipodal stance with theraband
Treatment + patient progression	 Ultrasound-guided cortisone inje No pain with CKC / plyometrics 	ction and landing exercises	

Table 4.Phase 4 of the rehabilitation program and patient progression: return-to-play.

Timeline	Goal	Exercises description	Pictures
Phase 4 Weeks 11-14	 Sport-specific exercises Return-to-play 	 Running patterns with acceleration/deceleration (minimum: 2x 10 runs) Cut and turns (minimum 2x5 each direction) Forward and backward running (minimum 2x5 repetitions each direction) Exercises above: 3x/ week (20 min duration) Rope jumping program continued between running exercises every other day (20 minutes duration) 	Cut and turns circuit example
Patient progression	 Pain free sport sp Plantar flexion pa Return to play 	becific exercises (running, jumping ain free (NPRS: 0/10)	g, quick turn)

inappropriate technique in sport, inadequate equipment, lower limb kinematic chain dysfunctions and poor proprioception.^{21,22} A group of experts stated that those factors combined with the presence of a bony or soft tissue structure located between the calcaneus and the tibia can lead to a PAIS in professional ballet dancers.²⁰ Symptoms can also develop four to six weeks after an ankle injury. This presentation proposes the hypothesis that the acute injury leads to intraarticular hemarthrosis and FHL sheath inflammation as well as further capsular lesion, at first subclinical. As the initial anterolateral symptoms, such as bruising and swelling settle, the athlete starts feeling pain at the posterolateral aspect of the ankle as he or she tries to sprint, push off and change direction.⁹ This post injury apparition of PAIS was studied on soccer players, but a similar mechanism seemed to have happened in our case study.9

There is a paucity of evidence on the prevalence and

natural history of the various conditions contributing to PAIS.²² One study revealed a one-year prevalence of 6.5% in a group of 186 trained ballet dancers.²³ However, there are no longer-term prospective studies conducted on the general population or following any sporting organizations that have published upon the prevalence of PAIS and response to conservative treatment.²²

An os trigonum is a small bony ossicle located posterior to the talus. It is formed from a separate ossification center that fuses with the talus between the ages of seven and thirteen years.²⁴ In most individuals, this small bone fuses to the talus to compose the posterolateral process of the talus. However, this fusion fails to occur in up to 14% of the population. The prevalence of an os trigonum bilaterally is approximately 50% when one is present.¹¹ An os trigonum is usually asymptomatic, but trauma or repeated plantarflexion motions can create inflammation and trigger the symptoms. The pain is caused by abnormal movements between the os trigonum and talus or calcaneus or compression of thickened joint capsules and/or scar tissues at the talocrural joint.^{8,16} A bony fragment was identified by ultrasound imaging in the present patient's left ankle and could potentially be referred to as an os trigonum, which is a risk factor for developing a PAIS.

PAIS is characterized by pain lateral or medial to the Achilles tendon with repetitive or forced plantarflexion. Clinical presentation of PAIS may be either due to trauma, such as an ankle sprain illustrated in the case above, or as a result of overuse.¹⁶ Common signs and symptoms include recurrent swelling and pain that is aggravated by activities requiring plantarflexion and ankle mobility.²⁵ During physical examination, patients may report pain in plantarflexion and in hyperdorsiflexion from the posterior structures, such as the flexor hallucis longus tendon and the capsule being stretched.⁶ Both of those actions triggered the pain while the present patient was playing dek hockey. Sensation of blocking in plantar flexion can also sometimes be felt. The examiner can occasionally palpate thickening of the posterior soft tissues.²⁰

Imaging can be helpful in confirming the diagnosis of PAIS or excluding other plausible posterior ankle conditions such as; Achilles tendinopathy, tarsal tunnel syndrome, osteochondral lesion, talocrural osteoarthritis and syndesmosis rupture that can often mimic PAIS.²⁵ Radiographs, especially the lateral view, are valuable for diagnosis of the bony impingement such as a loose body or trigonal process. Further imaging such as ultrasound, CT scan and MRI can also be useful. To date, MRI is considered as the technique of choice to evaluate PAIS.²⁶ In this case, no radiograph was taken at the beginning of the treatment. The patient was referred to his general practitioner for advanced imaging. An MRI of his ankle was conducted due to ongoing pain.

An interesting fact in this case is that a bony fragment was seen on the ultrasound, but not on the MRI. Since the ultrasound results can be operator dependent and, as mentioned previously, the MRI is the technique of choice to evaluate PAIS, and tenosynovitis of the FHL sheath was also found on the ultrasound, we did not change our initial diagnosis of posterior ankle impingement caused by tenosynovitis of the FHL sheath. However, the presence of an os trigonum might be a contributing factor in the patient's pain and dysfunction in this case. Further investigations could have been done to find the exact cause of the impingement. However, this would not have affected the management in this case.

Treatment for PAIS varies depending of the cause of the impingement. Currently the literature is lacking good quality outcome studies investigating the optimal treatment of ankle impingement. However, in a study by Hedrick et al, non-operative treatment consisting of physical therapy and rehabilitation was shown to be successful in approximately 60% of patients with posterior ankle impingement.⁷ The treatment consisted of ice, rest, anti-inflammatory medications and avoidance of forced plantarflexion for all patients and cortisone injection for patients presenting with higher levels of pain. As the pain decreased, patients followed a physiotherapy program that included phonophoresis, isometric exercises, Achilles tendon stretching, and selected isometric strengthening.⁷

A literature review on conservative treatment of the PAIS in professional ballet dancers and expert consensus by Soler et al., suggested that initial treatment of the PAIS should focus on decreasing inflammation; non-steroidal anti-inflammatory drugs and activity restriction (avoidance of hyperplantarflexion).²¹ Further, physical therapy that included soft tissue therapy, stretching and mobilizations/adjustments of restricted joints of the lower kinetic chain should be done in conjunction with a progressive strengthening, balance and proprioception program.^{21,23,27} An example of this type of rehabilitation program for PAIS was described in the case presentation above. This program was built from the chiropractor's clinical experience, return to play guidelines for ankle injuries as well as the current literature on the conservative management of PAIS. In this case, the patient needed to be able to maintain adequate balance when standing at work. Also, full ankle active ROM, strength, agility and ability to perform acceleration/deceleration movements quickly were needed to fully return to play. It is suggested to tape or brace the ankle in a protective dorsiflexion position when the patient returns to sports activity.25 A systematic review showed that athletes with a history of ankle sprains have 70% fewer ankle injuries when taped or braced in comparison with those who did not wear prophylactic support.28

Cortisone injections into the affected area may alleviate the pain and allow the patient to progress into a rehabilitation program.^{7,29,30} The present patient received a successful corticoid injection. His pain decreased from a NRPS score of 4/10 to 2/10 post-injection. This decrease of pain allowed the patient to progress in the rehabilitation program.

In case of failure to conservative care, referral to orthopaedic surgery should be made. These patients may benefit from open surgical or arthroscopic resection of an os trigonum or tenosynovitis debridement of the area.^{4,5} The natural history of PAIS is largely unknown. However, the cause and severity of the impingement and activities done will surely impact the prognosis and the time before a complete return to physical activity. For example, a ballet dancer might need a longer rest period before being able to return to sport since a very high level of stress is put on the posterior aspect of the ankle when competing.

Summary

Ankle sprains are common sports-related injuries.^{1.2} Although most inversion-type ankle sprains resolve without any chronic disability, some cases can lead to PAIS.^{2.6} The diagnosis can be made from a rigorous history and physical examination and after ruling out more severe conditions. However, many structures can be causing the impingement and confirming the cause of the symptoms can be difficult. Diagnostic ultrasound, CT scan, radiographs and MRI imaging allow the practitioner to rule out other pathologies and provide additional information to identify the cause of the impingement to facilitate treatment. MRI imaging is considered the technique of choice in the diagnosis of PAIS due to its ability to evaluate soft tissue and osseous structures as well as its high specificity and sensitivity to identify soft tissue abnormalities.^{17,25,26}

Conservative management may be recommended as a first line treatment for PAIS, however, the literature is lacking to support specific conservative management strategies. Rehabilitation programs applied vigorously play an important role in the therapeutic management of PAIS; it is an effective way to avoid surgery in many cases.^{7,21} A personalized strengthening program in conjunction with proprioception and balance exercises that progressively increase in intensity help improve static and dynamic stabilization of the ankle and prevent recurrence of injury.²¹ In case of failure to conservative care, surgery can be an option to consider.⁸

Additionally, information is needed about PAIS especially in regard to epidemiology and conservative care. However, PAIS should be included in the differential diagnosis when a patient experiences posterior ankle pain exacerbated with plantarflexion.

To conclude, this 37-year-old dek hockey player was diagnosed with a PAIS caused by tenosynovitis of the flexor hallucis longus sheath associated with ostechondral lesion of the anterior aspect of the talus after spraining his ankle. He went through a 14 week conservative management program and cortisone injection that helped him gain pain free ROM, regain the strength of his left lower limb, improve his balance and proprioception as well as return to sport. This manuscript was written to present a potential consequence of a condition that clinicians encounter very often in their practice, an ankle sprain.

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Identification and management of chronic shoulder pain in the presence of an MRAconfirmed humeral avulsion of the inferior glenohumeral ligament (HAGL) lesion

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Objective: To present the assessment and conservative management of chronic shoulder pain in the presence of a humeral avulsion of the inferior glenohumeral ligament (HAGL) lesion in an active individual.

Clinical Features: A 47 year-old female officeworker with constant, deep, right shoulder pain with occasional clicking and catching claimed to have "tore something" in her right shoulder five years ago while performing reverse bicep curls. A physical exam led to differential diagnoses of a Superior Labrum Anterior to Posterior (SLAP) lesion, Bankart lesion, and bicipital tendinopathy. A Magnetic Resonance Arthrogram revealed a HAGL lesion.

Intervention and Outcome: A conservative chiropractic treatment plan in addition to physical therapy was initiated. The patient reported 75% improvement in symptoms after 4 treatments over a fourweek duration. Objectif : Présenter l'évaluation et le traitement conservateur de la douleur chronique à l'épaule en présence d'une avulsion humérale d'une lésion du ligament glénohuméral inférieur (HAGL) chez une personne active.

Caractéristiques cliniques : Une employée de bureau de 47 ans, souffrant d'une douleur constante et profonde à l'épaule droite avec un craquement occasionnel, a affirmé avoir « déchiré quelque chose » dans son épaule droite il y a cinq ans en effectuant des flexions inversées des biceps. Un examen physique a posé des diagnostics différentiels d'une lésion du labrum supérieur antéropostérieur (SLAP), d'une lésion de Bankart et de tendinopathie bicipitale. Une arthrographie par résonance magnétique a révélé une lésion du ligament glénohuméral inférieur (HAGL).

Intervention et résultats : *Un traitement chiropratique conservateur avec une physiothérapie a été entrepris. Le patient a fait état d'une amélioration de 75 % des*

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Written patient consent to publish this case was obtained. @ JCCA 2016

Summary: This case demonstrates the successful implementation of a conservative plan of management suggesting that the treatment provided to this patient should be considered and attempted prior to arthroscopic surgery.

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KEY WORDS: chiropractic, glenohumeral, instability, ligament, avulsion, sports, HAGL, shoulder pain

Introduction

Chiropractors frequently see patients with upper extremity injuries that include the shoulder. Respondents to the 2015 National Board of Chiropractic Examiners¹ Practice Analysis indicated that on average 8.3% of patients present with a chief complaint involving the upper extremity. The pathology of shoulder instability frequently includes injury to both the labrum and the capsule. Labral injury can occur via separation of the labrum from the glenoid rim or direct bony injury to the anteroinferior glenoid, also known as a Bankart lesion^{2,3}, whereas capsular injury occurs as plastic deformation of the capsule or capsular stretching. In a small number of cases, capsular rupture may occur either midsubstance or directly off the humeral attachment^{4,5}. This type of capsular detachment is known as a humeral avulsion of the glenohumeral ligaments (HAGL).

The inferior glenohumeral ligament-labral complex is the primary anterior stabilizer of the shoulder when the arm is at 90 degrees of abduction and external rotation. This complex consists of anterior and posterior bands, in addition to an interposed axillary pouch that attaches to the humerus just below the articular margin of the humeral head in two distinct configurations: a collar-like attachment or V-shaped attachment⁶. If the glenoid is viewed as a face of clock (Figure 1), the attachments of the anterior band of the inferior glenohumeral ligament labral complex range from the 2 o' clock to the 4 o' clock position, whereas the attachments of the posterior band range from the 7 o' clock to the 9 o' clock position.^{6,7} In the two largest clinical series in the literature, the HAGL lesion has been reported to occur in 7.5% to 9.4% of patients undersymptômes après un traitement de 4 séances sur quatre semaines.

Résumé : Ce cas montre la mise en œuvre réussie d'un plan conservateur de traitement, suggérant que le traitement prescrit à ce patient doit être envisagé et tenté avant la chirurgie arthroscopique.

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MOTS CLÉS : chiropratique, glénohuméral, instabilité, ligament, avulsion, sports, HAGL, douleur à l'épaule



Figure 1.

Schematic drawing of the shoulder joint capsule indicating the location and extent of the inferior glenohumeral ligament labral complex. A – anterior, P – posterior, B – biceps brachii tendon, SGHL – superior glenohumeral ligament, MGHL – middle glenohumeral ligament, IGHLC – inferior glenohumeral ligament labral complex, AB – anterior band, PB – posterior band, PC – posterior capsule. Numbers are clock referents.



Figure 2.

MRA images showing direct visualization of discontinuity of the inferior glenohumeral ligament and extravasation of contrast material in the region of the capsular avulsion²¹ with white arrows indicating the HAGL lesion in the patient presented in this case report.

going arthroscopic surgery for anterior instability and in 1.0% to 9.0% of patients with recurrent instability.⁸

The purpose of this case presentation is to present the assessment and successful conservative management of a patient with multi-factorial chronic shoulder pain in the presence of an MRA-confirmed HAGL lesion.

Case Presentation

A 47 year-old active female presented with a chief complaint of constant, deep, right shoulder pain with no radiation, rated as a 2 to 3 out of 10 on a verbal pain-rating scale (VPRS) at rest and 5 to 6 out of 10 with certain activities, including rowing and using an elliptical. She explained that she "tore something" in her right shoulder approximately five years ago while performing reverse bicep curls with her personal trainer. The patient commented that she occasionally found this pain would interrupt her sleep and noticed a catching and clicking sensation, but she was unable to describe the specific movements that would recreate this. She had found mild relief with massage therapy and exercises prescribed by a physical therapist. Associated symptoms included mild neck stiffness and a "sore upper back". A systems review was unremarkable with respect to her chief complaint. A diagnostic ultrasound study ordered by her medical doctor revealed mild-to-moderate acromioclavicular osteoarthritis and no evidence of rotator cuff pathology. The patient explained that she had previously been taking medication to treat vertigo but was now in good health and had an unremarkable family history. She also revealed two previous motor vehicle accidents in 1987 and 1995 in which she was rear-ended and suffered what she described as mild whiplash.

Upon physical examination, active and passive shoulder ranges of motion were full while recreating the chief complaint at all end ranges. Resisted right shoulder flexion at 90 degrees was rated a 4/5 using the Medical Research Council Scale for Muscle Strength^{9,10}, a cervical spine screen – testing for facet, disc, and neurological incarceration in the cervical spine was normal with the exception of a positive Kemp's test between C7-T1. Yergason's, Speed's and O'Brien's tests were positive on the right as was horizontal adduction and the Crank test, insofar as reproducing the pain of chief complaint. Neer's, Empty Can, Full Can and Hawkins-Kennedy tests were negative, however weakness of the right supraspinatus (4/5)^{9,10} was

Table 1.

Breakdown of the early, middle, and late phase rehabilitation protocol utilized in this case.

	Early Phase (Approximately 0-3 weeks)	Middle Phase (Approximately 3-8 Weeks)	Late Phase (8 + Weeks)
Goals	 Maintain full range of motion (ROM); Improve resting scapular positioning and mobility; Improve postural awareness 	 Progression of scapular stabilization; Strengthen muscles of rotator cuff 	Continue strengthening incorporating multi-directional movement patterns
Exercises	 Shoulder elevation active ROM; Scapular Retraction/Bilateral Row with resistance band; Prone lying isometric shoulder adduction and external rotation with scapular depression ("Robbery" position) (Figure 3); Shoulder Circles at wall (with ball) – clockwise and counter clockwise; Scapular Clock (Figure 4) – Resistance band shoulder protraction 	 Push-up plus from table level; Lat pull down; Resistance band shoulder flexion/ abduction from 0° to 90°. Progress to full range of motion as able; Resistance band external rotation and internal rotation. Progress exercise elevating the arm moving the elbow away from the body up to 90°. 	 Resistance band horizontal abduction and alternating diagonal movement patterns²² (Figure 5); Pulley resistance ascending/ descending diagonal shoulder movement patterns; Incorporate sport/activity specific exercises
Milestones for Progression/ Outcome Measures	 Full active ROM without compensation patterns; Good scapular position in resting position; Improved postural awareness 	• Able to complete all exercises with proper technique without pain	• Return to all functional activity and sport related activity

noted with the Empty and Full Can tests. Palpation of the cervical spine, anterior chest wall, and periscapular muscles revealed a hypertonic and tender rhomboid major, levator scapulae, trapezius, and pectoralis major on the right. The patient was diagnosed with a suspected chronic SLAP lesion. Differential diagnoses included chronic right bicipital tendinopathy with associated myofascial pain, as well as a suspected chronic Bankart lesion.

A magnetic resonance arthrogram (MRA) was requisitioned to identify the severity of damage to the glenoid labrum and to rule out any other intra-articular pathology. While waiting for the MRA, the patient underwent a course of treatment once per week for six weeks. Her plan of management included spinal manipulation and mobilization of the cervicothoracic spine, shoulder mobilizations, and myofascial release to treat the biceps tendon, infraspinatus, teres minor, rhomboid major, levator scapulae, trapezius, and pectoralis major on the right. Shoulder mobilizations included long-axis distraction and lateral gapping of the glenohumeral joint, in addition to the "shoulder shake" – inferior distraction and oscillation while moving from neutral to 90 degrees abduction in the frontal plane.¹¹ Lateral gapping is described as a medial to

lateral push along the coronal plane of the patient with an axillary contact while bracing the distal aspect of the arm against the patient's body.¹¹ Long-axis distraction utilizes an axillary contact for stabilization while generating an inferior pull on the distal arm in the patient's coronal plane.¹¹ An individualized, physiotherapist-guided shoulder-strengthening program was initiated (Table 1). The patient responded very well to this plan of care – a VPRS rating of two out of 10 at worst and subjectively described 75% improvement after four visits (in four weeks) during a subsequent visit. Intra-articular viscosupplementation (Monovisc®) was also prescribed and administered 5 months after initial presentation to ameliorate the pain secondary to the AC joint arthropathy. Local anaesthesia was obtained with 1% Xylocaine and 2 cc was injected into the right AC joint under fluoroscopic guidance.

The MRA was obtained after a three-month wait (Figure 2), and indicated the following: moderate hypertrophic degenerative arthropathy of the acromioclavicular joint; mild narrowing of the supraspinatus outlet; mild subacromial/subdeltoid bursitis; humeral avulsion of the inferior glenohumeral ligament; no Hill-Sachs fracture or osseous Bankart fracture. The labrum, long head of the bi-



Figure 3. "Robbery" isometric exercise. While lying prone, bend the elbows into a "W" position. Focus on depression of the shoulder blade. Target muscle: lower trapezius.



Figure 4. "Scapular Clock". Protract the shoulder and in a controlled motion move to the 4 points on a clock (12, 3, 6, 9). Target muscle: serratus anterior.



Figure 5.

From starting position (A), perform controlled movements of horizontal abduction bilaterally (B) and diagonal movement patterns (C/D). Target muscles: rhomboids, lower trapezius.

ceps tendon, supraspinatus, infraspinatus, subscapularis, and teres minor tendons were intact. The coracohumeral ligament was intact as well. Further to these findings, the radiologist noted that the patient's pain decreased only minimally with diagnostic intra-articular anaesthetic (5 cc of 1% Xylocaine) suggesting that intra-articular pathology may not be the primary pain generator, but rather the moderate AC joint arthropathy and mild subacromial bursitis as potential sources of pain.

Discussion

Although the literature has not identified a correlation between the biomechanics of a reverse bicep curl and a HAGL lesion, this particular case highlights an example of conservative management of complex chronic shoulder pain that included a fairly uncommon intra-articular lesion. Wolf¹² in a review of 64 shoulders with the diagnosis of glenohumeral instability, found a humeral avulsion of the glenohumeral ligaments lesion in 6 patients (9.4%). Bokor¹³ reviewed 547 shoulders with instability, and the cause of instability was considered to be avulsion of the lateral capsule, including the inferior glenohumeral ligament from the neck of the humerus, in 41 patients (7.5%)^{8,14}. A review conducted by Bui-Mansfield⁶ suggested that the HAGL lesion has a male predominance of 97% and occurs most often in rugby players (52%); however, this lesion is found in patients who participate in many other activities and sports including diving, football, basketball, surfing, skiing, or in those having been involved in a motor vehicle accident. Bokor¹³ found that of the patients diagnosed with a HAGL lesion, those with rotator cuff tears had a mean age of 33.8 years, while those with isolated HAGL lesions had a mean age of 25.9 years (range of 17 to 41). This case is unique as the patient is female and was 42 years of age at the time of her injury.

94% of HAGL lesions are diagnosed after violent trauma, however, they can result from repetitive microtrauma including overhand throwing.¹⁴ Nicola¹⁵ suggested from a cadaveric study that the articular capsule is torn from the humerus as a result of 105 degrees of hyper-abduction and external rotation, whereas a Bankart lesion occurs as a result of hyper-abduction and impaction. Further to this, Bigliani¹⁶ showed that three failure sites exist for the components of the inferior glenohumeral ligament complex: glenoid insertion (40%), ligament midsubstance (35%), and humeral insertion (25%). Considering the humeral involvement of this patient's injury and its decreased likelihood of occurrence, it is unclear as to why this patient suffered a HAGL lesion.

In a review, Bui-Mansfield⁶ found that 68% of patients presenting with HAGL's have associated injuries such as Hill-Sachs lesions (10%), Bankart lesions (22%), and most commonly, rotator cuff tears (27%) – particularly of the subscapularis muscle¹³. The patient in this case did not present with any of the aforementioned pathology, however, MRA findings indicated moderate hypertrophic degenerative arthropathy of the acromioclavicular joint, mild narrowing of the supraspinatus outlet, and mild sub-acromial/subdeltoid bursitis.

There is no specific clinical test that may differentiate a HAGL from a standard Bankart lesion¹⁴, however, in the case of anterior instability, a history of repetitive microtrauma with generalized ligamentous laxity during the physical exam is thought to be a common presentation with the hallmark abnormality believed to be inferior capsular laxity with or without associated lesions of the labrum-ligament complex¹⁷⁻¹⁹. In spite of this, the patient did not present with generalized glenohumeral joint laxity during the physical exam. In an effort to identify therapeutic techniques that were relieving during treatment visits, mobilizations such as lateral gapping and long-axis distraction were utilized. This may be the direct result of decreasing compression to the subacromial bursa that was found to be inflamed via MRA, or perhaps an analgesic response to stretching hypertonic musculature such as the right trapezius.

Plain radiographs are rarely helpful in the diagnosis of a HAGL lesion, although scalloping of the medial aspect of the humeral neck on the anteroposterior view has been reported a specific finding.¹⁴ MRA is the most reliable diagnostic imaging technique for detecting labroligamentous lesions and the presence of joint effusion or intra-articular injection of contrast fluid is necessary to detect HAGL lesions on MR images.⁸ That being said, Bui-Mansfield⁶ asserts that the diagnosis of the HAGL lesion is missed in up to 50% of cases based on imaging studies alone.

Management of a HAGL lesion depends on the presence of associated injuries. An isolated HAGL lesion may be treated with a sling immobilizer for 4 weeks followed by a shoulder-strengthening program.²⁰ To the best of our knowledge, we are the first in the English language to describe in detail the conservative management of complex chronic shoulder pain in the presence of a HAGL lesion. When necessary, arthroscopic surgery of a HAGL is safe, reproducible, and effective.¹⁴

Summary

The HAGL lesion is a potentially important cause of anterior instability of the glenohumeral joint. The HAGL lesion should be considered after any traumatic shoulder injury, including anterior shoulder dislocation, or in any patient presenting with recurrent instability. Of note, the HAGL lesion tends to present concurrently with shoulder pathology including rotator cuff tears. In athletic populations, the need for, and the recovery associated with arthroscopic surgery should be weighed against an attempt at non-surgical treatment. This case demonstrated the successful implementation of a conservative plan of management suggesting that arthroscopic surgery may not be necessary in some cases.

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High incidence of persistence of sacral and coccygeal intervertebral discs in South Indians – a cadaveric study

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The sacrum, by virtue of its anatomic location plays a key role in providing stability and strength to the pelvis. Presence of intervertebral discs in sacrum and coccyx is rare. Knowledge of its variations is of utmost importance to surgeons and radiologists. The current study focused on the presence of intervertebral discs between the sacral and coccygeal vertebrae in south Indian cadaveric pelvises. We observed 56 adult pelvises of which, 34 (61%) pelvises showed the presence of intervertebral discs between the sacral vertebrae and between the coccygeal vertebrae, while 22 (39%) pelvises did not have the intervertebral discs either in the sacrum or the coccyx. We also found that most of the specimens had discs between S1 and S2 vertebrae (39%), followed by, between S4 and S5 (18%), between S2-S3 (14%) and least being between S3-S4 (13%). In the coccyx it was found that 7% of pelvises had disc between Col-Co2, 4% of them had between Co2-Co3

Le sacrum, en raison de son emplacement anatomique, joue un rôle essentiel pour assurer la stabilité et la force du bassin. La présence de disques intervertébraux dans le sacrum et le coccyx est rare. La connaissance de ses variations est d'une importance capitale pour les chirurgiens et les radiologues. L'étude actuelle a porté sur la présence de disques intervertébraux entre les vertèbres sacrées et coccygiennes sur des bassins cadavériques dans le sud de l'Inde. Nous avons observé 56 bassins adultes, dont 34 (61 %) ont montré la présence de disques intervertébraux entre les vertèbres sacrées et coccygiennes, tandis que 22 (39 %) autres n'avaient pas des disques intervertébraux, dans le sacrum ou le coccyx. Nous avons également constaté que la plupart des spécimens avaient un disque entre les vertèbres S1 et S2 (39%), 18% avaient un disque entre les vertèbres S4 et S5, et enfin 14 % entre S3 et S4. Dans le coccyx, on a constaté que 7 % des bassins avaient un disque entre Co1 et Co2, 4 % d'entre eux l'avaient entre

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KEY WORDS: sacrum, intervertebral disc, coccyx, mobility of sacrum, sacral screw, sacral lesion.

Introduction

The sacrum is a large, triangular bone formed by the fusion of five sacral vertebrae. It forms the posterosuperior wall of pelvic cavity. Its apex articulates with the coccyx and its base articulates with the fifth lumbar vertebra at the lumbo-sacral angle. Between the base and apex are dorsal, pelvic and lateral surfaces and a sacral canal.¹ The coccyx is a small triangular bone. It usually consists of 3-5 fused rudimentary coccygeal vertebrae. The base of the first coccygeal vertebra articulates with the sacral apex. The second to fourth coccygeal vertebrae diminish in size and are usually mere fused nodules and represent rudimentary vertebral bodies.¹ Sacrum contributes significantly for the stability and strength of the pelvis by transmitting the weight of the body to the pelvic girdle. The five sacral vertebrae are connected by intervertebral discs during childhood with subsequent fusion of the S4-S5 and S3-S4 levels in late adolescence and fusion of the S2–S3 and S1–S2 levels by the third decade of life. This fusion process is partially dependent on human upright posture and locomotion. It is not infrequent to observe a residual disc at S1-S2 levels on imaging studies, especially in young adults. When this disc space is prominent, care must be exercised so as not to incorrectly count intervertebral disc space levels.² Variant anatomy may lead to misinterpretation of a radiograph or computed tomography (CT) scan. Lumbosacral fusion and instrumentation are common procedures for several spinal disorders including spondylolisthesis, lumbar scoliosis and for metastatic, infectious, degenerative and traumatic diseases affecting the sacrum.3-5

Dysmorphic sacra have distinct anatomic variations that must be noted prior to surgical intervention. Dysmorphic osseous characteristics include colinearity of Co2 et Co3 et 4 % entre Co3 et Co4. Il est important de noter la connaissance de ces variations anatomiques de la région sacro-coccygienne en raison des modifications nécessaires à apporter aux diverses procédures d'instrumentation impliquant le sacrum.

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MOTS CLÉS : sacrum, disque intervertébral, coccyx, mobilité du sacrum, vis sacrée, lésion sacrée.

the upper portion of the sacrum and the iliac crests, noncircular anterior sacral foramina, residual upper sacral discs, etc. Many surgeons believe that these variations are important to note because they require alterations in surgical fixation constructs in the sacrum, which will avoid any iatrogenic nerve injury.⁶ They opine that sacral dysmorphism has been identified in almost half of the adult population using CT scans and that these variants complicate the interpretation of sacral anatomy and thus hinder many surgical and radiological interventions.

Thus, understanding the morphological variations of sacrum and coccyx is imperative. Persistence of intervertebral discs between the sacral and coccygeal vertebrae is a very rare finding. To the best of our knowledge, to date there is no study conducted on human cadavers which focuses on this idea and the importance related to it. Thus the current study was undertaken which focused on the presence of intervertebral discs between the sacral and coccygeal vertebrae in South Indian cadaveric pelvises.

Materials and Methods

During our regular dissection classes for medical undergraduates, we noticed a high incidence of persistent intervertebral discs between the sacral and coccygeal vertebrae. We decided to conduct a systematic study and document the percentage occurrence of intervertebral discs between sacral and coccygeal vertebrae. We had in our collection, 112 pelvic halves which were obtained by making midline saw cuts through 56 adult human south Indian cadaveric pelvises. The age of the formalin embalmed bodies ranged between 45 and 80 years. They were grouped into male and female pelvises. Incomplete or irregular pelvic halves were excluded from the study. The following par-



Graph showing the presence of intervertebral discs in male sacrum.

ameters were noted: presence or absence of intervertebral discs in the sacrum and coccyx; vertebral levels at which the discs were present; maximum and minimum vertical thickness of the intervertebral disc. Results were expressed as percentages.

Results

Among the 56 pelvises that we observed, 47 were male and 9 were female pelvises. 34 (61%) of the pelvises showed the presence of intervertebral discs between the sacral vertebrae and between the coccygeal vertebrae while 22 (39%) pelvises did not have the intervertebral discs either in the sacrum or the coccyx. Among the pelvises with presence of at least one disc, 27(79%) were

Table	1.
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Table showing the number of intervertebral discs present in the sacrum (Total number of pelvises studied = 56).

No of intervertebral discs present in sacrum	No of pelvises and percentage			
0 discs	22 (39%)			
1 disc	27 (48%)			
2 discs	3 (5%)			
3 discs	2 (4%)			
4 discs	2 (4%)			





Graph showing the presence of intervertebral discs in female sacrum.

male pelvises while 7 (21%) were female pelvises. When we compared females with males for the presence of discs in sacrum, 78% of females had at least one disc in the sacrum while 57% of males had at least one disc in the sacrum (Figures 1 and 2). 15% of males had at least one disc in the coccyx, whereas none of females had any disc in the coccyx.

In most of the male pelvises, the intervertebral discs were found in sacrum and coccyx, while in female pelvises, the intervertebral discs were present only in the sacrum. In the sacrum, only 1 disc was present in 27 pelvises, while 2 discs were present in 3 pelvises, 3 discs in 2 and all 4 discs were present in 2 pelvises (Table 1). In the coccyx, we observed the presence of only 1 disc in 3

Table 2.
Table showing the number of intervertebral discs present
in the coccyx. (Total number of pelvises studied $= 56$).

No of intervertebral discs present in coccyx	No of pelvises and percentage			
0 discs	49 (87%)			
1 disc	3 (5%)			
2 discs	2 (4%)			
3 discs	2 (4%)			

	B/w S1& S2	B/w S2& S3	B/w S3& S4	B/w S4 & S5	B/w Co1&Co2	B/w Co2&Co3	B/w Co3&Co4
М	19	6	5	9	4	2	2
F	3	2	2	1	_	_	_
%	39%	14%	13%	18%	7%	4%	4%

Table 3.Table showing the position profile of intervertebral discs in male (M) and female (F) pelvises.

pelvises, 2 discs in 2 and 3 discs in 2 pelvises (Table 2). The position profile of the intervertebral disc is shown in Table 3, where we found that most of the specimens had discs between S1 and S2 vertebrae (39%), followed by between S4 and S5 (18%), S2-S3 (14%) and least being between S3-S4 (13%). In the coccyx, it was found that 7% of pelvises had disc between Co1-Co2, 4% of then had between Co2-Co3 and another 4% had between

Co3-Co4. 2 pelvises (both male) had persistence of all 4 sacral and 3 coccygeal discs. Figures 3 and 4 show the occurrence and distribution of the intervertebral discs in the sacrum and coccyx respectively. Photographs of the pelvises showing the presence of intervertebral discs at various levels can be seen in Figures 5-9.

We measured the thickness of the discs and found that





Figure 5. Figure showing the presence of a single intervertebral disc (D1) in sacrum between S1 and S2. L5= fifth lumbar vertebra.



Figure 7. Figure showing the presence of 3 intervertebral discs (D1, D2, D3) in sacrum between S1, S2, S3 and S4.



Figure 6. Figure showing the presence of 2 intervertebral discs (D1 and D2) in sacrum between S1, S2 and S3. L5= fifth lumbar vertebra.



Figure 8. Figure showing the presence of 4 intervertebral discs (D1, D2, D3, D4) between the 5 sacral vertebrae (S1, S2, S3, S4, S5). L5= fifth lumbar vertebra.



Figure 9. Figure showing the presence of intervertebral discs (D1, D2, D3, D4) between all the sacral vertebrae (S1, S2, S3, S4, S5) and coccygeal intervertebral discs (CoD 1, 2, 3) between all the coccygeal vertebrae (Co1, Co2, Co3, Co4). L5 = fifth lumbar vertebra.

the maximum vertical thickness was 0.5 cm and minimum thickness was 0.2 cm.

Discussion

The vertebral column is formed by articulation of individual vertebrae. Its morphology is influenced externally by mechanical and environmental factors and internally by genetic, metabolic and hormonal factors.¹ The adult vertebral column usually consists of 33 vertebral segments. Between the vertebrae a fibrocartilaginous intervertebral disc is present which allows for the intervertebral movements and can sustain high compressive loads. The intervertebral disc consists of a central gelatinous core; the nucleus pulposus encircled by concentric layers of a densely fibrous connective tissue, the annulus fibrosus. The intervertebral discs are usually absent in the sacrum and coccyx due to the fusion of these vertebrae.

Vertebral body formation occurs during the fourth week of embryonic development as mesenchymal sclerotome cells migrate to surround the notochord. Each vertebral body is a combination of the caudal part of the sclerotome above and the cranial part of the sclerotome below; mes-

enchymal cells between cephalic and caudal parts of the original sclerotome segment form the intervertebral disc. The nucleus pulposus part of the intervertebral disc is formed from the notochord cells while the annulus fibrosus develops from the mesenchymal cells. In the sacrum, five vertebrae begin to fuse during childhood, beginning caudally and ascending, leaving no residual intervertebral sacral discs by early in the fourth decade of life.^{7,8} A range of sacral segment fusion occurs during these stages of development, which may lead to the presence of residual disc remnants between the vertebral bodies in the sacrum.9 Cadavers are the best means to study the variant anatomy of any region. During our literature review we found that there are no reports on any studies conducted about the persistence of intervertebral discs in sacrum and coccyx among the Indian population. Thus this study was conducted and we found promising results wherein 61% of the adult pelvises observed by us showed the presence of intervertebral discs between sacral vertebrae and coccygeal vertebrae. We assume that this variation may be due to the late fusion or incomplete fusion pattern of sacral and coccygeal vertebrae which may cause mobility of sacrum and coccyx leading to instability of the pelvic girdle. In a CT study done by Woon et al.¹⁰, on adult coccyx they have found that sacrococcygeal and intercoccygeal joint fusion were common and it was not related to age or gender. Wu et al.11, in their study on morphology of sacrum in the Chinese population believe that variations in sacral morphology are common in the Chinese population and these anatomic variations should be taken into consideration when diagnosing and treating sacrum-related diseases. They also postulate that such anatomic studies involving eastern populations are very rare and stress its importance.¹¹ Kaiser et al.¹², in their study on CT scans of pelvises opined that the prevalence of sacral dysmorphism ranged from 30% to 50%.

The lumbosacral region is one of the most variable regions of the spinal column. Most skeletal malformations occur in the area of the lumbosacral transition.¹³⁻¹⁵ Lumbosacral transitional vertebrae are congenital spinal anomalies defined as either sacralisation of the lowest lumbar segment or lumbarization of the most superior sacral segment of the spine. Nicholsen *et al.*¹⁶, have observed that when a lumbarized S1 is present, the disk space between S1 and S2 is larger than the rudimentary disc. This fact was observed in our study wherein there was presence of intervertebral disc between S1 and S2 in 39% of the pelvises. O'Driscoll *et al.*¹⁷, have developed a 4-type classification system of S1–2 disc morphology by using sagittal magnetic resonance images, depending on the presence or absence of disc material and the anteriorposterior length of the disc. Type 1 exhibits no disc material. Type 2 consists of a small residual disc with an AP length less than that of the sacrum. Type 3 is a well-formed disc extending the entire AP length of the sacrum. Type 4 is similar to type 3 but with the addition of squaring of the presumed upper sacral segment. Depending on this, we can claim that most of the discs in our specimens can be classified into type 2 and type 3. In type 3 disc types we found that the maximum vertical thickness of the disc was 0.5 cm and minimum thickness was 0.2 cm.

Valer Dzupa *et al.*¹⁸, in their study have confirmed a high incidence of congenital malformations in the area of the lumbosacral transition and demonstrated a higher incidence of such cases in males. In our study, we observed that 78% of females had at least one disc in the sacrum while only 57% of males had at least one disc in the sacrum.

We also found the presence of discs between coccygeal vertebrae in 15% of male pelvises. We believe that this may lead to instability or excessive mobility of the coccyx. Some surgeons have opined that instability of coccyx may lead to pain in this region which is known as coccydynia. The pain is felt when the subject is in sitting position wherein the mobile coccyx may then align itself parallel to the seat. The coccygeal mobility can be assessed by dynamic radiographs. Lateral stress radiographs of the coccyx can show an organic lesion which affects coccygeal mobility.¹⁹ Birender Balain et al.²⁰, have studied the fate of coccygeal intervertebral discs histologically and have found that out of total 22 intact specimens 10 had at least 2 discs or moving joints, and 11 had only 1 disc or moving joint. They observed that the disc spaces in the region were extremely variable, with examples of intact discs, discs with clefts, discs with cystic or fibrocystic changes, and discs replaced by synovial joints all being found. Wray et al.²¹, report that it is possible to identify such variations before surgery radiologically by discography.

The fusion process of sacral and coccygeal vertebrae is said to be partially dependent on human upright posture and locomotion. It is found that in children who do not bear weight across the sacral region, as in paraplegia, the sacrum and coccyx do not fully fuse. Fusion at the lumbosacral junction, sacrum and coccyx distinguishes human sacra from other hominoid sacra.⁹

A residual disc space can be visualized between the dysmorphic upper and second sacral segments on the pelvic outlet plain radiograph and it happens in persons with dysmorphic sacral anatomy.⁶ They suggest that dysmorphic sacra have distinct anatomic differences that must be noted prior to surgical intervention. Dysmorphic osseous characteristics of the sacrum include colinearity of the upper portion of the sacrum and the iliac crests, presence of mammillary bodies at the sacral ala, noncircular anterior sacral foramina, residual upper sacral discs etc.

These anatomic variations of the sacrum and coccyx are important to note because they require alterations in surgical fixation constructs which involves the sacrum like in sacral screw fixation for joint correction. The sacrum is a target point for sacral fixation during posterior lumbar body fusion (PLIF) and anterior lumbar body fusion (ALIF) procedures. Such instrumentation may carry the risks for neurovascular injury resulting in morbidity, and even mortality.22 This dictates detailed knowledge of the sacrum and its regional anatomy. We are unsure of the exact factors behind such a high occurrence of intervertebral discs in the sacrum and coccyx of South Indians. We are unaware of the possible advantages or disadvantages of having these discs since we do not have any history of the cadavers. We had a limited number of pelvises. An extended study on a large number of pelvises might help us to understand the persistence of the disc better. Since it is difficult to get many cadavers, radiological studies on South Indians might produce interesting data about the persistence of intervertebral discs in sacrum and coccyx.

Conclusions

Surgical treatment of any sacral lesions requires detailed understanding of the underlying anatomy of sacro-coccygeal region and any variations related to it. Significant studies have been done towards the understanding of the sacral region by both anatomists and surgeons using MRI and CT scans. Much is to be learned with advances in surgical methods and instrumentation in the field of spinal surgery.²³ Presence of intervertebral discs in the sacrum and coccyx is a rare variation and knowledge regarding its prevalence is useful for orthopaedic surgeons, neurosurgeons, radiologists, obstetricians and anthropologists. Hence more studies on cadaveric specimens or radiological studies on living people have to be conducted to get a better understanding regarding the anatomy of this region.

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Subluxation and semantics: a corpus linguistics study

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Introduction: The purpose of this study was to analyze the curriculum of one chiropractic college in order to discover if there were any implicit consensus definitions of the term subluxation.

Methods: Using the software WordSmith Tools, the corpus of an undergraduate chiropractic curriculum was analyzed by reviewing collocated terms and through discourse analysis of text blocks containing words based on the root 'sublux.'

Results: It was possible to identify 3 distinct concepts which were each referred to as 'subluxation:' i) an acute or instantaneous injurious event; ii) a clinical syndrome which manifested post-injury; iii) a physical lesion, i.e. an anatomical or physiological derangement which in most instances acted as a pain generator.

Conclusions: In fact, coherent implicit definitions of subluxation exist and may enjoy broad but subconscious acceptance. However, confusion likely arises from failure to distinguish which concept an author or speaker is referring to when they employ the term subluxation.

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KEY WORDS: chiropractic, subluxation, semantics, discourse analysis, corpus linguistics

Introduction : *Le but de cette étude était d'analyser le programme d'études d'un collège de chiropratique afin de découvrir s'il y avait des définitions consensuelles implicites du terme subluxation.*

Méthodologie : Un corpus d'un programme de premier cycle en chiropratique a été analysé à l'aide du logiciel WordSmith Tools, en examinant les termes cooccurrents et par une analyse du discours de blocs de texte contenant des mots dont la racine est « sublux ».

Résultats : Il a été possible d'identifier 3 concepts distincts chacun décrit comme « subluxation » :' i) un événement dommageable aigu ou instantané; ii) un syndrome clinique qui se manifeste après une blessure; iii) une lésion physique, c.-à-d. un trouble anatomique ou physiologique qui, dans la plupart des cas, a agi comme un générateur de douleur.

Conclusions : Des définitions implicites et cohérentes du terme subluxation existent et sont largement, quoique subconsciemment, acceptées. La confusion se pose probablement de l'absence de distinction entre les concepts faite par les auteurs ou conférenciers lorsqu'ils emploient le terme subluxation.

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MOTS CLÉS : chiropratique, subluxation, sémantique, analyse de discours, corpus linguistique

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Introduction

Subluxation is, in the terminology of linguistics, a *keyword* in the chiropractic literature, and two studies have indicated that it is over-represented in comparison to its prevalence in general English.^{1,2} Subluxation is a core concept in the discipline of chiropractic, and so in chiropractic education, and *vertebral subluxation* remains, by far, the most common term used in the curriculum of Canadian Memorial Chiropractic College (CMCC) to refer to what has been called the 'definitive chiropractic lesion'.³

Notwithstanding the currency of the term, there is much debate within the chiropractic profession concerning the meaning(s) of *vertebral subluxation* and its synonyms, fixation and restriction.⁴ Any number of attempts has been made to consolidate a broadly accepted definition (see for example ^{5,6}). Nonetheless, consensus seems elusive⁴, and one must wonder how this could be so when most chiropractic clinicians identify and treat the entity referred to as *subluxation* on a regular basis.

Outside of chiropractic, the term *subluxation* refers to a displacement of a joint, less than a frank dislocation. The *chiropractic subluxation*, if we may use that term, is a different entity – something affecting the spine and often thought of as encompassing something beyond a biomechanical lesion.⁷ Of course, profession-specific language may at times be a challenge to interprofessional communications.⁸ Interestingly, other professions seem to have little specific concern about the use of the term *subluxation* by chiropractors (see ^{9,10}). However, little consideration is given to the possibility that the difficulty in settling on a single broadly accepted definition within chiropractic may be that there is not a single entity (but see ⁴).

Thus, the purpose of this current study was to analyze a corpus of the written curriculum of CMCC to determine whether, in fact, the single term *subluxation* was being used to refer to multiple concepts.

Methods

As described previously, a corpus of the CMCC curriculum was created from instructional materials archived on the school's learning management system.³ The archived texts comprised 3,076,237 tokens (words) from thirtynine 1st to 3rd year courses taught during the 2010-2011 academic year; i.e. every textual learning object posted on the school's learning management system. The 4th year of the program is primarily an internship with little didactic instruction. The archived documents included all course syllabi, lecture notes, texts of Powerpoint[™] presentations and published articles which were required or recommended readings.

Using methods conventional to corpus linguistics¹¹, the corpus was analyzed in two steps: first looking at immediately adjacent words to discern immediate contexts, and secondly by examining entire sentences for a finely granulated semantic analysis. Thus, the corpus was first analyzed using the software, Wordsmith Tools V6.0. The collocation function was used first to identify terms most commonly collocated (i.e. located within 5 words to the left or right within running text) with subluxation. This provides some indication of immediate context. Subsequently, the concordance function was used to identify 1,000-character blocks of text centred on the root sublux*. That is to say that each word identified as based on the root sublux* was centred within 1,000 alphanumeric characters which would normally be equivalent to approximately 200 words. This provided a broader context within which to deduce the meaning(s) of the target term. Initially, 1,777 such blocks of text were captured (supplementary file attached). However, by eliminating duplicates, 573 unique text blocks were identified. Duplicates occur commonly in electronic archives when sections of text are copied and pasted, for example from original articles into class notes or PowerpointTM presentations.

Text blocks were laid out in a spreadsheet and read once in succession. Notations concerning meaning were added after each block of text. The investigator then reviewed these notations and grouped meanings into what appeared to be three naturally occurring taxa. The investigator then re-read each of the text blocks and assigned it to one of the three taxa.

In this exploratory study, the single author read each block of text and attempted to discern whether any natural taxonomy appeared for the terms *subluxation* and *subluxations*. As this was an exercise in imputation, the investigator brings their own biases to the analysis. Another investigator might look at the same data and see a greater or lesser number of natural taxa, or might assign different meanings to extracted texts, based on their own understanding of the language. Nonetheless, the apparent classes of meaning, whether natural or fanciful, will likely provide a useful departure point for further discussions on the semantics of *chiropractic/vertebral/spinal subluxation*.

Results

The most common collocations with *subluxation(s)* (and the number of such instances) were *vertebral* (207), *chiropractic* (195), *theory* (135), *complex* (123), *joint* (118), *dysfunction* (110), *model* (96), *syndrome* (67) and *spinal* (64).

Fifty-four text blocks referred to subluxation of an extra-vertebral joint; most often (21 instances) the glenohumeral joint. As reported previously, there were 189 instances of the phrase *vertebral subluxation*, 23 instances of the phrase *spinal subluxation*, and 44 instances of the phrase *chiropractic subluxation*, all of which referred to *vertebral subluxation*.³ All expressions of concern about the definition of subluxation referred to the vertebral subluxation, not extravertebral subluxation. Thus, unless otherwise stated, the results reported herein refer to vertebral subluxation.

The nature of the source material, meant that the term subluxation often occurred outside of coherent sentences, for example in word lists, titles and legends, so that it was most often not possible to assign any particular nuance to the word. Nonetheless, in a sizeable minority of instances (178 in total) a natural taxonomy did seem to occur, suggesting 3 different meanings for 'subluxation,' as follow. In 15 cases, the term *subluxation* appeared to refer to the essentially instantaneous event of spinal injury, referred to hereinafter as the 'subluxation event.' In a further 82 instances, the term referred to the clinical presentation which developed following the subluxation event, and hereinafter referred to as the 'clinical subluxation.' In an additional 81 instances, the term referred to an anatomical lesion or pathophysiological process which was independent of the precipitating event or clinical presentation, hence, referred to hereinafter as the 'subluxation lesion.' The relationship of these concepts is, of course, that i) a patient is exposed to some kind of injurious event, ii) which creates clinical signs and symptoms, iii) which are due to some underlying tissue damage.

The criteria for assignment to the taxon of 'event' included reference to an essentially instantaneous biomechanical phenomenon resulting in perceived injury to the spine. Expressions assigned to the taxon of 'event' included, for example:

a) '... when subluxation occurs, it may be likened to a wheel, the hub of which is not the center...'

- b) '... the model of subluxation based on Triano's biomedical model of buckling...'
- c) '... develop the buckling model of subluxation from the scientific evidence...'
- d) '... spinal buckling: a mechanical model of subluxation...'
- e) '... spinal buckling failure = subluxation injury: mechanical form of deformation incompatible with intended function...'

The criteria for assignment to the taxon of 'clinical presentation' included reference to signs or symptoms, diagnostic tests, treatment or consideration of the foregoing. Expressions assigned to the taxon of 'clinical presentation' included:

- a) '... The word subluxation was the term first conscripted by D.D. Palmer to characterize the clinical entity on which he focused his manual interventions...'
- b) 'Subluxation syndrome; an aggregate of signs and symptoms that relate to pathophysiology or dysfunction of spinal...'
- c) '... the younger Palmer began to profess that subluxation detection and adjustive intervention should be...'
- d) 'A subluxation is evaluated, diagnosed and managed through the use of chiropractic procedures based on the best available...'
- e) 'Subluxation in which altered alignment, movement or function can be improved by manual thrust procedures...'

The criteria for assignment to the taxon of 'lesion' included reference to anatomical derangement or pathophysiological processes at any level of organization (whole organism to biochemical). Expressions assigned to the taxon of 'lesion' included:

- a) 'The pathophysiologic complex model of subluxation describes component elements without clarifying mechanisms...'
- b) '...left-right heat asymmetry purported to identify the inflammation associated with the chiropractic lesion, subluxation...'
- c) '...the term vertebral subluxation complex re-

fers to the theory that there are pathophysiologic and/or visceral events associated with spinal lesions...'

- 'Many hypothesized that a fundamental component of the vertebral subluxation complex is the development of adhesions in the z joints after hypomobility of these structures...'
- e) 'A subluxation is a complex of functional and/or structural and/or pathological articular changes...'

Discussion

In discussing the definition or the challenge of defining subluxation, authors in general do not distinguish between the event of subluxation, the clinical constellation and the physical lesion; see, for example.¹² Consequently, when different authors arrive at different but perfectly sensible definitions, this may mistakenly be taken as a difference of opinion or even a controversy. It is not. Different definitions of different entities, even if they use the same referent term, may be completely compatible and even help to present a consistent understanding of a phenomenon.

Within the current undergraduate curriculum at CMCC there appear to be three different but synergistic implicit definitions of subluxation. These are the subluxation event, the clinical subluxation, and the subluxation lesion.

The Subluxation Event

The subluxation event is characterized as an essentially instantaneous failure of spinal stability, sometimes expressed as 'spinal buckling'. The terminology and the concept have been championed by authors including Cholewicki and McGill¹³, and Triano¹⁴. In brief, the proposed mechanism is failure of a local stabilizing element such as an intersegmental ligament or muscle. This results in an injurious concentration of forces which would otherwise be more broadly distributed. An actual subluxation event in the lumbar spine was serendipitously captured with videofluoroscopy by Cholewicki and McGill.13 Furthermore, Kaneoka et al demonstrated essentially the same phenomenon in an experimental study involving a whiplash-like injury delivered to human volunteers.¹⁵ In other words, the subluxation event is not simply a hypothesis. It is something which has been captured in real life and duplicated experimentally.

The Clinical Subluxation

The clinical subluxation, as presented in the modern CMCC curriculum is quite congruent with its presentation in the historical curriculum², a modern corpus of the Journal of the Canadian Chiropractic Association¹, and, likely, in the broader literature. In other words, with a few outlying descriptions, the implicit operational definition is not controversial at all. Implicit characteristics of the clinical subluxation are that it is an acquired, spinal, intersegmental, biomechanical phenomenon. It is acquired in the sense that it is not inherited. For chiropractors, it is spinal rather than extravertebral. It is very much a local phenomenon - if the phenomenon spreads across more than one joint level then it is likely to be referred to as a series of subluxations or some other phenomenon altogether. It is biomechanical in the sense that posture or movement is invariably affected. Furthermore, explicitly expressed characteristics include sustained involuntary muscle contraction, pain or tenderness on palpation, asymmetry of position or motion, restricted motion and tissue texture changes. In some instances, neurally mediated phenomena, such as skin temperature asymmetries, are also mentioned.

The Subluxation Lesion

Within the CMCC curriculum, no single definition of the subluxation lesion is presented, nor could it be, based on the foregoing. From the definition of the subluxation event above, it is logical that different tissues would be injured and different pathological processes initiated in different people. By way of example, in a whiplash-like injury as modeled by Kaneoka et al.¹⁵, one would predict injury to the facet joints, and, indeed, studies have demonstrated the efficacy of facet joint anaesthesia/neurotomy in some cohorts of whiplash patients¹⁶. In other regions of the spine, or with other vectors, it might well be ligament, discs or muscles which are injured. Hence, a single pathophysiological definition for a subluxation lesion makes about as much sense as a single pathophysiological definition for a 'sports injury' or a 'traffic accident injury.'

Conclusions

In summary, this analysis of discourse in the CMCC curriculum suggests that three distinct but related concepts are all referred to as subluxation. Only one model is presented for the subluxation event, and this is a coherent model based on conventional anatomical and biomechanical concepts, and validated through observation and experimentation. The clinical subluxation also has a very coherent operational definition grounded in the history and symptomatology reported by patients, and the findings of conventional diagnostic techniques.¹⁷ The subluxation lesion has no single definition, as seems most appropriate, since it is likely that different tissues and processes are involved in different patients.

Both in education and in professional discourse, it would likely be beneficial, when using the term subluxation, to clarify which of these three concepts is/are actually under consideration.

Limitations

The findings of a corpus analysis are, naturally, constrained by the corpus. In this instance, the texts analyzed were all taken from the curriculum of Canadian Memorial Chiropractic College. The corpus was comprised of virtually every text document presented to the students through the learning management system and so was a very good representation of the written language that students are exposed to. However, no attempt was made to represent aural exposure, as for example through lectures, labs or audiovisual resources. Furthermore, a corpus based on materials from another institution would produce quantitatively different results, and might well reveal a different taxonomy. Consequently, the results of this study should not yet be extrapolated to other schools nor to the profession at large. Additionally, semantic analysis, while it may be machine-assisted, is a human endeavor, with meanings seen through the eyes the researcher. The raw data from this study are provided as a supplementary file to permit alternative analyses by others.

Competing interests

The author declares that he has no competing interests.

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