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Editorial Board

The Launch of the Institute of Musculoskeletal Health and Arthritis 2014-2018 Strategic Plan: Positive Implications for Canadian Chiropractors and their Patients

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In October 2014, in downtown Toronto, the Canadian Institutes of Health Research (CIHR) Institute of Musculoskeletal Health and Arthritis (IMHA) held a meeting called Science in Motion. The purpose of the meeting was to bring together IMHA stakeholders to discuss the implementation of IMHA's Strategic Plan for 2014-18. One hundred and nine delegates were invited from over 17 universities, and 34 agencies, centres, networks, coalitions, societies, alliances, companies and institutes from across Canada, and around the world. According to the Director of IMHA, Dr. Hani El-Gabalawy, the responsibility of the invitees was to share their "wealth of assembled knowledge and experience to bear on the key challenge of operationalizing IMHA's Strategic Plan". It was exciting to see the chiropractic profession represented at such a pivotal event for health research in Canada.

CIHR integrates research through an interdisciplinary structure made up of 13 institutes. CIHR's Institutes are networks of researchers and research users brought together to focus on important health problems. IMHA is the most relevant institute for Canadian chiropractors. IMHA supports research to enhance active living, mobility and movement, and oral health. IMHA addresses causes, prevention, screening, diagnosis, treatment, support systems, and palliation for a wide range of conditions related to bones, joints, muscles, connective tissue, skin and teeth. The overall vision of IMHA is to lead musculoskeletal (MSK), skin and oral health research and

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knowledge translation to improve the lives of Canadians. In order to achieve their vision IMHA has three guiding research themes: 1) Capacity Building; 2) Innovation; and 3) Translation.

The IMHA Strategic Plan for 2014-18 is titled "Enhancing Musculoskeletal, Skin and Oral Health" and has three priority investment areas: 1) Chronic Pain and Fatigue; 2) Inflammation and Tissue Repair; and 3) Disability, Mobility and Health. Four core values are at the heart of the strategic plan. They include: 1) Ethics; 2) Performance Measurement; 3) Evidence Informed Decision Making; and 4) Partnerships and Citizen Engagement.

The meeting was chaired by Dr. Monique Gignac, the Chair of the IMHA Institute Advisory Board. Following the initial remarks and welcoming to the conference by Dr. Hani El-Gabalawy, a video was played to introduce the IMHA Strategic Plan, and the conference. In the video Chiropractic was acknowledged as one of the healthcare disciplines which manages the clinical needs of Canadians. IMHA was committed to ensuring that individual meeting delegates had a voice, and one of the ways to do this was setting up a twitter hash-tag. Delegates were able to provide feedback and comments throughout the day via the twitter hashtag "#IMHASIM."

The meeting then began with presentations addressing the research gaps that presently exist in the three priority areas. Gary Macfarlane, a Professor of Epidemiology at Aberdeen University in the United Kingdom (UK) spoke on the first strategic priority, *Chronic Pain and Fatigue*. He acknowledged that for arthritis research in the UK, musculoskeletal pain is being explored by both pharmacological and non-pharmacological approaches. He discussed the conduct of clinical trials and that it is imperative to know what outcome measures to apply *a priori* to ensure accurate findings. He also mentioned the STarT Back screening tool developed at Keele University. The STarT Back tool stratifies low back pain patients, rather than simply sending them all directly for surgical consultation. Similar initiatives are occurring in Canada and could present unique opportunities for the chiropractic profession.

The next presentation addressed the second strategic priority *Inflammation and Tissue Repair* and was presented by Katherine Siminovitch, Director of the University Health Network's Clinical Genomics Centre and Centre for Genetic Medicine in Toronto. She focused on the genetic involvement in the manifestation of pathological conditions, and epigenetics, which is the study of specific cell types whose protein synthesis is reversible and sensitive to the environment. Her vision is that future medications can focus on "druggable pathways" by using genetic screenings to determine which people will respond to specific drugs. She predicted that the future of pharmaceutical intervention on genetically modifiable diseases will be predictive, preventive and personalized.

The final strategic priority presented on was *Disability, Mobility and Health*. Joy MacDermid a Professor in the School of Rehabilitation Science at McMaster University in Hamilton used a conceptual framework set out by the World Health Organization. She addressed how the severity of MSK disorders can impact mortality through sedentary behaviours that also leads to cardiovascular pathology. She acknowledged that injuries in the workforce related to trauma have gone down, but that the prevalence of MSK strain conditions has increased. She stressed that clinicians prescribing medications or physical activity need to be aware that adherence of patients to the recommended treatments is low. She stated that there is a need to consider alternative and innovative care delivery models, and that researchers need to study dosages of such interventions.

Next, meeting participants were divided into small groups to discuss the implementation of the strategic plan. Groups were asked to consider three specific questions for three 15-minute discussions as a group:

1) What are your suggestions for how the IMHA-specific strategic funding should be allocated within your assigned strategic priority area? Which programs/tools should be used?
2) What are the cross-cutting themes within the IMHA strategic priority area you were assigned that would allow IMHA to align itself with other multi-institute initiatives?
3) What would be the best way(s) for IMHA's stakeholder communities to have on-going input into shaping both the IMHA-specific and the CIHR multi-institute strategic initiatives?

Each group had a Rapporteur who summarized the discussions, and after consensus from the small group, reported back to the entire conference delegation.

Steven Passmore – Assigned to the Chronic Pain and Fatigue Strategic Priority Area

I participated in a group that consisted of members including the President of the Canadian Rheumatology Association, the Assistant Dean of Research from Dalhousie University, the Director of the Mineralized Tissue Physiology Program from the National Institute of Health's Institute of Dental and Craniofacial Research, the Chair of the Bone and Joint Decade, the Assistant Director of CIHR IMHA, the Executive Director of the Canadian Skin Patient Alliance, and several other professors from Canadian Medical/Doctoral Universities. It was a wonderful opportunity to have a national voice present for the chiropractic profession and the University of Manitoba.

We reached a consensus on the importance of several issues. For new and innovative ideas we proposed that several 1-year catalyst grants could be established. Such pilot grants could create the opportunity for researchers from different disciplines to become aware of how the work of other grantees complements their own and new teams may emerge that can collaborate on future team-based grants. Concern was expressed that if CIHR only focused on the most prevalent diseases, that important research on other diseases could be triaged as being of lower priority and thus valuable science could be missed. We spoke of developing improved measurement tools to evaluate patient progression through a course of care, moving away from questionnaire usage and toward objective and performance driven measures of patient ability, sleep, and physical activity. We discussed the importance of including representatives from patient advocacy groups in order to hear their perspectives from research design to dissemination and all steps in between. We identified that there should be two separate streams that research could be categorized to: 1) population study – focused on management (study of existing treatments); and 2) mechanism study – focused on finding the cure to disease (new treatment developments). We considered the role of mental health and aging as comorbidities associated with chronic pain and that perhaps successful aging includes having access to interventions that decrease chronic disabling pain. Beyond IMHA we can partner with research foundations, and professional clinical associations to advance our initiatives. The general discussion with all delegates, following each small group reporting back, showed that our discussion was aligned with other groups' discussions.

Simon French – Co-Chair of one of the small groups to discuss the Inflammation and Tissue Repair Strategic Priority Area

My group consisted of various IMHA stakeholders including Canadian university-based researchers working in this research area (Inflammation and Tissue Repair), and patient advocates. Along with my Co-Chair, my role was to facilitate the discussion to ensure that everyone had a voice and to ensure that all three questions were discussed. Our group came up with a number of ideas and suggestions for the implementation of IMHA's Strategic Plan, including: ongoing support of early career researchers; support of small grants to fund pilot work and proof-of-principal research; and effective knowledge translation strategies for the research community about IMHA's initiatives.

During lunch the Chief Scientific Officer and Vice President Research and Knowledge Translation for CIHR Jane Aubin spoke on the CIHR Roadmap II developments and how the IMHA community could engage with the CIHR's initiatives. One major new CIHR initiative is of particular relevance for chiropractors. Canada's Strategy for Patient-Oriented Research (SPOR) is about ensuring

Dr. Hani El-Gabalawy, Scientific Director for CIHR IMHA addresses the conference delegation at the Science in Motion meeting hosted by the Institute of Musculoskeletal Health and Arthritis in Toronto, Ontario on October 30th, 2014.

that the right patient receives the right intervention at the right time. In early November there was a call for grant applications to fund SPOR networks in chronic disease. The aim of SPOR network funding is to provide financial support to improve care and "mobility across multiple chronic diseases", a focus that should deeply engage the chiropractic community in a large $25M initiative. There is likely to be relevant musculoskeletal networks funded under this proposal, in which chiropractors, chiropractic researchers and the profession's stakeholders can become engaged.

The second half of the meeting explored "Networks and Partnerships". A presentation by Dr Pierre Boyle, Assistant Director of the CIHR Institute of Circulatory and Respiratory Health, focused on the lessons learned in developing research networks, opportunities and challenges experienced. The presentation was followed by a panel discussion on "Network and Partnership Opportunities," with panel members from a range of backgrounds who collectively had many years' experience developing and maintaining research networks and partnerships.

Hani El-Gabalawy Summarized the Event with Closing Remarks

Dr. El-Gabalawy's observations of the event included that participants endorsed the priorities proposed in the new IMHA strategic plan and the establishment of research networks as powerful tools for advancing complex research. He observed that delegates of the meeting now have a deeper understanding of partnership. He also commented that capacity building was needed so early career investigators can be integrated into successful research teams and networks. Further, Dr. El-Gabalawy suggested that the research community needed appropriate measurement tools to determine the impact of research at all levels including CIHR Network, Team, and Operating Grants. Finally, he endorsed the value of continuing engagement with the IMHA community at face-to-face meetings to maintain open communication.

The Role of Chiropractors and Spinal Health in IMHA's Strategic Plan

Spinal health is front and center in IMHA's Strategic Plan (2014-18). First, the cover image of the strategic plan is an artistically lit photograph of a human back. Second, several points of interest to chiropractors are raised in the Strategic Plan. There is the description that when considering chronic pain there is currently a "misuse of potent analgesics" including opiates because we do not fully understand the pathogenesis of chronic pain syndromes. IMHA acknowledges that the current system employs "less effective management" of chronic pain that can lead to "substantial healthcare expenditures," and that research is needed to address the root cause of pain and explore the extent of its impact on quality of life. To rectify the shortcomings of the existing approach to chronic pain management IMHA seeks to define "optimal strategies of care and management through improved models of care". Chiropractors in multidisciplinary clinics, hospitals, and universities across Canada are well placed to utilize CIHR funding to pilot, disseminate and evaluate new models of care that include chiropractic services.

In conclusion, supporting chiropractors to be in leadership roles at traditional research-intensive universities via the Canadian Chiropractic Research Foundation (CCRF) strategy has had many benefits. One of these benefits was highlighted by two chiropractic CCRF researchers invited to this important event and this has given the profession a louder voice in the national conversation about how research dollars should be allocated for the benefit of the musculoskeletal health of Canadians.

Online Supplemental Resources:

IMHA 2014-18 Strategic Plan on the web:
English – http://cihr-irsc.gc.ca/e/48830.html
French – http://cihr-irsc.gc.ca/f/48830.html
Video:
English – http://youtu.be/rvDmm65sz-U
French – http://youtu.be/_JJDC7r0Iuw

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JCCA Sports Chiropractic 6th Issue

Dr. Mohsen Kazemi, RN, DC, MSc, FRCCSS(C), FCCPOR(C), DACRB, PhD (Candidate)*

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It is my pleasure to introduce the 6th edition of Sports Issue of JCCA. The last 5 years have been very successful to showcase Sports chiropractic research. You will find this issue very versatile and filled with interesting and thought provoking manuscripts. It covers hot topics such as, "Chiropractors tackling the inactivity epidemic", "Concussions in the NHL", "Early sports specialization" and "Effects of spinal manipulation versus therapeutic exercise on adults with chronic low back pain". You will also find current evidence-based approaches to treat and diagnose various conditions such as Myositis Ossificans, Juvenile Osteochondritis Dissecans, and Ulnar Impaction Syndrome. There are yet other original research manuscripts exploring posture, functional movement screen, fascial-muscular lengthening therapy, and injury profile of Ontario and Canadian soccer players to name a few.

I believe you agree with me that the Sports Issues of JCCA have been a great venue encouraging our Sports Chiropractic researchers to publish their work and hence increase the evidence for Sports Chiropractic. This is vital in acceptance and utilization of sport chiropractors in sporting events and teams. I hope you enjoy reading and applying this issue to your clinical and research practice. Furthermore, I look forward to see your manuscripts in Sports Chiropractic published in future JCCA Sports Issues.

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Chiropractors tackling the inactivity epidemic

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Physical inactivity is a fast-growing public health concern and contributes to a variety of chronic diseases and health complications. In addition to improving a patient's overall health, increasing physical activity has been proven to be effective in the treatment and prevention of chronic disease. Canadians are facing what is now referred to as an "inactivity epidemic", with tremendous healthcare costs. Physical inactivity is the fourth leading risk factor for global mortality. The economic burden of physical inactivity in Canada is approximately 5.3-6 billion dollars per year.[1-7]

The problem with Canadians today is that currently 56% of all adults are physically inactive with 59% of Canadians being overweight or obese. Shockingly, 36% of Canadian adults admit to engaging in no leisure-time physical activity.[1-7] However, there is also an inconsistency within the healthcare system in Canada. Approximately 34% of patients receive advice from their primary healthcare provider, meaning that 66% of Canadians are not receiving advice on physical activity from their primary healthcare provider. More interestingly is that 40% of healthcare providers do not meet Canadian physical activity guidelines themselves. Furthermore, when healthcare providers are less physically active they are less likely to counsel patients on the importance of physical activity and certainly unlikely to prescribe it as a treatment approach to health. Healthcare providers that do not meet the guidelines are arguably less credible role models for patients for adopting healthy behaviours.[1-7]

A solution for the growing physical inactivity problem is movement. Exercise is Medicine Canada (EIMC) is an initiative focused on encouraging primary care physicians and other health care providers to include exercise prescription when designing treatment plans for patients. Exercise is Medicine is committed to the vision that exercise and physical activity are integral to the prevention and treatment of chronic disease and should be regularly assessed as part of medical care. Exercise is Medicine strives to make physical activity a "vital sign" that is routinely assessed at every patient interaction with a health care provider.

"Exercise is Medicine Canada" is a new nationwide initiative to get Canadians more active and to help patients achieve optimal health. The Royal College of Chiropractic Sports Sciences (RCCSS(C)) is encouraging health-

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care practitioners to use its formal prescription pad to prescribe exercise as a form of medicine to patients. Exercise can be prescribed to treat a dozen of the chronic illnesses, such as diabetes, hypertension and obesity. Using exercise as a form of medicine is based on an abundance of evidence that physical activity, exercise, and movement reduces the risk of chronic disease. The RCCSS(C) is encouraging patients to find simple ways to incorporate movement into their daily routines to ultimately increase health.

The mission of EIMC is to call on all healthcare providers to assess and review every patient's physical activity program at every patient visit. This includes establishing physical activity as a vital sign, educating healthcare professionals about the importance of exercise and physical activity and incorporating exercise and physical activity education into healthcare curriculums. The vision of EIMC is to create an overall improvement in the public's health and ultimately a long-term reduction in healthcare costs to Canadians.

EIMC is a national initiative established approximately 2 years ago and is guided by a task force made up of chiropractic, family and sports medicine, physiotherapy, exercise physiology, and other allied healthcare professionals who are working on increasing the physical activity of their patients.

Last year, Dr. Chris DeGraauw, current president of the RCCSS(C), had the opportunity to attend the Canadian Academy of Sport and Exercise Medicine (CASEM) conference in Whistler, B.C. He attended meetings on EIMC held by Drs. Renata Franckovich and Pierre Fremont of CASEM. It followed that Susan Yungblut, the national task force manager of EIMC, asked Dr. DeGraauw to represent chiropractic on the task force.

Dr. DeGraauw has been working along side other members of the national task force to promote the use of the exercise prescription pad, to design and implement exercise prescription workshops for healthcare practitioners and he is working on a joint position paper regarding the importance of EIMC in our Canadian healthcare system. Most recently (April 2014), he presented on EIMC, exercise prescription, and utilizing the pads, at the Royal College's West sports conference in Vancouver. The attendees were excited to bring this information back to their practices and some were hoping to share the message with their medical colleagues.

Also, the public health committee of the RCCSS(C), chaired by Dr. Michelle Laframboise, has been in contact with Susan Yungblut on getting an "EIMC on Campus" club started at the Canadian Memorial Chiropractic College (CMCC). Drs. Brad Ferguson and Jason Porr with student representative Taylor Tuff have worked to educate the students at CMCC on the importance of EIMC and are currently assisting the Royal College to implement workshops into the 4th year curriculum. Further, Dr. Laframboise was invited to CMCC as a guest lecture to speak on behalf of the RCCSS(C) on EIMC to the student body. The initiative of EIMC on Campus is aimed at fostering early exposure to exercise and healthcare.

Incorporating Exercise is Medicine into healthcare curriculums is an essential element of transforming the overall healthcare system. Currently, there is a lack of undergraduate training in the area of physical activity and exercise prescription. Only 6% of medical schools have a course in exercise prescription. Thus, it is imperative that we start educating healthcare students to make this a standard of practice in the future. Healthcare students need to learn physical activity assessment, prescription and implementation. Also, it is important that students learn how to counsel patients on exercise and behavioural changes. Most importantly, healthcare students should learn how to be role models to create social change. These competencies represent the framework needed to introduce a basic exercise curriculum into undergraduate healthcare curriculums. Training students to integrate these basic skills into their practice from the outset will create a new generation of healthcare providers who have the skills and motivation to improve the health of patients through physical activity practices.[8]

Dr. Scott Howitt, first vice-president of the RCCSS(C), has also been important in conveying the message on EIMC. Dr. Howitt was invited to the 2013 Ontario Chiropractic Association's conference where he spoke about the value of incorporating exercise into patient care to improve overall health and wellness and address the difficult challenge of changing patient behaviours. In this presentation Dr. Howitt explained that chiropractors need to see themselves as positive role models when they prescribe exercise to patients and to make sure that chiropractors are following healthy exercise behaviours by following the Canadian physical activity guidelines. He goes on to say that chiropractors can be influential but need to practice what they preach. This presentation has been posted as a webinar for all RCCSS(C) members to view at www.rccssc.ca.

As chiropractors, we need to recognize barriers to providing physical activity advice. We need to recognize that inadequate training, inadequate time management, insufficient knowledge and inadequate reimbursement may play a role in not providing proper advice on exercise. Chiropractic educators need to implement formal training for healthcare providers for preventative care with exercise. Also, to use exercise prescription to treat conditions that are associated with physical inactivity. Chiropractors and chiropractic students must learn to create interdisciplinary care plans involving exercise prescription. We need to work together in unison to help educate our patients about living healthy active lifestyles.[9,10]

The future goal of the RCCSS(C) and EIMC is to increase the amount of healthcare providers, including chiropractors, who prescribe physical activity. This will increase the number of Canadians meeting the physical activity and exercise guidelines. We need to encourage appropriate use of qualified exercise professionals in the prevention of chronic diseases though exercise and physical activity. Finally, physical activity needs to be incorporated as a key health indicator, a vital sign.[9,10]

Please try to get involved in the initiative to help get Canadians healthier with exercise. Please visit Exercise is Medicine online at www.exerciseismedicine.ca and download your prescription pads. Also, visit www.exerciseismedicinemonth.org and the RCCSS(C) at www.rccssc.ca (members section) which highlights the importance of promoting EIMC in the chiropractic profession. If you are a chiropractic student please join the Exercise is Medicine on Campus at CMCC. Other healthcare students are advised to visit the Exercise is Medicine website for information on getting schools across Canada onboard with EIMC on Campus.

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Concussions in the NHL: A narrative review of the literature

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Ice hockey has been identified as a sport with a high risk for concussions. Given the health sequelae associated with the injury, a great deal of attention has been placed on its diagnosis, management and return-to-play protocols. The highest level of ice hockey in North America is played in the National Hockey League (NHL), and concussions pose a serious threat to the health of the players and the game itself. Unfortunately, the scientific literature on concussions in ice hockey is derived mostly from research conducted on youth and amateur levels of play, leaving a gap in our knowledge at the professional level. This narrative review attempts to summarize what is known about concussion incidence, mechanisms of injury and risk factors in the NHL.

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KEY WORDS: concussion, incidence, injury, risk, hockey, chiropractic

Le hockey sur glace est reconnu comme un sport à haut risque pour les commotions cérébrales. Compte tenu des séquelles pour la santé associées à la blessure, son diagnostic, son traitement et les protocoles de retour au jeu font l'objet de beaucoup d'attention. Le plus haut niveau de hockey sur glace en Amérique du Nord est joué dans la Ligue nationale de hockey (LNH), et les commotions cérébrales constituent une menace grave pour la santé des joueurs, voire pour le jeu. Malheureusement, les ouvrages scientifiques sur les commotions cérébrales dans le hockey sur glace proviennent principalement de la recherche menée sur les jeunes et les niveaux amateurs du jeu, laissant un vide au niveau professionnel. Cet examen narratif est un effort pour résumer ce que l'on sait sur l'incidence de la commotion cérébrale, les mécanismes de blessure et les facteurs de risque dans la LNH.

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MOTS CLÉS : commotion cérébrale, incidence, blessure, risque, hockey, chiropratique

Introduction

Ice hockey is a popular North American sport played on a sheet of ice between two teams with 5 players and one goalie per side. Youth registration rates attest to its popularity, approaching 600,000 per year in Canada[1] with USA Hockey reporting similar registration rates[2]. It is an aggressive fast moving game that sees players moving at speeds up to 30 kilometers per hour.[3] Given the speed and aggressiveness with which the game is played, it should come as no surprise that ice hockey has the highest rate of concussion incidence amongst contact sports.[4,5] Concussions have become a topic of considerable interest

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amongst the scientific community, media and general public due to the sensational mechanisms of injury and deleterious consequences they can impart. Since 2000, four international conferences have been held with the aim of streamlining information and providing guidelines for the medical community on its diagnosis and management.[6,7,8,9]

Concussion Incidence

Concussions occur at all skill and age levels in ice hockey, and have been reported to account for 2-14% of all hockey injuries[10,11,12,13] and 15-30% of all hockey head injuries[10,14]. The large range of concussion incidence may be partially explained by the varied outcome measures used by researchers (i.e. athletic exposures vs. game hours vs. overall percentages). Unfortunately, the lack of a streamlined approach has made it difficult to draw conclusions and comparisons across studies.

In North America, the highest level of ice hockey is played in the National Hockey League (NHL). Between 1993 and 2003 it has been estimated that at least eight players were forced to retire due to lingering concussion symptoms, while many more missed weeks, months and entire seasons.[15] However, this estimate is believed to be conservative, and the true number of concussion-induced retirements is thought to be at least double this estimate.[16] Part of the reason for uncertainty regarding the data's accuracy is the NHL's vigilance in not lending its epidemiological data to researchers, due to stated issues of medical confidentiality.[17]

While epidemiological data at the NHL level is sparse, a small but growing body of literature is beginning to emerge. Wennberg and Tator (2003)[18] studied concussion in the NHL using data from published media reports, which have been cited as a reliable source of information[17,18]. The authors justified their use, explaining that injuries suffered by professional athletes are part of the overall entertainment package supplied by sport, and that the media and public demand eventually uncover the nature of injuries incurred by the athlete. The authors found that from the 1986-1987 to 1995-1996 seasons, there was a mean of 12 concussions per season. From the 1996-1997 to 2001-2002 seasons, there was a mean of 56 concussions per season, more than triple that of the previous decade. The authors attributed this drastic increase in concussion incidence to the commencement of the NHL Concussion Program in 1997. Therefore, the authors postulated that the findings were not a true increase in concussion incidence, but rather due to heightened awareness and diagnosis of the condition.

In a follow-up study, Wennberg and Tator (2008) documented the incidence of concussion and time lost from play due to concussive injury during the 1997-1998 to 2007-2008 seasons.[19] The authors found the mean incidence over the ten seasons to be 1.45 concussions per 1000 athletic exposures, and reported a significant downward trend in concussions over that time period. In contrast to this decrease, a gradual increase in the average number of games missed per concussion was recorded and the mean number of missed games per concussion during the last five seasons was significantly greater than during the first five seasons. The authors hypothesized that this may represent an increase in concussion severity, or perhaps, more stringent concussion management protocols that are more rigid in their return-to-play (RTP) timelines. Without access to NHL data, an issue fraught with concerns regarding medical confidentiality, it is impossible to discern which is more likely to account for the increase in games missed per concussion in the latter five seasons examined.

Recognizing a significant problem within the league, the NHL in conjunction with the National Hockey League Player Association (NHLPA), established the NHL-NHLPA Concussion Program in 1997, with the purpose of examining the science of concussion as well as the education of its members on all aspects of the injury.[20] The program helps the NHL accumulate data on concussion incidence, mechanism of injury and RTP timelines. The data collected have not been released to the public and only two studies have been published to date. The first was an abstract authored by Meeuwisse, Burke and Benson (2003) reporting data collected from team physicians who reported on all players sustaining concussions during the 1997-1998 to 2002-2003 NHL regular seasons.[20] They reported an average of 97 concussions per year and found that the median games missed per concussion doubled from one to two over the 5 years of the study. As it was only an abstract, no detailed statistics were provided.

To date, only one detailed study has emerged from the NHL Concussion Program. Benson et al (2011) had NHL team physicians document all concussions sustained during the 1997-1998 to 2003-2004 seasons in a

Table 1.
Summary of reported concussion incidence

<table>
<tr><th></th><th>Wennberg & Tator (2003)</th><th>Meeuwisse, Burke & Benson (2003)</th><th>Stevens et al (2008)</th><th>Wennberg & Tator (2008)</th><th>Benson et al (2011)</th><th>Hutchison et al (2013)</th><th>Izraelski et al (2013)</th></tr>
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prospective case series format.[21] The authors reported a total of 559 physician-diagnosed, regular season in-game concussions with a mean of 80 concussions per season. The median time lost from play was six days. In line with the two studies by Wennberg and Tator[18,19], the authors established that concussion rates were declining, from 7.7 concussions per 100 players during the 2001-2002 season down to 4.9 per 100 players during the 2003-2004 season. The authors concluded that this may be due to a variety of reasons including underreporting of symptoms by players to avoid missing time, more conservative management by team medical personnel, higher thresholds for diagnosis of concussion and increased use of neuropsychological testing results before making RTP decisions. The results of the studies, while indicating a decrease in concussion incidence, should be taken with caution. The authors stated issues of underreporting, and that more conservative management of concussions theoretically helped prevent repeat incidents by ensuring complete recovery before RTP.

In an unpublished thesis, Izraelski et al. (2013)[22] examined reported concussions between the 2005-2006 and 2011-2012 seasons, recording a mean of 64 reported concussions per season during that time frame. This data is lower than Meeuwisse, Burke and Benson[20] (mean of 97 concussions per season between 1997-1998 to 2002-2003) and Benson et al.[21] (mean of 80 concussions per season between 1997-1998 to 2003-2004). The authors speculated that the decrease in mean concussions may be a result of numerous rule changes implemented by the NHL after the 2004-2005 lockout intended to protect players and reduce concussions. Additionally, the study was the first to examine reported concussions in the NHL following the lockout of 2004-2005. While these concussion totals are lower than previous work cited by the NHL-NHLPA researchers, there was an upward trend in reported concussions over the examined time period with a sharp increase in the 2011-2012 season. The study concluded that there was a trend towards rising concussion incidence rates to the high levels seen pre-lockout.

Recent work by Hutchison et al. (2013) has helped add data to emerging concussion statistics in the NHL.[23] For this study, the NHL isolated digital video records of events in which players had been medically diagnosed with concussions. Using these videos and an objective standardized tool to record concussions[24], the authors recorded 197 regular season concussions from the beginning of the 2006/2007 season to until the end of December 2009. It should be noted that 63 concussions were excluded due to "inconclusive evidence" or that simply had no video records available. Unfortunately, the authors provided no statistical breakdown per season, means or athletic exposures for comparison to previous work.

Mechanism of Injury

Concussion is a form of mild traumatic brain injury that is induced by the transmission of force to the brain from either a direct or indirect impact to the head, face, neck or elsewhere along the body.[9] Forces that occur as a result of impulsive head motions (the absence of the head striking an object) are believed to be directly responsible for concussions.[25] While the type of force incurred by the brain is important, the manner in which the brain responds to the force is just as significant. There is considerable evidence that the primary cause of concussion is the acceleration loading experienced by the brain at the moment of contact. While the brain is highly resistant to changing its shape in response to slow or transient forces, it deforms quite easily when shearing forces are applied due to the physical properties of the brain itself.[26,27,28] Rapid head rotations generate shear forces in the brain, and therefore, rotational acceleration forces applied to the skull have a high potential to cause shear-induced damage to brain tissue. Further to this point, a number of studies have led to the belief that shear deformation caused by rotational acceleration is the predominant mechanism of action in concussive injury.[29,30,31] Whether this mechanism of injury holds true in the sport of ice hockey had not been examined until recent work by Hutchison et al (2013).[32] The authors reported that the most common body part initially contacted was the concussed player's head (68%), followed by the torso (28%) and below the waist or inconclusive (4%). The lateral aspect of the head was most commonly contacted area (58%), and when these results are combined with initial contact, almost half of the events (47%) were classified as direct contact to the lateral aspect of the head by the opponent's shoulders, elbows or gloves. The head was observed to accelerate in multiple planes, typically in the sagittal and transverse planes (39%). There was a relatively even distribution of events classified as sagittal or coronal plane (25%) and transverse plane (27%). Also of note, the authors concluded that the concussed player was often not in possession of the puck, and that no penalty was called on the play.

Concussion Risk Factors in the NHL

The most commonly investigated injury risk factors include age, session type, level of play, player position and the presence/absence of body checking.[33] Additional factors such as participation in fair play programmes, aggression and empathy, weight and height, level of hockey experience, relative age and gender have received limited attention and have produced conflicting results.[33] However, these risk factors are investigated from a generalized injury perspective and are not-concussion specific. Furthermore, much of the research is based on minor, junior and collegiate hockey and has produced conflicting results. This has left us with an absence of high quality research on concussive risk factors at the professional level.

It has been hypothesized that concussion incidence and severity will continue to increase if athletes continue to grow bigger, faster and stronger.[34] This has been attributed to simple physics, as the magnitude of any collision is dictated by the size and speed of the two objects colliding. Demographic data from the NHL between 1986-1987 to 2001-2002 corroborates the notion that NHL players are getting progressively taller and heavier.[18] Over the 16-year period analyzed, there was an average height increase of one inch and weight increase of almost 10 pounds (72 inches, 191 pounds to 73 inches, 200 pounds). Hutchison et al (2013)[23] reported that injured players were on average 185.73 cm tall and weighed 92.78 kg. For concussions involving direct contact with another player (88%, n=174/197), the authors reported that the player delivering the contact was on average 186.87 cm tall and weighed 96.32 kg. The hitter was significantly taller (1.26 cm) and 3.58 kg (heavier) than the player he concussed. The hitter was taller than the injured player in 52% of events, with the hitter being heavier than the injured player in 65% of the cases.

Position as a risk factor has been examined previously, and between the 1997-1998 and 2004-2005 season, 341 (64.1%) of concussions were suffered by forwards, 179 (31.4%) by defensemen and 24 (4.5%) by goalies.[21] Hutchison et al. (2013)[23] reported that 65% (129/197) of the analyzed concussions were sustained by forwards, 32% (63/197) by defensemen and 3% (5/197) by goalies. The authors remarked that the number of concussions suffered by forwards was significantly higher than expected compared with their on-ice representation.

Research on concussion and age in the NHL cited the median age of concussion to be 27 years[21], while another study cited the mean age to be 28.0 years[23]. Work by Izraelski et al. (2013)[22] discovered a trend to younger and older players suffering concussions at an increased frequency, supported by findings in logistic regression during two of the examined seasons (2008-2009 and 2011-2012). While causation was not apparent, the author speculated that younger and older players may be more reckless in their style of play, leading to increased concussions.

Fatigue has been shown to increase injury risk in both rugby[35] and soccer[36], and it has been reported that concussions are more likely to occur under fatigued conditions in female ice hockey[37]. In male youth and Junior A ice hockey, time-on-ice has been implicated as a risk factor for concussion[38] and injuries in general[39]. One study examining fatigue in the NHL reported a significant effect for time-on-ice per game.[40] Those who played more than 15.22 minute per game had an increased likelihood of suffering a concussion. The authors suggested that in-game fatigue may explain their findings, that is, players may suffer a concussion more often when fatigued due to a reduction in physical abilities and awareness. Izraelski et al. (2013)[22] found that average time on ice was a significant predictor of injury, with those players in the 15-20 minute range 2.6 times more likely to suffer a concussion than those in the 0-5 minute range. However, if the underlying mechanism for this is indeed fatigue, one would expect to see an increase in concussive risk for the 20-25 minute and 25+ minute groupings. It is possible however, that there is an interaction between average time on ice and skill/performance in that concussions decreased following the 15-20 minute grouping due to an increase in skill in the 20-25 and 25+ minute groupings. Players in those groupings typically represent higher skill levels and perhaps their increased situational awareness helped decrease the number of concussions suffered.

Conclusion

Concussive injury is a serious form of mild traumatic brain injury that deserves the attention it has been given. While much still needs to be learned regarding the injury, a small body of literature is beginning to emerge. Epidemiological data are becoming clearer as researchers examine the topic in greater detail. While a drop in concussion incidence occurred following the NHL lockout of 2004-2005, it appears that the incidence of concussion is again rising and further research is required to help elucidate the reasons for this rise. As we begin to gain a better understanding of concussions and the manner in which they occur, the NHL should continue to take strict action in enforcing bans on hits to head, specifically to the lateral aspect, as it has been demonstrated to be the most likely manner to induce concussive injury. While reasons such as fatigue and increased height/weight have been speculated upon, it is clear that further investigation is required.

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Treatment of Myositis Ossificans with acetic acid phonophoresis: a case series

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Objective: *To create awareness of myositis ossificans (MO) as a potential complication of muscle contusion by presenting its clinical presentation and diagnostic features. An effective method of treatment is offered for those patients who develop traumatic MO.*

Management: *Patients in this case series developed traumatic MO, confirmed on diagnostic ultrasound. Patients participated in a treatment regimen consisting of phonophoresis of acetic acid with ultrasound.*

Outcome: *In all cases, a trial of phonophoresis therapy significantly decreased patient signs, symptoms and the size of the calcification on diagnostic ultrasound in most at a 4-week post diagnosis mark.*

Discussion: *Due to the potential damage to the muscle and its function, that surgical excision carries; safe effective methods of conservative treatment for MO are*

Objectif : *Sensibilisation à la myosite ossifiante (MO) comme complication possible de contusions musculaires grâce à la présentation de son tableau clinique et de ses symptômes. Une méthode efficace de traitement est offerte pour les patients qui sont atteints de myosite ossifiante traumatique.*

Traitement : *Les patients de cette série de cas souffrent de myosite ossifiante traumatique, confirmée par échographie. Les patients ont participé à un régime de traitement consistant en une irrigation d'acide acétique par phonophorèse.*

Résultats : *Dans tous les cas, un essai de traitement par phonophorèse a diminué considérablement les signes et les symptômes des patients ainsi que la taille de la calcification détectée par échographie dans la plupart des cas 4 semaines après le diagnostic.*

Discussion : *En raison de la lésion possible au muscle et des dommages potentiels à sa fonction posés par l'excision chirurgicale, il est essentiel d'adopter une approche sécuritaire et efficace de traitement conservateur de la myosite ossifiante. La myosite*

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Consent was obtained by all patients.

crucial. MO deserves more attention in the literature due to its common presentation in athletes.

(JCCA 2014; 58(4):353-360)

KEY WORDS: myositis ossificans, acetic acid, iontophoresis, phonophoresis, ultrasound, calcification, heterotopic bone formation

ossifiante mérite plus d'attention dans les revues scientifiques en raison de sa fréquence chez les athlètes.

(JCCA 2014; 58(4):353-360)

MOTS CLÉS : myosite ossifiante, acide acétique, ionophorèse, phonophorèse, échographie, calcification, formation osseuse hétérotopique, chiropratique

Introduction

Myositis ossificans (MO) is a non-neoplastic proliferation of cartilage and bone in an area of muscle that has been exposed to trauma.[1] Following a blunt trauma, 9-20% of athletes develop this condition and it is then termed myositis ossificans traumatica or myositis ossificans circumscripta. MO is diagnosed via findings of calcification in muscle identified on imaging.[2] MO is self-limiting, with resolution reported after 1-2 years, and therefore can be managed conservatively in most cases. Literature looking at conservative treatment of MO is sparse, consisting of one non-controlled clinical trial, case studies and expert opinion.[3,4] Surgical removal is considered in cases of persistent pain, limitations in range of motion (ROM), a decrease in function due to compression of neurological or vascular tissues. An attempt of 4-6 months of conservative care is tried initially prior to the consideration of surgery.[2,5]

The purpose of this study is to offer manual therapists a method of conservative treatment for patients presenting with MO. This is achieved by describing three cases of athletes with traumatic MO confirmed on x-ray and diagnostic ultrasound and successfully treated with acetic acid phonophoresis.

Case 1

A 27-year-old male soccer player presented to a chiropractor with right groin pain approximately one month after kicking a soccer ball. The patient had not been treated in the past month and kept re-aggravating his groin while trying to continue to play soccer. This current re-aggravation was described as achy groin pain was rated as a 7 on a 10-point numerical scale. No ecchymosis was present and active and passive ROM of the hip displayed a decrease by 50% in adduction, abduction, and internal rotation. Diagnostic ultrasound confirmed MO in the proximal adductor longus muscle due to a large calcific mass measuring 7.7 x 1.8 x 0.29 cm (Figure 1). Along with the ultrasound findings, radiographic examination showed a linear calcification over 15 cm adjacent to the proximal femur. The patient was treated 3x/week for 4 weeks with therapeutic ultrasound and a 2% acetic acid solution as the medium. After the 4-week treatment plan, the patient rated his pain as a 2 on a 10-point numerical scale and had

Figure 1.
Right Adductor, Transverse Proximal View. A large calcific mass measuring 7.7 x 1.8 x 0.29cm in the proximal adductor longus muscle is present.

regained full ROM of his hip. Post treatment diagnostic ultrasound demonstrated a decrease in the size of the calcification to 6.8 x 1.4 cm (Figure 2).

Case 2

A 45-year-old male horseback rider presented to a chiropractor approximately one month after being kicked in the right lateral quadriceps muscle by a horse. The pain was described as sharp and was rated as an 8 on a 10-point numerical scale. This patient presented with a mild limp and atrophy of his right quadriceps. Active and passive ROM of the right knee displayed 75% reduction in knee flexion and pain with adduction and abduction. Diagnostic ultrasound confirmed MO in the right vastus lateralis due to a finding of calcification in the muscle measuring 13.6 x 3.7 x 1.2 cm (Figure 3). In agreement with the findings on ultrasound, the same measurements were found on radiographic examination. The patient was treated with the same protocol as the patient in case 1 with acetic acid phonophoresis. After the plan of management, a follow-up ultrasound showed that the calcification had not decreased with an updated measurement of 14 x 3 x 0.61 cm (Figure 4). His pain score went from an 8 to a zero on a 10-point numerical scale. On the lower extremity functional scale (LEFS) the patients scored increased from 37 on an 80-point scale to 68 demonstrating significant improvement in function corresponding with full gains in ROM.

Case 3

A 24-year-old male soccer player presented to a chiropractor one year after injuring his right hip while kicking

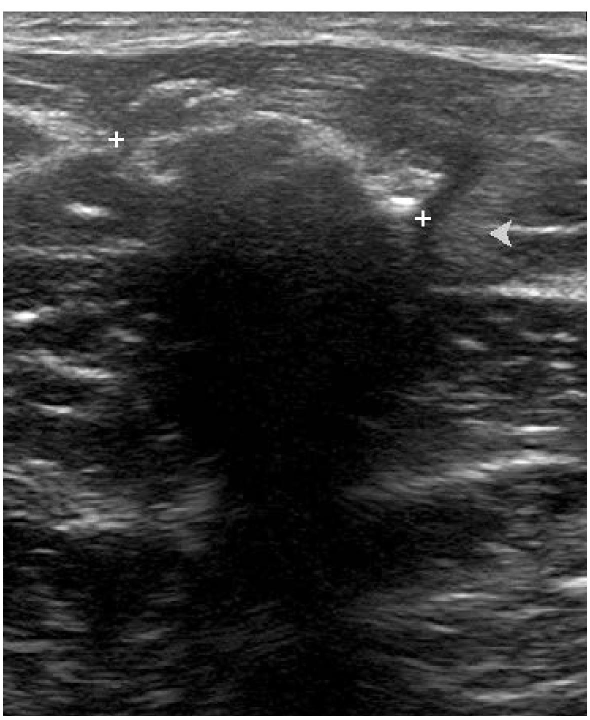

Figure 2.
Right Groin/Adductor Transverse View. A decrease in the size of the calcification was found (6.8 x 1.4cm).

Figure 3.
Right Thigh Transverse Distal Medial to Lateral View. Calcification in the right vastus lateralis muscle measuring 13.6 x 3.7 x 1.2cm.

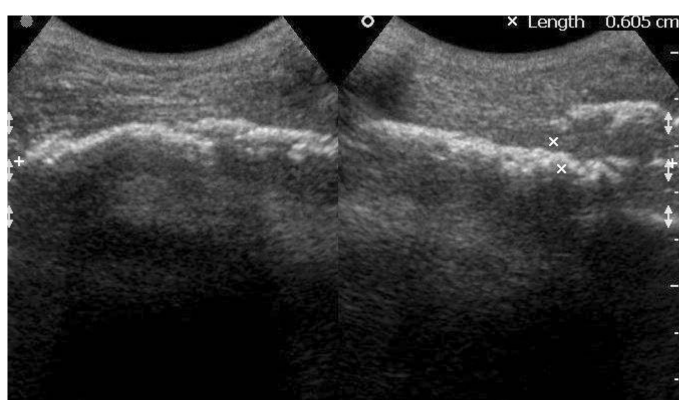

Figure 4.
Right Lateral Thigh Saggital View. Minimal to no change in the calcification size was found 14 x 3 x 0.61cm.

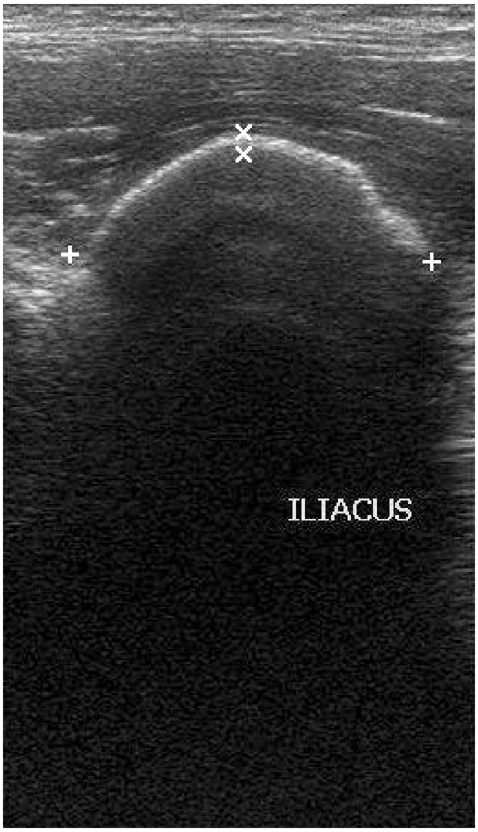

Figure 5.
Right Hip Saggital Anterior View. Calcification in the right iliacus muscle measuring 2.7cm.

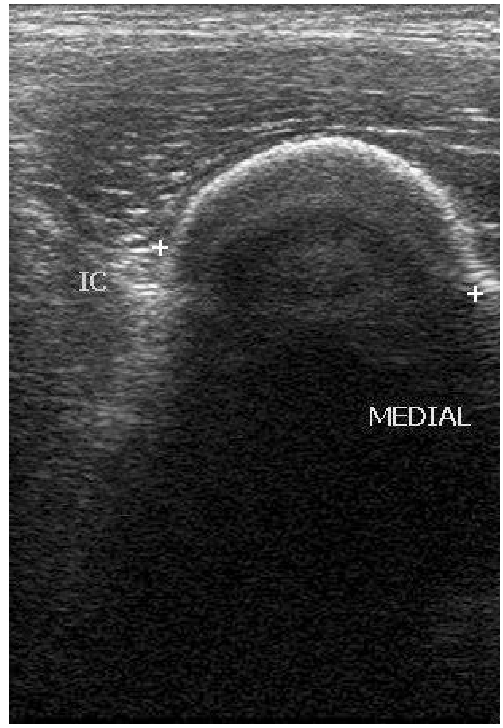

Figure 6.
Right Superior Iliac Crest Saggital View. The calcification decreased to 2.3cm.

a soccer ball. The injury has never been treated and gets re-aggravated with cutting, forceful kicking, and sprinting. Active ROM of the right hip created pain with full flexion and resisted ROM displayed pain with hip flexion and adduction. Diagnostic ultrasound confirmed MO in the right iliacus muscle due to a finding of calcification in the muscle measuring 2.7 cm (Figure 5). In agreement with the findings on ultrasound, measurements of the calcification on radiographic examination measured 1.8 x 1.1 cm. The patient was treated with the same protocol as the patient in cases 1 and 2. After the plan of management, a follow-up ultrasound showed that the calcification had decreased to 2.3 cm (Figure 6). The patient also has pain free ROM.

Discussion

The incidence of myositis ossificans ranges from 0% to 9% for mild contusions to 17% to 72% for moderate-to-severe contusions suggesting that the more severe the contusion, the greater likelihood of progressing to MO. Rates increase with severity and with recurrent injuries to the same location.[6] Myositis ossificans traumatica is a benign proliferation of cartilage and bone in skeletal muscle that has been exposed to trauma. A direct blow to a limb causes compression of the deep muscles to the adjacent bone. Within 24 hours, bleeding occurs between and within muscle.[6] The calcification can be from 2 up to 12 cm and can be debilitating in an athlete.[7] MO of a muscle can develop after a muscle contusion, tear, or wound and a bony fracture although there have been a few cases presented in the literature of MO that have not been associated with any trauma and must be differentiated from a malignant mass.[8,9]

The exact pathogenesis of MO formation is unclear but has been thought of as rapidly proliferating mesenchymal cells that differentiate into osteoblasts in the presence of localized tissue anoxia, producing abnormal bone and cartilage growth. Also, trauma to muscle leads to prostaglandin synthesis, which attracts inflammatory cells to the site of injury, fostering the formation of bone. Four theories of pathogenesis have been suggested in the literature, 1) displacement of bony fragments into adjacent soft tissues and hematoma with subsequent proliferation, 2) detachment of periosteal fragments into surrounding tissues with proliferation of osteoblasts, 3) migration of subperiosteal osteoprogenitor cells into adjacent soft tissues through periosteal tears due to trauma, and 4) metaplasia of extraosseous cells exposed to growth factors derived from the breakdown of bone fragments displaced within soft tissue during trauma. The fourth theory is the most commonly reported along with a hematoma as an important precursor.[9]

A patient with MO presents with local pain, warmth, ecchymosis, and swelling at the site of ossification for one week without a decrease in symptoms. Inability to bear weight or limited function of the adjacent joint may be evident depending on severity. MO should be suspected in patients who have had major direct trauma to muscle and have not responded to conservative treatment after 5 days or have worsening symptoms after 2 weeks.[1] Associated stiffness and decreased ROM is evident by 1-2 weeks in any joint related to the involved muscle and can significantly impact athletic performance. Within 1-2 months, a solid palpable mass appears with muscle atrophy.[2] MO usually affects young active males between 10-30 years of age, involved in contact sports.[2,4,8] It is most common in the quadriceps, gluteal muscles and biceps brachii, although it has been reported in the psoas, hand, neck, shoulder, hip, calf, deltoid ligament, and pterygoid muscles.[4,5,8-14] The diagnosis of MO is made based on imaging and histological examination.

Classification of MO based on its radiographic appearance is 1) flat bone formation adjacent to the shaft of bone with damage to the periosteum (periosteal), 2) bone formation that remains attached to the shaft of bone with damage to the periosteum (stalk), 3) intramuscular bone formation without disruption of the periosteal sleeve (intramuscular or disseminated).[1]

The goal of examination is to rule out other causes of a palpable mass. Differential diagnoses for MO include osteosarcoma, malignant fibrous histiocytoma, osteochondroma, foreign-body granuloma, giant cell tumor of soft tissue (osteoclastoma), atypical fibroxanthoma, pseudosarcomatous fibromatosis (nodular fasciitis), and deep vein thrombosis.[2,15,16] Criteria to help differentiate these cases from a malignant osteosarcoma are 1) MO is located close to the diaphysis of the bone, whereas osteosarcoma is located near its metaphysis and 2) in MO, pain and swelling increase during the early phase, then subside gradually, whereas in osteosarcoma, both pain and swelling increase slowly, but continuously.[8] In 1958, Ackerman described three zones in the lesion, 1) central zone (fibroblasts); 2) middle zone (osteoblasts that deposit trabeculae of woven bone); 3) outer zone (well-formed mineralized trabeculae).[2] The three zones are identified via imaging and differentiate MO from malignant tumors giving a peripheral calcified appearance and a radiolucent centre.[10] Occasionally, there is difficulty differentiating calcification and ossification, and a biopsy can be performed displaying the same 3 zones described above and to differentiate a benign lesion from a malignant one.[5,17]

Radiographs will show floccular calcified density in the soft tissues 2 to 6 weeks from the disease onset; within 6 to 8 weeks the calcification becomes well circumscribed and ossifications begin to adhere to the periosteum. A peripheral calcified appearance and a radiolucent centre is diagnostic of MO on radiographs.[8] It is also important to note that the cortex and periosteum remain intact.[8]

Ultrasound can pick up MO as early as one week and before an x-ray based on changes in the soft tissue.[18] Similar to its histological appearance, ultrasound shows a homogenous hypoechoic soft tissue mass with a circumscribed border and central reflective core. The mass appears oval on longitudinal images and round on transverse images. The peripheral calcifications as seen on radiographs is also seen on ultrasound along with its ultrasound-specific finding of lamellar calcification. Earlier phases show neovascularization, a center of decreased echogenicity with no clear zonal demarcation and no calcification while later phases show ossification with a more reflective rim and a distal acoustic shadowing. Although in the muscle belly, no damage to muscle fibers is seen. Ultrasound can also be used for guided surgical excision.[19,20]

MRI has been useful in the acute stages of the disease but radiographs are more beneficial in later stages.[2] On T2, MO is seen with a high signal intensity core and a low signal intensity rim representing the zonal pattern of the condition. The specificity of MRI increases when injecting MO with gadolinium but radiographs remain the diagnostic tool of choice due to the inability of MRI to detect soft-tissue calcification.[8,20]

Computed tomography (CT) has been shown to be the imaging modality of choice in diagnosis and surgical treatment in terms of identifying the exact location of the lesion with an axial image and, it is the best imaging modality to show the zonal pattern of MO.[9,20]

Triple-phase bone scans are helpful in the early detection of MO and are typically positive a few weeks before bone mineralization is detected on radiographs. They are also helpful in determining the maturity of the lesion once a diagnosis has been made.[1]

In 2010, Beck et al. wrote a case report in which he utilizes and recommends the use of hybrid imaging with single photon emission tomography (SPECT) and CT helped to confirm the diagnosis of MO in the paraspinal cervical muscles. It provides anatomical imaging with CT and the ability to determine the activity of the lesion via SPECT.[10]

Further confirmatory studies include blood work. Serum alkaline phosphatase and erythrocyte sedimentation rate levels are elevated in patients with MO.[1]

All of the cases presented in this series were athletic men, from 24-45 years of age, presenting with pain or decreased ROM. In our cases we chose to image patients with radiographs and diagnostic ultrasound, which showed calcifications from 2.7-14 cm in size. Based on the history of trauma and the radiographic and ultrasound findings all patients were diagnosed with MO. Cases 1 and 3 similarly report re-aggravation of a pre-existing muscle injury. This suggests trauma to an injured area may predispose an individual to developing MO. No imaging was performed at the time of initial injury so the presence of calcification prior to re-aggravation is unknown. The patient in case 2 presented to the chiropractor 4 weeks after being kicked by a horse. This coincides with the timeline of progression from a muscle contusion to MO. A palpable mass along with muscle atrophy was evident in this patient at presentation, which typically presents around one month post trauma.

For treatment of MO, the literature suggests immobilization, ice, elevation, rehabilitation, ultrasound, cold laser, iontophoresis, non-steroidal anti-inflammatory drugs, therapeutic injections, and surgical excision. Rehabilitation of patients with MO should include restoration of ROM, strength and proprioception.[2] Heat, continuous ultrasound, massage, stretching, and exercise should be avoided initially to prevent further bleeding in the area that may promote the progression to MO.[3] Protective padding should be worn to prevent further injury to the area.[6] NSAIDs have been shown to be beneficial if used for at least 2-6 weeks and the literature suggests that if implemented immediately after injury, it would further decrease the risk of progression to MO.[6] When swelling has subsided and the patient is pain free, light active and passive ROM exercises are recommended while those with lower limb contusions are able to bear weight. Progressions for functional rehabilitative exercises are made within patient tolerance. When patients have regained near full ROM and strength they can progress to sport specific activities. Throughout conservative care, patients must be monitored for a palpable mass or other signs of MO. If the mass is not painful, rehabilitation may be continued while continuous monitoring for pain and/growth is performed.[6]

Elbow mobilizations have shown to be effective at restoring normal ROM and sports specific function in a basketball player with MO of his brachialis muscle. The patient presented with a severe flexion contracture and a palpable mass in his brachialis confirmed as MO on radiographs. Joint mobilizations allowed for the gains in ROM with out overstressing the brachialis muscle.[21]

A recent non-controlled study by Buselli et al. looked at the effect of extracorporeal shockwave therapy (EWST) for the treatment of MO. Twenty-four athletes with radiographic and MRI confirmed MO were given 100 shocks per cm^2 of ossification, every 2 weeks for 3 sessions at an intensity of 0.15 mJ/mm^2. Concurrently, subjects were participating in a physiotherapy program consisting of ROM, progressive muscle strengthening, and proprioceptive exercises. Post intervention, only partial reduction of the ossification was observed on radiographs but all patients showed signs of functional improvement immediately after treatment. At 2 months post intervention, normal ROM and strength was observed. At 3 months post intervention, 87.5% of patients resumed regular sports activities. The theory this method of treatment is that ESWT creates mechanical stimulation to the tissues, inducing bleeding and ultimately, tissue repair.[2] Torrance and deGraauw also found success with a treatment plan consisting of icing, progressive stretching and strengthening, and EWST on a 20 year-old male semi-professional rugby player with MO in his right vastus lateralis. The patient was able to return to full sport participation after three ESWT treatments.[22]

In the presented cases, a 2% acetic acid solution was administered via phonophoresis into the MO (8 minutes of pulsed ultrasound at 1.5 W/cm^2), 3 times per week for 4 weeks. This method was chosen based on a study by Wieder in 1992 on a case of a 16-year-old male with MO in his quadriceps from a diving accident. The patient participated in a 3-week physical therapy program consisting of a 2% acetic acid iontophoresis treatment followed by pulsed ultrasound and mild ROM movements. Results showed 98.9% decrease in the size of the patient's MO based on radiographic measurement. The patient also regained full knee ROM and was able to return to play without pain.[3] As a follow-up to Weider's case, Gard and Ebaugh (2010) performed acetic acid iontophoresis (2% solution) as a primary method of treatment in a case of a 19 year-old college, club hockey player with MO in his brachialis muscle, diagnosed through clinical examination conducted by an orthopedic surgeon. He was referred for physiotherapy where he received 9 treatments over 29 days consisting of acetic acid iontophoresis and active ROM exercises. After his treatment plan the patient went from a significant decrease in elbow extension and inability to play hockey to full ROM and back to full sport participation.[23]

Iontophoresis is the application of, physiologically active ions through the skin using continuous direct current. The theory of iontophoresis was first described by Le Duc in 1908 as an electrical charge that will repel a similarly charged ion. Psaki and Carroll (1955) and Kahn (1977) described the use of acetic acid iontophoresis for treatment of calcium deposits as effective in reducing the size of calcium deposits through the absorption of calcium due to the negative polarity of the acetate ion found in acetic acid. Before completely ossifying, MO usually consists of precipitates of calcium carbonate that are non soluble in normal blood pH levels. It has been proposed that the acetate radical replaces the carbonate radical in the insoluble calcium carbonate deposit, forming a more soluble calcium acetate.[3] Other clinical implications for acetic acid iontophoresis mentioned in the literature are, calcific joint deposits, frozen shoulder, and heel spur formation.[3,24] There currently are no studies on acetic acid phonophoresis but theory is similar to that of iontophoresis except the application of the ions is directed through the skin via sound waves instead of an electrical current.

Although most cases of MO are managed conservatively, 3 cases in the literature went on to have surgery. One of the cases requiring surgery was due to an intra-articular MO in the knee associated with significant ROM loss and its unique attachment to the anterior cruciate ligament and the 2 other cases being MO in the masseter muscle affecting temporomandibular joint function.[17,25] Surgery may be necessary with significant decreases in ROM, muscle atrophy, unrelenting pain, and deterioration of function after 6-12 months of unsuccessful conservative care. It is important to note that there have been reports of exacerbation of symptoms, prolonged disability, and recurrence of MO after surgery. To prevent recurrence, MO cannot be operated on until the lesion has reached complete maturity. A case series by Lipscomb et al presented 4 football players all necessitating surgical removal of a MO. All athletes reported satisfactory recovery and were able to return to play.[26] After surgery, NSAIDs are recommended for up to 6 weeks followed by a similar rehabilitation protocol as mentioned above for those managed conservatively.[6]

In our cases, all of the patients experienced residual calcification, and one with no change in the size of the calcification at all. This residual calcification is found in most other cases presented in the literature, similar to this report, with no further pain or limitations in strength and ROM.[26]

As previously stated, the natural history of MO is 1-2 years.[3,4] Conservative care may shorten this healing time. A shortened healing time is crucial in an elite athlete and therefore, surgical consultation may be considered sooner in these individuals.

All of the cases presented in this report had significant improvements on range and function within 4 weeks of conservative treatment. Based on these results, acetic acid phonophoresis can significantly improve pain and ROM caused by calcification in a muscle with or without reduction in the size of the lesion. Because the lesion did not fully absorb, we cannot be certain that the decrease in size of the MO on radiograph was not due to natural history. No long-term follow-up has been reported so we do not know the long-term effects of phonophoresis but we know that it may create benefits in the short-term and should therefore be considered as a treatment option for MO by manual therapists.

Research on conservative care is necessary for chiropractors and other manual therapists to appropriately manage patients with MO. Proving to be effective in this case and the paucity of literature on conservative treatment, this area needs to be investigated. Proper diagnosis and management could prevent the need for surgical cases and risks that come along with it.

Conclusion

This case series presents conservative management of MO with acetic acid phonophoresis. With a treatment protocol of 3x/week for 4 weeks (8 minutes of pulsed ultrasound at 1.5 W/cm^2), all patients had significant decreases in pain and gains in ROM to be able to return to play. This correlated with decreases in the size of calcification on diagnostic ultrasound in some of the cases. The presented cases along with a case by Weider show resolution of symptoms of MO with an under-investigated approach. Acetic acid phonophoresis deserves more attention in the literature. For conclusive information about conservative care, studies must investigate long-term effects of conservative care in a randomized trial with a clinically significant number of participants.

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A pilot study of postural stability testing using controls: the modified BESS protocol integrated with an H-pattern visual screen and fixed gaze coupled with cervical range of motion

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Objective: *The purpose of this study was to investigate baseline postural stability of a normal healthy population using the modified balance error scoring system (M-BESS) integrated with H-pattern testing (HP) and cervical range of motion with fixed ocular gaze (CROM).*

Methods: *Postural error scores for twelve participants were scored during each twenty second trial of the M-BESS protocol stances (double-leg [DL], tandem [TL] and single-leg [SL]). Participants also completed the same M-BESS protocol with the inclusion of HP and CROM conditions for a total of nine trials.*

Results: *The total mean ± standard deviation and median of errors within each condition were not different*

Objectif : *Cette étude vise à étudier la stabilité posturale au niveau des pieds de sujets en santé en utilisant le système modifié de pointage des erreurs d'équilibre (M-BESS) intégré à l'examen des mouvements extra oculaires (modèle H) et l'amplitude de mouvement cervical (CROM) avec un regard oculaire fixe.*

Méthodologie : *Le pointage des erreurs de posture de douze participants a été marqué pendant chaque période d'examen de vingt secondes des positions du protocole M-BESS (deux-jambes [DL], en tandem [TL] et une seule jambe [SL]). Les participants ont également participé au même protocole M-BESS simultanément à l'examen des mouvements extra-oculaires (modèle H) et de la CROM pour un total de neuf essais.*

Résultats : *La moyenne totale ± l'écart type et la médiane des erreurs dans chaque état ne sont pas*

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Declaration: The authors have no conflict of interest, financial or otherwise.

(M-BESS 2.6 ± 2.1, 2.0; HP 1.3 ± 1.1, 2.0; CROM 2.0 ± 2.0, 2.0; p>0.05).

Conclusion: *Although a small sample size, our findings suggest that with normal, healthy, subjects challenging their visual input and cervical range of motion while balancing gives you a similar number of errors as the standard M-BESS protocol.*

(JCCA 2014; 58(4):361-368)

KEY WORDS: concussion testing, postural stability, H-pattern, BESS, mild traumatic brain injury.

différents (M-BESS 2,6 ± 2.1, 2.0, HP 1,3 ± 1,1, 2,0, CROM 2,0 ± 2,0, 2,0; p > 0,05).

Conclusion : *Bien que l'effectif de l'échantillon soit petit, nos résultats indiquent que l'examen des mouvements extra-oculaires (modèle H) et de l'amplitude de mouvement cervical (CROM) des sujets en bonne santé lorsqu'ils essaient de garder leur équilibre donne un nombre comparable d'erreurs à celui du protocole M-BESS standard.*

(JCCA 2014; 58(4):361-368)

MOTS CLÉS : tests de commotion cérébrale, stabilité posturale, mouvements extra-oculaires, BESS, lésion cérébrale traumatique légère, chiropratique

Introduction

The assessment of neuropsychological and postural stability for the management of concussion is gradually becoming more commonplace among sports medicine clinicians. Testing postural control provides an indirect means of identifying concussion related neuropsychological abnormality and serves as one of several recommended tools for determining readiness to resume activity.[1]

Recent research suggests that the use of a comprehensive approach, including postural instability assessment, may assist the health care provider in identifying signs of a concussion not easily detected during a routine clinical examination.[2] Within this comprehensive approach, baseline testing is an important component to preseason physical examinations. Baseline tests are used to establish an individual athlete's normal, pre-injury performance and to provide the most accurate and reliable benchmark against which post-injury assessments can be compared. This becomes especially important in the diagnosis and management of concussion, and subsequent return to play recommendations.

Maintaining balance requires the aid of visual, somatosensory (proprioceptive), and vestibular systems. Research shows that athletes often demonstrate decreased stability post-concussion.[1] The postural stability deficit can best be explained by a sensory interaction problem that prevents concussed athletes from accurately using and exchanging sensory information from the visual, vestibular, and somatosensory systems.[1] Large negative effects in postural sway are often identified at both immediate and follow-up assessment points, demonstrating the need for assessment of postural control as part of a concussion protocol. Difficulty in postural sway control may persist even after signs and symptoms of concussion recede.[3] Among these difficulties encountered are oculomotor and vision problems, many of which can impede daily activities. Blurred vision, light sensitivity and diplopia have been reported subsequent to concussive injuries, regardless of severity.[4] Problems with binocular vision, extraocular muscle function, and the accommodative system have also been found at relatively high frequencies.[5]

The M-BESS protocol has been established as an objective measure of balance. It has also been shown to have an increased number of errors in concussed patients compared to normal, healthy subjects.[2] Therefore, in this pilot study we investigated baseline postural stability of a normal healthy population using a modified balance error scoring system (M-BESS) protocol integrated with H-pattern testing and cerivcal range of motion with fixed occular gaze. We hypothesized that the inclusion of an H-pattern visual test or cervical range of motion with fixed gaze will not change the amount of errors scored during the M-BESS procedure in a normal healthy population. The findings of this pilot study may provide baseline data for further investigation that tests the efficacy of the new tests on a symptomatic population.

Methods

Ethical considerations

The current experimental protocol was approved by the Canadian Memorial Chiropractic College Research Ethics Board. Written informed consent was obtained from all volunteers before their participation in the study.

Participants

Our study population included 6 male and 6 female students from a post-secondary institution. Anyone who could walk freely without a limp or aid was included. Exclusion criteria included visual field deficits, blurred vision, light sensitivity, diplopia, current neck pain, history of ankle, knee or hip injury in the past 6 weeks, vertigo or dizziness, postural hypotension, and neuromusculoskeletal disorders that interfere with normal balance. Subjects with a concussion in the past 6 months or who had been diagnosed with post-concussion syndrome were also excluded from this study. A brief questionnaire, Neck Disability Index (NDI), Lower Extremity Functional Scale questionnaire and Oswestery low back disability index were all completed to assist in assessing exclusion criteria. Participants with an NDI >10% or Oswestery >10% were excluded.

Description of experimental maneuver

Our procedures were designed to parallel those used in the M-BESS protocol developed by researchers and clinicians at the University of North Carolina's Sports Medicine Research Laboratory.[6] The M-BESS is an integral component of the recently released Sport Concussion Assessment Tool – 3rd Edition (SCAT3).[2,6] The M-BESS is designed to be a portable, cost-effective, and objective method of assessing static postural stability utilized by clinicians in making return to play decisions following mild head injury.[6] We used the M-BESS as a framework for our study with alterations that focus on the effects of visual input and cervical range of motion on static postural stability. All test procedures were performed with the participants wearing shorts and shoes removed. This was done to standardize participant setup and to allow proper observation of any movements that could have caused failure during the testing protocol.

Three testing conditions were assessed in this study, which included: the standardized M-BESS protocol alone and combined with H-pattern (HP) and fixed gaze with cervical range of motion (CROM) in the three standard positions: double leg stance (DL), single leg stance (SL) and tandem stance (TL). Thus there were nine, twenty second trials quantified using a stopwatch and observers trained in the BESS protocol for scoring errors. We were only interested in the amount of errors that occurred in each 20 second trial in the various positions. The participants were randomly assigned an order in which they performed the nine trials. The nine trials were broken up by two minute periods of rest in order to prevent the effects of fatigue. The participants were also allowed to practice the various protocols for two minutes before testing began.

The three testing conditions were as follows:

1. Double leg stance:
   The participants placed feet together (touching) on a firm flat surface, hands on their hips and were asked to close their eyes. Participants were instructed to maintain hand contact on their hips while trying to maintain stability for 20 seconds.
2. Single leg stance:
   Foot dominance was determined by asking the participants "if you were to kick a ball, which foot would you use?" The foot that the patient indicated they would kick a ball with was identified as the dominant foot. The participants were then asked to stand on their non-dominant foot. The dominant leg was held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. A spotter assisted the participants into the appropriate position. Again, participants were instructed to maintain stability for 20 seconds with their hands on their hips. The participants were instructed that if they moved out of this position or stumbled, to open their eyes, return to the start position and continue balancing. We informed the participants that we counted the number of times they moved out of the set position.
3. Tandem Stance:
   For the final stance, participants were instructed to stand heel-to-toe with their

non-dominant foot in the back and their weight evenly distributed across both feet. As in the other two stances, participants were instructed to attempt to maintain stability for 20 seconds with their hands on their hips and that if they stumbled they were to open their eyes, get back into the set position and continue balancing.

H-pattern Test

For the H-pattern test, the spotter stood in front of the participants and instructed them how to get into one of the stances stated above. While holding this position, participants were asked to follow the instructor's finger with their eyes while keeping their head in a neutral position facing anteriorly. The instructors used their finger to trace an "H" pattern approximately 30 centimeters in front of them, making sure their finger moved far enough in a horizontal and vertical plane to ensure all visual fields were covered (ie. right-side up and down, left-side up and down). A metronome was used to standardize one H-pattern every 10 seconds for a total of two H-patterns per trial.

Fixed Gaze

For the fixed gaze tests, the spotter stood in front of the participants and instructed them how to get into one of the stances stated above. While holding this position, participants were asked to maintain eye contact with the instructor's finger placed approximately 30 centimeteres in front of them, while moving their head through full left rotation, right rotation, extension and flexion, respectively. After each movement, the patient returned to the neutral position. To ensure that each movement was completed twice in the 20-second trial, the patient paused in the neutral position for one second at both the beginning and end of each movement sequence.

Error Scoring

An error was credited to the participant when any of the following occurred;

- The hands moved off of the iliac crests
- Step, stumble or fall
- Abduction or flexion of the hip beyond 30 degrees
- Lifting of the forefoot or heel off the testing surface
- Loss of eye contact

The maximum total number of errors for any single condition was ten. If a participant commited multiple errors simultaneously, only one error was recorded. For example, if an individual stepped or stumbled, opens their eyes, and removed their hands from their hips simultaneously, they were credited with only one error. Subjects that were unable to maintain the testing procedure for a minimum of five seconds were assigned the highest possible score (ten) for that testing condition. Errors were not revealed after each trial to avoid any bias (ie. encouragement to beat their previous score). To avoid any injury, the testing was stopped if pain or dizziness with the participant was observed. For safety reasons, a spotter was present during all testing conditions.

Statistical analysis

According to Julious 2005[7], a sample size of 12 subjects in a pilot study is justified when reasons of feasibility, gains in the precision about the mean and variance, and regulatory considerations are taken into account. A one-way repeated-measures ANOVA was used to compare the independent effects of each condition (M-BESS, HP, and CROM) and stance (DL, TL, and SL) on postural errors. A one-way repeated measures ANOVA was also used after adding the total number of errors for each stance within each condition. For all analyses, when a significant main effect of condition was observed, post hoc comparisons were carried out with a paired-sample t-test corrected for multiple comparisons using the Tukey procedure. The level of significance was set to an α level of $P \leq 0.05$. All analyses were performed using the statistical software program Prism 6 for Mac OS X (GraphPad, La Jolla, CA.).

Results

The mean ± standard deviation physical characteristics of the participants were as follows: age: 25.6 ± 2 yr, height: 177.2 ± 8 cm, weight: 76.4 ± 12 kg.

The mean, median and standard deviation of errors during each protocol for each specific stance are presented in Table 1. There was a significant main effect of condition and stance on the number of errors scored during the testing procedures (p=0.01). The SL-M-BESS condition resulted in significantly more errors than the M-BESS-DL (p=0.03), and HP-DL (p=0.03) and HP-TL (p=0.03) con-

Table 1.
Mean, standard deviation and median error scores during the M-BESS protocol and M-BESS protocol combined with H-pattern (HP) and cervical range of motion with fixed gaze (CROM) for each stance.

Condition	Mean	Standard Deviation	Median
M-BESS-DL	0.0*	± 0.0	0
M-BESS-TL	0.4	± 0.7	0
M-BESS-SL	2.2	± 1.8	1.5
HP-DL	0.0*	± 0.0	0
HP-TL	0.3*	± 0.9	0
HP-SL	0.9	± 0.9	1
CROM-DL	0.3	± 0.7	0
CROM-TL	0.8	± 0.9	0.5
CROM-SL	0.9	± 1.1	0.5

DL – double leg; TL – tandem leg; SL – single leg. P<0.05, significantly different than M-BESS-SL (*).

ditions. No other conditions were significantly different (p>0.05).

The mean, median and standard deviation of the total number of errors (adding the total number of errors from each stance) for each protocol are presented in Table 2. No significant main effect of condition on the total number of errors between each condition was observed (p>0.05). This suggests that regardless of the stance, altering visual input and cervical motion does not change the total number of errors scored during the M-BESS procedure in a normal healthy population.

Discussion

Summary

To our knowledge, the present study is the first to examine the effects of the M-BESS protocol integrated with H-pattern testing and fixed gaze with cervical spine range of motion on the number of errors scored in a normal, healthy population. In the current study, calculated error scores using the M-BESS assessment protocol were not affected by varying visual input or cervical position. These results support our hypothesis that individuals who have not suffered a concussion or a mTBI, or are not currently suffering from neck, low back, or lower extremity injury, will score similarly when performing the M-BESS protocol with the addition of H-pattern testing or fixed gaze with cervical spine range of motion. However, we do not know how the results of the current study may differ with participants in the acute phase of a concussion. Given the effects mTBI or concussions can have on postural stability, ocular, vestibular, and somatosensory deficits[1,3,4,5,8,9], it is possible that including visual input and cervical spine range of motion in the M-BESS protocol

Table 2.
Mean, standard deviation and median of the total error scores for the M-BESS protocol, and M-BESS protocol combined with H-pattern (HP) and cervical range of motion with fixed gaze (CROM). Total error scores represent the summed totals of the three stances (single-leg, double-leg, and tandem-leg) for each condition.

Condition	Mean	Standard Deviation	Median
M-BESS	2.6	± 2.1	2.0
HP	1.3	± 1.1	2.0
CROM	2.0	± 2.0	2.0

may provide a more sensitive or specific testing tool for the diagnosis and management of concussions. Therefore, further investigation of the current study protocol on concussed subjects is warranted.

H-pattern

Dependent upon the severity and location of the injury, mTBI or concussion results in a spectrum of dysfunctions involving sensory, motor, perceptual, physical, behavioral, cognitive, linguistic and emotional aspects. Vision is a primary component of sensation and its deficits following mTBI will likely have an adverse effect on the patient's balance as well as many activities of daily living.[10] Visual dysfunctions following TBI or mTBI can be subsequently linked to the functioning and organization of the visual processing system.[11] Results of a study examining magnetoencephalographic (MEG) signals on visual-feature matching tasks in TBI patients versus healthy controls revealed an increase in gamma synchronization in the visual cortex of TBI patients, which authors propose "reflect the extra effort that the patients used to compensate for inefficient sensory processing due to disruption of cortical network by their injury".[11]

Approximately 90% of individuals with mTBI having vision-related symptoms examined in an optometric clinic setting were diagnosed with one or more oculomotor dysfunctions following their acute care phase and natural recovery period. Of the same sample population, 70% manifested non-strabismus types of oculomotor deficiencies involving version, vergence, and accommodation.[10] Vergence can be defined as disjunctive movement of the eyes in tracking objects varying in depth over the range of ones binocular visual field. The vergence system acts in synchrony and precision with the versional system to track objects laterally in one's visual space accurately and independently. The accommodative system is continuously activated to maintain target clarity. Five retrospective studies assessing the prevalence of oculomotor abnormalities in patients with mTBI, vergence dysfunctions range from 24-48%.[10] Identifying these abnormalities and rehabilitating them is essential in improving reading ability and overall quality of life.

The high prevalence of visual dysfunction following TBI or mTBI validates the necessity for the administration of a visual screen as part of both baseline and sideline concussion testing. The H-pattern test is an effective tool in assessing oculomotor functioning and the integrity of extraocular muscles, cranial nerves and the vergence system. The simplicity and convenience of the H-pattern test in combination with the M-BESS protocol allows for easy administration in both clinical and field settings, and could be an additional tool used to identify patients with an mTBI or concussion. The mean total numbers of errors during the M-BESS and H-pattern protocols in our study were 2.6 (with a median number of 2.0 and a standard deviation of ± 2.1) and 1.3 respectively (Table 2). Our M-BESS errors were similar to the normative reference values for the M-BESS for the corresponding age range of 20-29 years of age that showed a mean number of errors of 2.7 (with a median number of 2.0 and a standard deviation of ± 2.5).[12] These comparative results further validate our hypothesis that individuals who have not suffered a recent concussion or mTBI, or are not currently suffering from neck, low back, or extremity injury, will have no difficulty performing the M-BESS protocol with the addition of H pattern visual field testing.

Cervical Range of Motion

The vestibular system, in conjunction with visual and somatosensory input, acts to keep the eyes fixed on a stationary target in the presence of head and body movements. To accomplish this fixed gaze during cervical range of motion, the semicircular canals of the vestibular labyrinth sense angular acceleration of the head, converts this to velocity information and transmits it along the vestibulo-ocular reflex pathways to the ocular muscles. Concurrently, input of linear acceleration from the utricles and saccules of the inner ear is delivered via the vestibulospinal tract to the lower extremity and spinal muscles, which is necessary for maintaining balance.[1]

Accurate utilization and exchange of sensory information from the visual, vestibular and somatosensory systems occur during normal conditions. However, in subjects with possible vestibular or cervical spine dysfunction, such as after a mTBI, these processes can be disrupted or provide conflicting information.[1] Following a mTBI, two potential mechanisms for vestibular dysfunction exist: (i) the peripheral receptors themselves may be damaged and provide inaccurate senses of motion, or (ii) the brain centers responsible for ventral integration of vestibular, visual and somatosensory information may be impaired. Another mechanism of injury regarding neural deficits causing postural instability following an mTBI is also debated. It has been proposed that minor axonal dysfunction at the level of the brainstem or cerebellum may be a potential cause.[13] Taking this into consideration, assessing potential cranial nerve dysfunction as an underlying cause of instability using cervical range of motion with a fixed gaze may be warranted in individuals with an acute mTBI or concussion.

In the current study, we incorporated cervical range of motion with a fixed gaze into the M-BESS protocol in a healthy population. The number of errors scored was similar to the M-BESS protocol[12] and therefore more research is needed to determine how patients with a recent concussion score compared to healthy controls.

Limitations

Repeat administration of the postural stability tests warrants concern for possible short-term practice or learning effects that can influence test score results. For example, Valovich et al reported that high school athletes scored significantly fewer errors on repeated administration of BESS testing 7 days after baseline.[14] To compensate for any short-term improvements unrelated to the difficulty of each individual test, we randomized the ordering of the trials and allowed a 2-minute period where the participant could practice the different stances and protocols.

In addition to a learning effect, we must also consider the possibility of fatigue when performing numerous postural stability tests in succession. Wilkins et al found that performance in a controlled clinical laboratory environment resulted in decreased total BESS scores after a 20-minute fatigue protocol.[15] Susco et al also found that BESS scores were adversely affected by fatigue immediately after exertion.[16] To account for fatigue, we ensured that our subjects did not participate in any exercise prior to the administration of the testing protocols. We also allowed a 2 min break between each stability test.

Finally, another limitation to this study is the fact that the participants were a small, convenient sample of healthy, athletic students. This may limit our findings to a young and athletic population, as baseline errors may be higher in an older population who is not athletic.

Perspective and Significance

Since concussions are so prevalent, the development of valid and reliable testing protocols would have large clinical benefits. Various concussion testing protocols have been developed to help assist in the diagnose of a concussion, and baseline testing is vital for reasonable pre and post concussion comparability. Once a concussion has been diagnosed, these concussion testing protocols have great value in determining severity, patient progress, and resolution. Impact from an initial mTBI does not result in permanent structural damage, but rather causes temporary functional impairment. However, a person who has sustained a concussion is more succeptible to a subsequent concussion, and risk of permanent damage. Thus, valid and reliable objective measures of concussion are necessary to ensure the patient has recovered completely before normal activities of daily living and sport are resumed.

Patients who have sustained a concussion display a variety of symptoms ranging from cognitive, emotional, somatic, balance and sleep disturbancees. While symptoms vary from patient to patient, one of the most common is balance disturbance.[17,18] Therefore testing balance in a patient who is suspected of having a concussion may be critical to its diagnosis. Often balance disturbances persist longer than emotional or cognitive impairements so this may also be a better indicator of the recovery process. Studies done to date pertaining to concussions and the effect that concussions have on balance have primarily assessed balance via the BESS or M-BESS protcol.[19] While the BESS protocol is designed to measure static postural stability, we know that there are multiple systems that influence static posture, including the visual system and proprioceptive feedback from the cervical spine. The existing literature is very limited in the assessment of these aspects of postural stability and their relation to concussion diagnosis and management. Consequently, our study is the first to incorporate these influences on static posture into the M-BESS sideline protocol in a normal healthy population.

The intention is that now this information can be used as a base-line comparison to test the effect that concussions have on these aspects of postural stability. It is our goal to take this protocol and evalute its effect on participants in the acute phase of a concussion. We would also like to include our protocol in the baseline concussion testing of a few competitive sports teams (i.e. men/ womens rugby). This will help us generate more baseline data to confirm the findings of the current study and provide us with a means to recruit participants in the acute phase of a concussion who already have baseline data that we can use for a strong statistical analysis.

In conclusion, based on the design of our study and the results obtained during testing, the M-BESS protocol with fixed gaze and cervical spine range of motion, and H-pattern testing can easily be incoporated into side-line concussion testing. Future studies are needed to determine if the addition of visual input or cervical motion to the M-BESS protocol results in more errors in patients who have suffered a mTBI or concussion. Similar to the M-BESS protocol, these tests are easy to administer, require minimal equipment and technical skill, and may be a tool for health care professionals to more effectively diagnose and manage patients with concussions.

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A four year prospective study of injuries in elite Ontario youth provincial and national soccer players during training and matchplay

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Introduction: *With over 200 million amateur players worldwide, soccer is one of the most popular and internationally recognized sports today. By understanding how and why soccer injuries occur we hope to reduce prevalent injuries amongst elite soccer athletes.*

Methods*: Via a prospective cohort, we examined both male and female soccer players eligible to train with the Ontario Soccer Association provincial program between the ages of 13 to 17 during the period of October 10, 2008 and April 20, 2012. Data collection occurred during all player exposures to potential injury. Exposures occurred at the Soccer Centre, Ontario Training grounds and various other venues on multiple playing surfaces.*

Results: *A total number of 733 injuries were recorded. Muscle strain, pull or tightness was responsible for 45.6% of all injuries and ranked as the most prevalent injury.*

Discussion: *As anticipated, the highest injury reported*

Introduction : *Avec plus de 200 millions de joueurs amateurs dans le monde, le soccer est aujourd'hui l'un des sports les plus populaires et internationalement reconnus. En comprenant comment et pourquoi se produisent les blessures dans le soccer, nous espérons réduire les blessures répandues parmi ses athlètes d'élite.*

Méthodologie : *Du 10 octobre 2008 au 20 avril 2012, nous avons étudié une cohorte prospective de joueurs et de joueuses de soccer de 13 à 17 ans qui s'entraînaient dans le cadre du programme provincial de l'Ontario Soccer Association. Nous avons recueilli des données à toutes les occasions de risques de blessures pour les joueurs, à savoir au Centre de soccer, sur les terrains d'entraînement de l'Ontario et divers autres lieux sur différentes surfaces de jeu.*

Résultats : *On a enregistré un total de 733 blessures. Le claquage ou la raideur musculaire comptait pour 45,6 % de toutes les blessures et se classait parmi la blessure la plus répandue.*

Discussion : *Comme prévu, la blessure la plus*

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was muscular strain, which warrants more suitable preventive programs aimed at strengthening and properly warming up the players' muscles.

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KEY WORDS: soccer, injury, athlete, muscle strain

fréquemment signalée était le claquage musculaire. Pour l'éviter, il faut mettre sur pied des programmes de prévention plus appropriés visant au renforcement et à l'échauffement adéquat des muscles des joueurs.

(JCCA 2014; 58(4):369-376)

MOTS CLÉS : soccer, blessure, athlète, claquage musculaire, chiropratique

Introduction

Participation in sports is considered to be a vital component in achieving an active and healthy lifestyle. With over 200 million amateur soccer players and approximately 200,000 professional athletes worldwide, soccer is one of the most popular and internationally recognized sports played today.[1] The 2010 Fédération Internationale de Football Association (FIFA) World Cup was one of the most watched television events in history. TV broadcasters transmitted the event to a cumulative 26 billion people, with over 400 million views per match.[2] As of 2006 there were approximately 270 million active player memberships to FIFA.[3] With such a vast number of participants worldwide the concern of safety becomes an important and timely issue. Sports injuries are inevitable, but as with any sport the more vigorous, extensive and frequent the training the greater the potential for injury. As reported by Schmikli et al. the incidence rate of outdoor soccer injuries, particularly for adult male soccer players, is among the highest of all sports including rugby, boxing, fencing, and cricket.[4] Although there is some variation as to the exact number of injuries per 1,000 playing hours, according to Goncalves et al. the incidence of soccer related injuries is estimated to be 10 to 15 injuries per 1,000 hours of practice. Furthermore, Haruhito et al. found that in competition there is an incidence of injury of 16.6 to 34.8 injuries per 1,000 playing hours. Injury avoidance is crucial for elite soccer athletes of all competitive levels. It allows them to train and develop their skill sets at their maximal effort without unnecessary layoffs. Time loss due to injury is critical for both a promising soccer athlete and their team due to injury limiting the possibility of the team reaching its highest performance potential. There is an estimated time loss due to injury of two weeks for a team made up of 25 players.[5]

Moreover, with injury comes an associated economic cost. The immediate health care costs as well as the long term-consequences of being injured are substantial. FIFA estimates that the average treatment cost is 150 U.S. dollars per injury, which leads to an estimated 30 billion dollars a year for treatment of injuries in soccer around the world.[6] Also, English Premier League clubs were estimated to be 19 to 26 million U.S. dollars out-of-pocket in lost wages due to the extra injuries suffered by their players in the 2010/11 season after taking part in this summer's World Cup.[7]

Consequently, it is evident that injury prevention plays a necessary role in reducing the costs incurred from soccer related injuries as well as minimizing a player's time loss due to injury. Prevention is the first step in maintaining optimal health, and as such to prevent injury we must understand what types of injuries are commonplace for soccer athletes and how they occurred. The consensus is that the majority of soccer injuries are related to the lower extremities, which is not surprising since soccer is a high-intensity sport characterized by continuous changes of direction and high-load actions.[8] Nonetheless, it has been noted in various soccer nations, such as the United Kingdom, the United States and Brazil, the epidemiology of injuries within the sport has shown a variation in injury patterns. For instance, the Carling et al study suggests strains to the hamstring region are the most common type of injury at the professional levels in soccer.[9] It has been shown though that eccentric strength training can reduce the risk of hamstring injury in heterogeneous populations of soccer players.[10] In addition, plyometric training and agility drills, the main components of a preventive program developed by Heidt et al, was effective in lowering the incidence of injuries in soccer.[11] The Dick et al. study concludes ankle ligament sprains, knee internal derangements and concussions are common injuries in women's soccer, where as Ekstrand et al. determined that almost one third of all injuries in professional soccer are muscle injuries with the vast majority affecting the hamstring, adductors, quadriceps and calf muscles.[5,12] According to Aaltonen et al. a decreased risk of sports injuries was associated with the use of insoles, external joint supports, and multi-intervention training programs.[13] A paper by Emery and Meeuwisse found that an implemented training program was effective in reducing the risk of all injuries as well as acute-onset of injuries.[14] The protective effect of the neuromuscular training program in reducing lower extremity injury is extremely clinically relevant. Finally, Junge and Dvorak showed that there is some evidence that multi-modal intervention programs result in a general reduction in injuries. They found that external ankle supports and proprioceptive/coordination training, especially in athletes with previous ankle sprains, could prevent ankle sprains. In addition, training of neuromuscular and proprioceptive performance as well as improvement of jumping and landing technique seems to decrease the incidence of anterior cruciate ligament injuries in female athletes.[15]

The inconsistency of the studies mentioned demonstrates that there are many factors (i.e. location, weather, surface playing field, age, sex and performance level) that ultimately determine the variation on why and how soccer players are injured and in turn, the preventative strategies that can be utilized to help reduce both the occurrence and reoccurrence of such injuries. Therefore, it will be difficult to correlate injury incidence and thus injury prevention for elite soccer athletes outside the geographic domain in which the study was conducted. To date such a study has not been conducted within the scope of elite soccer athletes in Canada.

By taking into consideration the model for epidemiological studies on professional soccer player injuries in Brazil, the purpose of this preliminary study is to provide an injury incidence report for elite soccer athletes in both Ontario as well as nationally in Canada.[1] As such, due to differences in climate, technical level and total hours we believe that occurrence of injury per 1,000 hours will be less in Canada compared to other soccer nations. The second objective is to provide an incidence report for the most common injuries during training and matchplay among elite youth soccer players in Ontario. By understanding how and why soccer injuries occur we ultimately hope to reduce the most prevalent injuries amongst elite Canadian soccer athletes.

Research design and methods

In concordance with Goncalves et al. (2011) the research design selected for this study is a prospective cohort. Historically, epidemiologic studies examining soccer injury incidence have been prospective in nature. Previous methodology utilizing retrospective study design had many biases, which reduced the validity of risk assessments. Prospective study design has been shown to be the most useful method for estimating the risk of injury or disease, the incidence rate and or relative risk.

Through a prospective concurrent longitudinal study we can determine and define the population at the beginning of the study and follow the subjects through time. Non-cases are enrolled from a well-defined population, current exposure status is determined as non-injured and the onset of injury is observed in subjects over time. Injury status can be compared to non-injured status relative to exposure time. The study begins at the same time as the first determination of exposure status of the cohort. The characteristics of the group of people studied have been pre-determined as healthy eligible Ontario Soccer Association (OSA) provincial and National Training Centre Ontario (NTCO) players. Non-cases or non-injured eligible players are followed forward in time. Exposure status has been predetermined as all strength and conditioning sessions, training sessions and games overseen by an athletic therapist. Cases or injury status and recording of the aforementioned have also been pre-determined.

The population of this study included all soccer players, male and female, eligible to train with the Ontario Soccer Association provincial program between the ages of 13 to 17 years during the period of October 10, 2008 and April 20, 2012. It also included all players eligible to play for the National Training Centre Ontario Under-17 women's program between the aforementioned period. The players were selected based on selection criteria determined by the Ontario Soccer Association Coaches and are considered among the elite population of soccer players in the province and country. In total, the study followed seven teams with 28 players per team through four calendar seasons. The total exposure hours were calculated combining training, match and strength conditioning hours for one calendar year or the provincial program from mid-October until the end of April. The exposure hours were then extrapolated over four years due to the consistency in scheduling within the provincial program related to limitations in field time. A total of 32,270 hours of exposure were recorded over one calendar year and estimated as 129,080 hours over four years.

Collection of data

The source of data collection is The Sports Injury & Rehabilitation Centre, Inc. (SIRC) located at 7601 Martingrove Rd. Woodbridge, Ontario. The clinic director of operations is Dr. Robert Gringmuth. The staff and associates overseen by Dr. Gringmuth at SIRC are contracted to provide medical coverage for the Ontario Soccer Association Provincial program and Women's National Training Centre Ontario Program. All player injuries are tracked on site along with patient intakes they are recorded in the clinics patient database called Injury Tracker®.

Data collection occurred during all player exposures to potential injury including strength and conditioning sessions, training sessions and matches. Exposures occurred at the Soccer Centre, Ontario Training grounds and various other venues on multiple playing surfaces. An athletic therapist employed by SIRC oversaw all exposures. Injury reports (Appendix I & II) are filled out by athletic therapists at occurrence of injury and before a player is referred to the clinic if necessary. An injury report is required to be completed if any of the following criteria are met:

- Player is removed from field of play by athletic therapist or player is unable to return to play.
- Player requires treatment to return to play.
- Player suffers a concussion.
- Player does not participate in practice due to injury/condition.
- Player intake at the clinic directly due to inability to play.

Injury Reports are submitted at the end of the session by the athletic therapists to the clinic supervisor who ensures that a clinic employee enters them into the clinic database.

Ethics and Human Subjects Issues

Players' names or personal medical information cannot be tracked or identified in any manner. The Canadian Memorial Chiropractic College Research and Ethics Board approved this study.

Results

A total number of 733 injuries were recorded through 129,080 exposure hours experienced by the seven teams over the span of four seasons. The cumulative injury incidence rate among all players through four seasons was 5.68 injuries per 1,000 hours of training, strength and conditioning, or matchplay. The highest injury incidence rate per 1,000 hours occurred during the 2008 to 2009 season valued at 6.97 injuries per 1,000 hours. The injury incidence variation seasonally across four years is presented in Figure 1.

Myofascial pain resulting from muscle strain, pull, or tightness was responsible for 45.6% of all injuries. It was ranked as the most prevalent of all diagnosed injuries with an incidence rate of 1.42 occurrences per 1,000 hours. Ligamentous sprain comprised 20.7% of all injuries ranking it the second most common injury presented. Its incidence rate was 0.64 injuries per 1,000 hours. Sprain and strain injuries comprised 66.3% percent of total injuries incurred. Concussion injuries consisted of 4.2% of total injuries and had an incidence rate 0.13 per 1,000 hours.

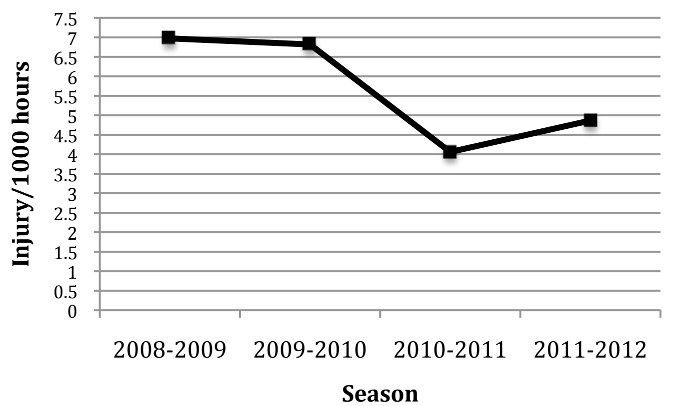

Figure 1.
Injury incidence of youth provincial and national soccer players in Ontario per 1,000 hours of exposure over four seasons.

Table 1
Incidence of most diagnosed injuries between 2008 to 2012

	n	%	Incidence
Sprains	83	20.7	0.64
Muscle strain/pull/tightness	183	45.6	1.42
Fractures	15	3.7	0.12
Concussions	17	4.2	0.13
Blisters	29	7.2	0.22
Bleeding/lacerations/abrasions	35	8.7	0.27
Separation of joint	2	0.5	0.02
Bunion of the big toe	4	1.0	0.03
Common cold	7	1.8	0.05
Asthma causing symptoms with participation	9	2.2	0.07
Plantar fasciitis	5	1.3	0.04
Poked in eye	2	0.5	0.02
Turf toe	2	0.5	0.02
Avulsion fracture	2	0.5	0.02
Achilles tendonitis	3	0.8	0.02
Hyperextension of unspecified joint	1	0.3	0.01
Joint instability	2	0.5	0.02
Total	**401**	**100.0**	**3.11**

Other common injuries reported include bleeding, lacerations, abrasions, blisters, and fractures. The most prevalent diagnosed injuries and their incidence rates per 1,000 hours are presented in Table 1.

The most commonly injured body part across all four years was the ankle/foot complex. It comprised 35.6% of all injuries over four years and had an incidence rate of 2.02 per 1,000 hours. The knee was the second most common across all seasons except in 2008 to 2009, where it interchanged positions with the lower leg complex. The knee comprised 16.4% of total injuries and had a reported incidence rate of 0.93 injuries per 1,000 hours. Injuries of the lower leg complex consisting of the achilles, shin and calve injuries were the third most common injuries. It comprised 12% of total injuries with an injury incidence rate of 0.68. Muscle injuries to the quadriceps, hamstring and groin comprised a combined 16.2% of injuries and had an incidence rate of 0.92 injuries per 1,000 hours. Lower extremity injuries encompass 82% of total injuries and had an incidence rate of 4.7

Discussion

With the ongoing growth of soccer in Canada, risk of injury and avoidance of it can be a deciding factor on how young elite Canadian athletes compare with their peers from competing soccer nations. In order to help determine

Table 2
Prevalence of injury location and injury incident rate per 1,000 hours

	2008 to 2009			2009 to 2010			2010 to 2011			2011 to 2012		
Body part	**n**	**%**	**Incidence**	**n**	**%**	**Incidence**	**n**	**%**	**Incidence**	**n**	**%**	**Incidence**
Ankle/foot	90	40.00	2.79	84	38.7	2.60	34	25.56	1.05	53	33.54	1.64
Knee	23	10.22	0.71	48	22.2	1.49	25	18.79	0.77	24	15.19	0.74
Quadriceps	18	8.00	0.56	9	4.1	0.28	12	9.02	0.37	2	1.27	0.06
Hamstrings	11	4.88	0.34	6	2.6	0.19	8	6.01	0.25	11	6.33	0.31
Groin/adductors	11	4.88	0.34	10	4.5	0.31	14	11.00	0.43	7	3.80	0.19
Head/face	11	4.88	0.34	16	7.3	0.50	9	7.00	0.28	14	8.86	0.43
Neck/back	9	4.00	0.28	7	3.2	0.22	5	4.00	0.15	7	3.80	0.19
Shoulder/arm/hand/fingers	16	7.11	0.50	9	4.1	0.28	2	1.50	0.06	5	5.06	0.25
Lower leg/achilles/shin/calf	24	10.66	0.74	24	10.1	0.74	20	15.03	0.62	20	13.92	0.68
Toes	11	4.88	0.34	0	0.0	0.00	0	0.00	0.00	2	1.27	0.06
Hip	1	0.44	0.03	7	3.2	0.22	2	2.00	0.06	12	6.96	0.34
Total	**225**	**100.00**	**6.97**	**220**	**100.0**	**6.82**	**131**	**99.91**	**4.06**	**157**	**100.00**	**4.90**

what the incidence or risk of injury is there are two things that need to be defined: the definition of an injury and the standard measure for reporting soccer related injuries. The term injury in its relation with soccer is currently defined as anything that incapacitates a soccer player from full participation in imminent training or matches.[3] Moreover, the standard measure for reporting the incidence of soccer related injuries are determined by how long an individual athlete is exposed to the possibility of an injury, as such the measure is the number of injuries per 1,000 hours of soccer participation (i.e. practice, training, leisure, and game play).[1] Our study concluded that the total injury incidence rate over all exposures was 5.68 injuries per 1,000 hours. This rate is far less than what is reported from Ha et al who conducted a 15-year epidemiological study on injuries during official Japanese professional soccer league matches. The study had a comparably high incidence rate ranging from about 11 to 24 injuries per 1,000 hours, but this is significantly higher than a study conducted by Le Gall et al on elite French youth players which has an overall injury rate ranging from 4.6 to 5.3 injuries per 1,000 hours. Similarly, our study figure is comparable to other studies conducted on youth soccer players, which had incidences ranging from 0.535 to 5.640 injuries per 1,000 hours.[16] Furthermore, there are comparable findings with common injury sites in which our study along with the participants found in the study by Le Gall et al and a study on elite English academy players had the most prevalent diagnosed injury being injury due to muscle strain, sprain and pull or tightness with 66.34%, 62.5% and 66% respectively.[16]

The shortcomings of conducting a prospective cohort study include changes in methodology for detecting or recording injury due to the length of study period. In this specific study inter-examiner variability exists between the various athletic therapists. Although they are trained to follow protocol, their interpretation of the injuries can affect reported findings. Exact exposure hours are unattainable, as attendance was not taken during all sessions. Therefore, exposure hours are calculated based on the assumption that all players were present for all training sessions and games, which is not always the case. Exposure hours will most likely be overestimated. In addition, the study did not look at how the exposure time was split between time spent training and time spent during games. By differentiating match play and training we can make conclusions as to whether overtraining may be the cause of injury or if match intensity results in higher injury rates.

The strength of this study includes the sample size of the study, the study period and the elite status of the athletes. Few studies have followed as many elite athletes, over as many exposure hours, at such a high level of competition. Due to the size and methodology of the study, conclusions can be made with sufficient empirical evidence and validity.

Future recommendations for improving data collection/data analysis are to include the following: whether injury was due to contact, foul play or spontaneous occurrence; the time of the injury; player's position; and prior injuries. Noting how an injury arose can be a useful tool in understanding how to prevent the same injury from reoccurring. With players forcefully colliding for the soccer ball, pushing for positioning during a corner kick and receiving/delivering a tackle or charge, there can be various moments in which a player can get injured due to contact or foul play.[12] During the 2002 and 2006 World Cups it was reported that 73% of the injuries occurred during contact play.[3]

The time of injury can also be a useful tool to use. There have been many studies with various results on when injuries do in fact occur. Hawkins et al reported that there was a difference between the incidence of injury with each 15 minute segment in a game compared to 45 minute halves, whereas Rahnama et al reported that mild injuries occur during the first 15 minute segments of each half and that moderate injuries occur during the last 15 minute segment of the game.[3] Dick et al reported that the risk of injury is the highest during the first and last 15 minutes of game play. Since there is no precise time for when injuries occur in soccer matches, further studies should be conducted to determine an estimated time for when Canadian soccer athletes are most likely to sustain injuries.[12]

Consideration of the player's position is also a factor that can be analyzed. Was the player injured playing their regular position or a different one due to external circumstances? After discussion with the coach, players usually settle on their particular position for the season, and barring any unforeseen circumstances they stick with that position throughout the season. Moreover, another factor that can be analyzed is which position gets injured more?

Elite youth defenders are injured more often than their fellow teammates during competition, where as the injury rate for goalkeepers account for only 6% of all player injuries in adult professional soccer games.[16] These results show that the physical demands for each position vary and thus may account for the frequency and also type of injury Canadian soccer players may face.

Lastly, prior injury is a factor that can be used to help improve the analysis of this study. Re-injuries cause 30% longer absence from game play, thus knowing whether there is prior case of injury can help evaluate the risk and scope of training needed.[12] A prior injury can increase the risk of future injuries and thus a proper evaluation is needed by teams to determine whether a player is susceptible to a particular injury. In addition, if a player has a history of a specific reoccurring injury, rehab programs can be analyzed to see what can be improved in order to prevent the injury from occurring again.

This study sheds light on the number and varying types of injuries sustained by elite Canadian soccer players, however it fails to address certain issues that need to be looked at in the future, which include injury predictors in soccer, such as behavioural, environmental, and physical. However, some practical applications can be drawn from what was found, such as the fact that muscular strains, pulls and tightness were the most commonly found injury of soccer players. Thus, an appropriate strengthening program and proper implementation of warm-up and cool down exercises before training and matches can potentially help reduce the number of muscular strain occurrences. The occurrence of injuries in high-level soccer players is most likely multifaceted. Volpi and Taioli noted several external, personal, and behavioural risk factors likely associated with injuries, as well as risk factors that can be avoided or prevented through appropriate interventions.[17] Over the past years the intensity and speed of both training and game play along with the players' skill level and experience are hypothesized to be a contributing factor to the type and number of injuries registered.[17,18] Another risk factor that has been noted is the ratio of time-spent training to playing in games. Less time available for appropriate training was noted to be a good indicator of injuries in soccer players. A few factors have been identified, but have not been fully addressed to our knowledge, which include environmental factors, such as training and playing surfaces, field conditions at the time of injuries and type of shoes. Another predictor is the amount of time spent playing between players, meaning that in high level teams coaches are more prone to select the best players to play larger number of minutes during a game sometimes overworking these individuals.

All in all, results from the present study on injury rates of elite Canadian soccer youth revealed what was suspected for occurrence over 1000 exposure hours in comparison to major soccer countries. The highest injury reported was muscular strain, which warrants more suited preventative programs aimed at strengthening and properly warming up the players' muscles. Also, as noted by several other soccer injury studies, the ankle region was the area of highest sustained injuries, justifying the possible need for further prospective intervention studies to evaluate an injury prevention protocol. This study is specifically important to the Canadian Soccer Association, the Ontario Soccer Association and its respective medical providers. Identifying an epidemiological model for injury incidence is important in understanding how injury develops. As such, preventative programs can be designed in the focusing on maintaining the growth and development of amateur and elite Canadian soccer players alike.

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A case of early sports specialization in an adolescent athlete

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Early sport specialization (ESS) refers to intense year round training in a specific sport with the exclusion of other sports at a young age. This approach to training is heavily debated and there are claims both in support and against ESS. ESS is considered to be more common in the modern day youth athlete and could be a source of overuse injuries and burnout. This case describes a 16 year old elite level baseball pitcher who engaged in high volume, intense training at a young age which lead to several significant throwing related injuries. The case highlights the historical context of ESS, the potential risk and benefits as well as the evidence for its effectiveness. It is important for health care professionals to be informed on the topic of ESS in order to educate athletes, parents, coaches and organizations of the potential risks and benefits.

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KEY WORDS: sport specialization, youth, adolescent, baseball, chiropractic

La spécialisation précoce dans un sport (SPS) se réfère à l'entraînement intensif toute au long de l'année dans un sport particulier à l'exclusion des autres formes de sport dès le jeune âge. Cette approche de l'entraînement est fortement débattue et la SPS a ses détracteurs tout comme ses défenseurs. La SPS est considérée comme plus fréquente chez les jeunes athlètes de nos jours et pourrait être une source d'épuisement et de blessures dues à un surentraînement. Ce cas décrit un lanceur de baseball de 16 ans au niveau provincial qui a suivi un entraînement intense à un jeune âge qui lui a causé plusieurs blessures importantes liées au lancement. Le cas met en lumière le contexte historique de la SPS, les risques et les avantages potentiels, ainsi que les preuves de son efficacité. Il est important que les professionnels de la santé soient renseignés au sujet de la SPS afin de sensibiliser les athlètes, parents, entraîneurs et organisations aux risques et avantages potentiels.

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MOTS CLÉS : spécialisation dans un sport, jeune, adolescent, baseball, chiropratique

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Introduction

Early sport specialization (ESS) is a relatively new topic in the literature however its relevancy appears to be on the rise. There is no standardized definition for ESS, with authors providing their own interpretation.[1,2,3,4] However, the majority of definitions have a similar construct focusing on intense year round training in a specific sport, with the exclusion of other sports a young age. Figure 1 lists some of the common themes seen across the definitions.

The lack of a concrete definition has lead to confusion over what qualifies as ESS. Currently, ESS can be viewed as a continuum and should be determined on an individual basis taking into account all factors listed in Figure 1.

ESS is gaining attention in the media and scientific literature. There is much debate whether or not ESS is necessary and/or appropriate for obtaining elite status in sports.[2,5,6] It is also questioned if ESS leads to more injuries and burnout in youth sports.[7,8]

ESS is a broad topic in the sports medicine realm. The purpose of this paper is to describe a specific case of ESS in a youth provincial baseball pitcher, highlight the potential outcomes of ESS and bring awareness of the current information to health care professionals.

- High volume, intensity, duration of training at a young age
- Minimal rest or time off
- High structured training with emphasis on physical development
- May involve exclusion of other sports
- May be initiated by parents, coaches or trainer
- Goal of obtaining provincial status

Figure 1.
Typical aspects of early sport specialization

Case

A 16 year old elite level baseball pitcher presented to a sports chiropractor with several ailments including right (throwing arm) shoulder, right elbow, left hip and low back pain. All of these injuries impaired the athletes' performance and lead to significant time away from throwing.

The patient grew up in the Dominican Republic and began playing baseball at the age of five. He played baseball year round, at a frequency of 2-3 times per week mostly consisting of structured practice sessions. He became the top pitcher on the team and assumed a significant pitching role. In this league there was no pitching machine or pitching counts or limitations. At age 10, he moved to Canada. He joined a local city baseball league and became a dominant pitcher. His baseball volume dramatically decreased from year round baseball to playing only in the summer months. He began to notice some intermittent, low intensity low back and left hip pain. The pain did not impair his play so he ignored the symptoms. At the age of 14 his talent was recognized by an elite travel team within the city.

As a young teenager he played for the local AAA baseball team as well as the elite travel team. During the off season he engaged in several high intensity, off season throwing programs to improve his arm strength. At this stage, he was participating in baseball training 10+ months a year. During this time, he began to notice gradual onset of right medial elbow pain. The pain was reported as low level allowing him to continue his training. Leading into the next baseball season, he reported not feeling 100% regarding his right elbow, low back or left hip. At this point he was playing on two teams (local AAA and the travel team) which lead to about 3-7 games per week and 2-3 practices per week. Near the end of the season, his pitching volume increased into the playoffs and the medial elbow pain intensified to the point that he could no longer throw. Even swinging a baseball bat was unbearable due to the elbow pain. He sought treatment from a sports physician and was encouraged not to throw for several months. He was uncertain of the exact diagnosis rendered but reported it was most likely an ulnar collateral ligament sprain.

He spent the following off season resting and rehabilitating his elbow. At the beginning of the next season his elbow pain significantly decreased and he was able to return to pitching. However, he reported not feeling up to his full potential. He returned to playing for both teams at this point at a similar frequency and intensity as the prior season. As this season progressed he began to experience gradual onset of right shoulder pain. He continued to pitch as the pain was low in intensity. In the middle of the season he was selected to go to a provincial level tournament. He pitched at this event and reported "throwing his arm out" during one of the games. The shoulder pain was so severe that he could no longer throw. He was advised to rest by his sports physician and was referred for an MRA. His MRA revealed a type II SLAP (superior labrum anterior-posterior) lesion in his right shoulder. He was advised to rest for 3-4 weeks and begin rehabilitation. He returned to play after 3-4 weeks of rest in a limited role with this teams, mainly consisting of non-pitching positions and batting. At this point he presented to the local chiropractor with the list of ailments described above.

Discussion

Epidemiology

In general, today's youth are becoming less active, but activity in youth organized sport is on the rise.[9] In the United States, youth participation in organized sports has dramatically increased over the past 25+ years from approximately 18 million children in 1987 to 60 million in 2008.[9] Children are engaging in organized athletics at a younger age. In 1987, children aged 6 and under made up 9% of all youth athletes in organized sports.[9] In 2008, this number grew to 14% highlighting the earlier entrance into organized sports.

There is no statistical data to confirm that ESS is occurring more commonly today than it was in the past. This is owing to the fact that categorizing ESS is difficult and the topic is relatively new in the literature. However, when looking at current evidence, it appears that ESS is becoming increasingly common in youth athletics.[9,10,11]

A group of US high school sports directors were surveyed and 78% reported an increase in sports specialization in high school athletes.[10] In 2008, it was reported that 75% of US high school sports programs were offered on a year round basis with increased usage of privately owned sports training facilities.[9] Suggesting that a more streamlined specialized approach to sport has been developing. There has been a study showing that it is common for youth athletes to specialize in a sport before the age of 10.[11] And that the youth are often playing year round, for multiple teams including provincial travel teams.[9]

The effectiveness and safety of ESS

The effectiveness and safety of ESS is being debated and there are currently two main schools of thought (Figure 2). The claims supporting ESS state that specializing at a very young age may allow faster skill development to help gain a competitive edge.[4,5,6] This advantage aids in acquiring talent recognition earlier leading to opportunities such as provincial programs, showcase teams, scholarships or professional contracts.

Against Early Specialization	**For Early Specialization**
○ Avoid overuse injury ○ Allow proper rest ○ Cross sport skill development ○ Maintain interest in sport ○ Prevent social isolation ○ Prevent burnout ○ Prevent over-dependence	○ Gain competitive edge ○ Develop and hone skills faster ○ Early talent recognition ○ Increase opportunity for scholarships or professional contracts

Figure 2.
Claims for and against early sports specialization.[3-6,8,11]

The claims against ESS state that specializing at a very young age could lead to more physical and psychosocial problems and stall athletic development.[3] ESS may lead to more overuse injuries and burnout from excessive training at a young age.[8] Claims against ESS support diversification in sports in order to sample many sports, develop a variety of motor skills and maintain interest in sport by keeping it fun.[11]

Roots and Societal Influences on ESS

There are several different theories and rationales for the occurrence of ESS in North America. The main theory is a misinterpretation of a popular study done by Ericsson et al in 1993.[5] Ericsson investigated what factors helped predict expert performance. His results stated that high volumes of deliberate practice (defined as specific, focused, skill based practice) at a very young age was the strongest predictor of becoming an expert performer. This study lead to the famous "10,000 hour rule". Specifically, beginning a task at a very young age (before age 5-7) and acquiring high volumes of deliberate practice (5,000-

10,000 hours) resulted in the likelihood of an individual becoming an expert. It was shown that it was difficult to become a master at a task if one began late and did not acquire many deliberate training hours. However, there is no specific number of hours that was proven as enough to master a task. The number of hours varies on the person, the task and type of training.[5] Of note, these studies were done to determine expert status on musicians, mathematicians, chess players and were not performed on athletes. It does not necessarily indicate how to become to a better athlete, which often requires a diverse set of skills, and appropriate physical development. Regardless, this research by Ericsson et al, has made its way to the sports training world with the belief that early acquisition of training hours will lead to greater success.

When examining what leads a child to become involved in ESS there are multiple factors to consider. It was found the parents are the strongest initiator of sport for youth provincial athletes.[12] However, coaches are typically the first to recognize a child athlete as "gifted" or "special" and encourage specialization.[10,12] It is not commonly the athlete that encourages specialization before the age of 10. Before this age the athlete is typically not psychologically mature to understand the importance, responsibility, commitment and ramifications of year round training in sport.[6] It is also important to note that our modern day media driven, commercialized society plays a role in encouraging ESS. There are endless commercials, advertisements, training programs being geared towards specialized sports training targeting youth athletes.

Position Statements and Evidence

There have been lists of associations, organizations and authorities that have provided positions statements on ESS (Figure 3).[7,13-17] All position statements are slightly different but there is not one single position statement that supports early sports specialization. All of the position statements state that there is no evidence to support that ESS leads to improved outcomes in athletics compared to a late specialization model. A position statement by the American Medical Society for Sports Medicine (AMSSM) states that ESS "may increase the risk for overuse injury and burnout and should be avoided at younger ages." However, AMSSM also recognizes that ESS may be necessary for early entry sports such as gymnastics, diving and figure skating since the nature of these sports require peak performance at a young age.[7] Other positions statements encourage early sports diversification to help develop multiple athletic skills and maintain motivation and engagement in sport as well as standard periods of rest from any single sport.[13-17]

Position Statements Against ESS[7, 13-17]

- American Medical Society for Sports Medicine
- American Academy of Pediatrics
- National Athletic Trainers Association
- International Society for Sports Psychology
- World Health Organization
- International Federation of Sports Medicine
- National Association for Sports and Physical Education

Figure 3.
Position Statements from various authorities on early sports specialization.

There are some limitations to the position statements listed in Figure 3. The current state of the literature on ESS is not robust. Therefore, the position statements consist of consensus based expert opinion of the literature from a non-systematic approach. This approach can lead to various forms of bias and is on the lower end of the level of evidence hierarchy. There are also some inherent issues when examining ESS in the literature. When examining the literature the majority of studies are of poor design. They often have heterogeneous populations and do not separate results based off specific sport. Since the studies are commonly retrospective in design, there are recall bias issues regarding training habits and injury reporting. As well, the definition for ESS varies within studies. ESS can be described as year round training, playing only one sport, or high volume deliberate training at young age. Lastly, ESS is expected to be not as common in the past. Therefore you are less likely to find high level athletes attributing their success to ESS in more dated literature.

Developing a Sport Specific Approach

With the limited evidence surrounding the topic, ESS could be approached from a sport specific standpoint. All sports have their own inherent demands, risks and cultures that must be considered. Therefore, when considering what age is appropriate to initiate specialization, it is critical to look at each sport differently. It is essential to understand the typical ages for talent recognition, peak performance and length of typical career. Diverse examples would be comparing gymnastics and golf. Gymnastics is an early entry sport that has an age of peak performance at a very young age, especially for females. Gymnastics also has a short career, with peak performance lasting a short period. Golf on the other hand is a sport that has an age of peak performance extending into the 4th and 5th decades of life, with a much longer career length. Therefore, these sports are hard to compare when discussing aspects of sport specialization. It is also important to always consider that each individual athlete is different and responds to different training volumes and demands differently.

When applying this logic to the case discussed in this paper, one must understand ESS within a baseball pitching context. Typically in baseball pitching, talent recognition for collegiate baseball (NCAA) occurs in the latter years of high school (ages 15-18) with peak performance in pitching occurring the mid-late twenties and retirement usually before the age of 40. Therefore it is important for a young pitcher to display talent at a fairly young age in order to be recognized. But they must also have the longevity to perform well into their thirties. However, only approximately 6% of high school pitchers in the USA will pitch at the NCAA level[18]; with even fewer going to professional leagues. Up to 50% of youth pitchers will report shoulder or elbow joint pain throughout the course of a season. This correlates with approximately 15% of all pitching appearances.[19] Also 5-8% of youth pitchers will suffer injuries severe enough to end their pitching careers or require shoulder/elbow surgery.[20] Due to the fact that 70-80% of pitching injuries are progressive, many youth pitchers are pitching through pain or discomfort leading to significant arm pain and disability.[21] Therefore, understanding risk factors to help predict these injuries at such a young age is key. There are four main studies that discuss pitching habits and injury rates in youth pitchers.[19,20,22,23] The summary of the results of these four studies showing the risk factors for arm injury in youth pitchers is presented in Figure 4.

The results from these studies help illustrate that there are modifiable risk factors for pitching practices in youth pitchers. The odds ratios in Figure 4 display the odds of an adolescent pitcher becoming injured if they engaged in these behaviours. These statistics are important as they highlight what pitching and training habits can be mitigated to reduce injury. The risk factors identified in Figure 4 can be monitored in youth pitchers to help prevent injuries.

When applying these risk factors to the case, the 16 year old pitcher had several of the risk factors for significant injury. He was regularly throwing while fatigued, playing for more than one team and throwing for greater than 8 months per year. He could have also been exceeding pitch count numbers but this was not recorded. The combination of risk factors placed this athlete at significant risk for injury.

This example helps illustrate a sport and athlete specific approach that can be taken when examining ESS. Al-

Risk of Developing Elbow or Shoulder Pain	
Risk Factor	**Odds Ratio**
Regularly Throwing with Arm Fatigue	6 (3.5-10.1)
Throwing >600 pitches/year	3.4 (0.84-14.12)
Throwing > 75 pitches/game	3.2 (1.84-5.61)
Playing for a second team	2.8 (1.26-4.38)

Risk of Elbow/Shoulder Surgery or Retirement	
Risk Factor	**Odds Ratio (95% CI)**
Regularly Throwing with Arm Fatigue	36 (5.92-221.22)
Throwing >8 months/year	5 (1.39-18.32)
Throwing > 80 pitches/game	3.8 (1.36-10.77)
Throwing > 100 innings/year	3.5 (1.16-10.44)
Playing catcher and pitcher	2.7 (0.93-4.47)
Pitch velocity > 85 mph	2.5 (0.94-7.02)

Figure 4.
Summarizing the modifiable risk factors for injury in youth pitchers. [19-20, 22-23]

though this paper focuses on pitching, these concepts can be applied to other sports and athletes. To gain an understanding of what training levels are age appropriate, looking at the inherent demands and risks of the sport as well as determining the potential risk factors for injury within that sport are key. An excellent resource from Canada Sport for Life highlights the appropriate training habits of Canadian youth. It is called the Long Term Athlete Development (LTAD) model.[24] This model is based off six stages of athletic development:

1. FUNdamental stage
2. Learning to train
3. Training to train
4. Training to compete
5. Training to win
6. Retirement/retainment

The focus of the early stages of the model is encouraging activity in many sports in a fun and engaging manner. While the later stages focus on sport specific skills, intense training and high level competition. The stages can be applied and modified to any sport and provide an excellent template when considering appropriate athletic development.

Lastly, it is important for all parties involved in the athlete's life to be on the same page. This involves coaches, parents, medical staff, trainers and of course the athlete. Specializing in sport at any age involves a lot of time, money and dedication. Therefore, it is paramount that realistic goals are set for the athlete, pros and cons of ESS are discussed and expectations are clear for all parties.

Conclusion

It is common for chiropractors to treat adolescent athletes. Therefore, it is important to be educated on how young athletes can perform their sport in a safe and effective manner. Chiropractors must take a sport and athlete specific approach when providing advice on the correct time to specialize. In today's world, sports are becoming increasingly popular, competitive and demanding. Youth are engaging in sports at a much younger age and taking on higher training loads with more specialized approach. There are currently claims both for and against specializing in sport at a young age. Presently, there is no evidence to support ESS and it is not supported by any authoritative body. To become an elite athlete, there may be situations when sport specialization is necessary. However, understanding when to specialize and focusing on the right training at the right time is imperative to promote long term success for the athlete.

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Juvenile Osteochondritis Dissecans in a 13-year-old male athlete: A case report

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Objective: *To present the clinical management of juvenile osteochondritis dissecans (OCD) of the knee and highlight the importance of a timely diagnosis to optimize the time needed for less invasive, non-operative therapy.*

Clinical Features: *A 13-year-old provincial level male soccer player presenting with recurrent anterior knee pain despite ongoing manual therapy.*

Intervention and Outcome: *A multidisciplinary, non-operative treatment approach was utilized to promote natural healing of the osteochondral lesion. The plan of management consisted of patient education, activity modification, manual therapy, passive modalities and rehabilitation, while being overseen by an orthopaedic surgeon.*

Conclusions: *Considering the serious consequences of misdiagnosing osteochondritis dissecans, such as*

Objectif : *Présenter le traitement clinique de l'ostéochondrite disséquante juvénile (OCD) du genou et souligner l'importance d'un diagnostic précoce en vue d'optimiser le temps nécessaire pour un traitement non chirurgical moins invasif.*

Caractéristiques cliniques : *Un joueur de soccer de 13 ans, au niveau provincial, présente des douleurs antérieures du genou (récurrentes) malgré un programme de thérapie manuelle en cours.*

Intervention et résultats : *Une approche de traitement multidisciplinaire non chirurgical a été utilisée pour favoriser la guérison naturelle de la lésion ostéochondrale. Le plan de traitement comportait la sensibilisation du patient, la modification des activités, la thérapie manuelle, les modalités passives et la réadaptation, sous la supervision d'un chirurgien orthopédiste.*

Conclusions : *Compte tenu des conséquences graves d'un mauvais diagnostic de l'ostéochondrite*

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the potential for future joint instability and accelerated joint degeneration, a high degree of suspicion should be considered with young individuals presenting with nonspecific, recurrent knee pain. A narrative review of the literature is provided to allow practitioners to apply current best practices to appropriately manage juvenile OCD and become more cognizant of the common knee differential diagnoses in the young athletic population.

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KEY WORDS: case report, osteochondritis dissecans, knee injuries, non-specific knee pain, osteochondral lesions, medial femoral condyle, ROCK

disséquante, telles que la possibilité d'une instabilité articulaire et d'une dégénérescence accélérée des articulations à l'avenir, il faut être extrêmement suspicieux avec les jeunes qui présentent des douleurs récurrentes non spécifiques du genou. Un examen narratif des revues scientifiques est offert pour permettre aux professionnels d'avoir recours aux pratiques exemplaires actuelles pour traiter adéquatement l'OCD juvénile et de se sensibiliser davantage aux diagnostics différentiels communs du genou chez les jeunes sportifs.

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MOTS CLÉS : observation, ostéochondrite disséquante, blessures du genou, douleurs non spécifiques du genou, lésions ostéochondrales, condyle fémoral médial, ROCK, chiropratique

Introduction

The knee is complex and is often affected by pathologies and/or traumatic events, resulting in a visit to primary health care practitioners, including chiropractors. It has been reported that a chiropractor's practice can consist up to 20% of extremity conditions, with roughly equal distributions between the upper and the lower extremities.[1] Therefore, it is important that a chiropractor have a thorough understanding of the common extremity conditions, particularly those that may have potentially significant sequalae. The anatomical structures that present in the knee region can make the assessment challenging. A thorough history and physical examination, is essential in determining the differential diagnosis for knee pain.[2,3] The necessity for a quick and accurate diagnosis becomes even more significant when these injuries are present in children and adolescents, given their skeletal immaturity and growth potential. Any inappropriate management or delay in diagnosis may result in significant consequences such as future chronic pain, limitations of daily activities or sport participation, joint instability, and accelerated joint degeneration.[4-10] A brief list of some of the more common injuries associated with the knee in the adolescent age group is outlined in Table 1. It would be appropriate for a chiropractor to be aware of these diagnoses, which include age-specific differentials such as epiphyseal and/or apophyseal injuries.

An important differential diagnosis that should be considered in both children and adolescents with vague, recurrent knee pain is juvenile osteochondritis dissecans (JOCD). Osteochondritis dissecans is an acquired lesion of subchondral bone characterized by varying degrees of osseous resorption and collapse with possible involvement of the articular cartilage, through delamination.[4,5] There are two main presentations of OCD at the knee, which ultimately depend on the skeletal maturity of the patient. As a point of clarification, JOCD of the knee is reserved for youth and adolescents who have open growth plates on radiographs, while the diagnosis of adult OCD is reserved for skeletally mature patients with closed physes.[4-7]

This case focuses on JOCD of the knee and highlights the importance of a timely diagnosis in preserving joint function and optimizing the time needed for less invasive, non-operative therapy for an adolescent. Through appreciation of the epidemiology, etiology, clinical presentation and management of JOCD of the knee, this case will not only help the practitioners to appropriately manage JOCD, but become more cognizant of the common knee conditions in the young athletic population.

Table 1:
Important differential diagnoses to consider in youth presenting with knee pain.

Differential Diagnosis of Knee Pain in the Adolescent	
Synovial Impingement Syndromes	Pathologic plica Hoffa syndrome
Osteochondroses/Tendonitis	Osgood-Schlatter Sinding-Laresen-Johannsen Patellar tendonitis
Patellar Instability	
Patellofemoral Pain Syndrome (PFPS)	
Osteochondritis Dissecans	
Hip Pathology*	Slipped capital femoral epiphysis (SCFE) Legg-Calve-Perthes (LCP) Stress (fatigue) fracture
Tumours	Osteosarcoma Osteoid osteoma
Infection	Brodie's abscess
Idiopathic Anterior Knee Pain	
Meniscal Tears	Discoid meniscus
Fracture	
Ligamentous Injury	
Iliotibial Band Syndrome	

**Likely associated with accompanying hip pain and/or dysfunction.*

Case presentation

A 13-year-old provincial level male soccer player presented to a chiropractic office complaining of right knee pain, one day after an on-field injury. The injury occurred while the right foot, which was planted, was abruptly slide-tackled on the lateral side while attempting to kick the ball with the left foot. The trauma created a valgus load in his right knee and the patient collapsed on field. He was helped off the field and was unable to return to play due to an inability to weight bear. The patient complained of significant generalized pain over his right knee and the only relieving factor for the first 24 hours was the application of ice to the right knee joint. He did not report any popping sensation or instability associated with the knee injury. He denied any prior history of right knee pain or injury. He reported that his training schedule consisted of four to five on-field practices along with one to two games per week.

Upon initial examination, there was mild swelling located over the right medial knee and pes anserine insertion. Digital palpation was associated with generalized pain over the right anterior knee, particularly over the medial joint line. Passively, right knee range of motion was limited to 60° in flexion with pain, while all other ranges were observed to be full. However, all passive movements were associated with end range discomfort. Resisted ranges of motion were not completed due to pain. Similarly, most of the orthopaedic testing was non-contributory with regard to the diagnosis, due to the degree of discomfort associated with the testing. However, tests for effusion, ligamentous laxity and meniscal involvement, such as the swipe test, Lachman's test, anterior and posterior drawer tests, valgus and varus stress tests, and McMurray's tests were deemed to be unremarkable. The valgus stress test to the right knee resulted in the most pain but no findings of laxity were elicited.

Based on these results, a working diagnosis of a grade I MCL sprain was made and the patient was placed on a three week course of conservative management, consisting of activity modification, cryotherapy, laser therapy, soft tissue therapy, and knee mobilizations. The patient was also placed on a gradual isometric strengthening program that was initiated at the end of the second week. He made good recovery and returned to play in 4 weeks without pain.

Approximately two weeks later, he returned back to the office complaining of right-sided retropatellar pain. The patient stated that this episode started after a training session that included a bout of uphill sprinting and repetitive squatting exercises. Upon examination, there was a notable tenderness reported over the medial proximal and middle facet surfaces of the patella in addition to the right medial joint line. At this time, a working diagnosis of patellofemoral pain syndrome (PFPS) was made and the patient was given a conservative treatment plan that included activity modification, progressive rehabilitation for PFPS, laser therapy, and manual therapies that included soft tissue therapy and graded knee mobilizations. The patient was able to return to play within 2 weeks with the aid of a soft patella stabilizing knee brace.

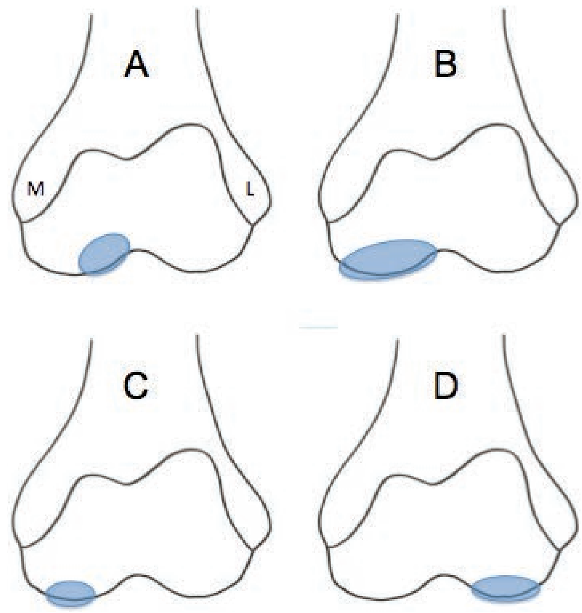
A few weeks later during training, he fell on his right knee after tripping over another player. Despite icing for a few days, the pain persisted. Examination findings demonstrated a mild knee effusion as well as focal bony tenderness over the medial joint line and condylar surfaces of the distal femur. Due to the reoccurring issues with his right knee and the suspicion of a possible osseous injury, a series of conventional radiographs of the right knee were requested (Figure 2). The findings were consistent with JOCD and the patient was referred to an orthopaedic surgeon for further consultation and advanced imaging (Figure 3). Since imaging revealed a stable osteochondral lesion with open distal femoral growth plates, a trial of conservative care was initiated that limited rigorous activity for 6 months and permitted light activities such as swimming and cycling under orthopaedic supervision. At 6 months, MRI revealed successful healing of the stable osteochondral fragment of the right knee.

Discussion

Epidemiology

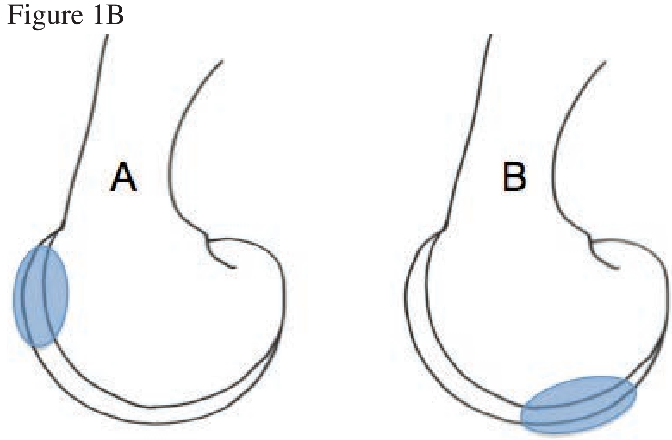
JOCD of the knee occurs in skeletally immature patients with open distal femoral physes visible on radiographs. Although the exact prevalence is unknown, reported ranges within the literature are 15-29 cases per 100,000

Figure 1A



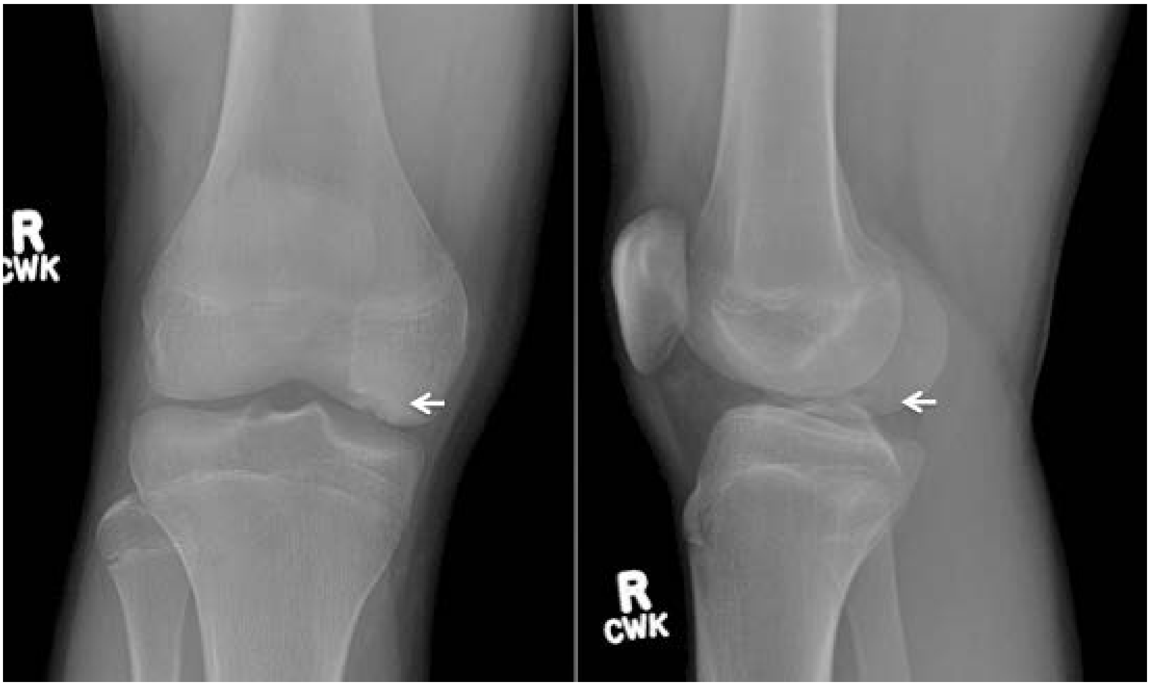
This image illustrates anterior-posterior presentations of OCD on the articular surface of distal femur. The medial (M) and lateral (L) condyles are labeled in image A for reference. OCD lesions may appear on the medial condyle in the classic (A), extended classic (B) and inferocentral locations (C). Image D shows the inferocentral location on the lateral femoral condyle.

Figure 1B



Osteochondral lesions at the knee may present on the anterior portion of the articular surface (A) or most commonly, at the weight-bearing posterior portion of the articular surface (B).

Figure 2



Conventional AP and lateral radiograph views of the right knee. The osteochondral defect (white arrows) is observed in the posterolateral aspect of the right medial femoral condyle.

with an average onset ranging from 11-13 years.[7-9,11-13] Many authors agree that the true prevalence and incidence may be under reported due to asymptomatic cases and clinical misdiagnosis.[4,12]

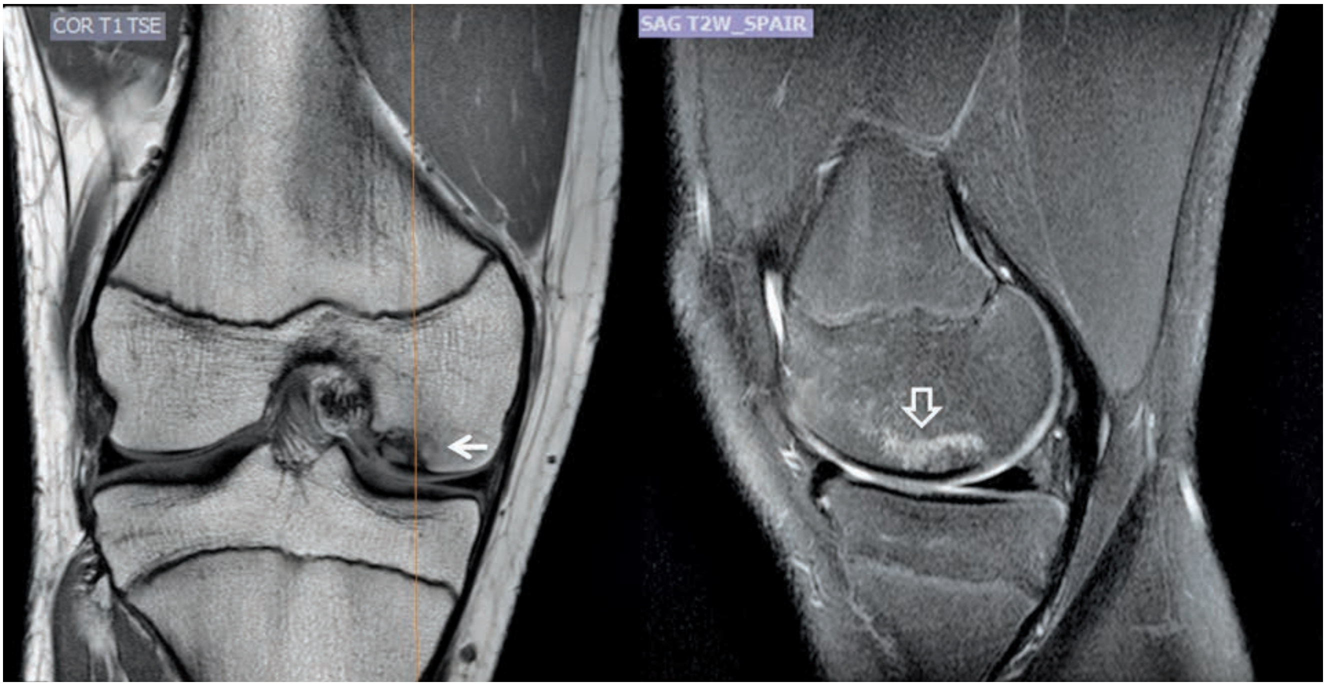
With regard to gender distribution, JOCD traditionally has a male predilection, with an approximate ratio of 5:3[4,5], although in recent years, an increasing prevalence in the female population, and a decreasing mean age of onset has been noted.[4-7] Several authors attribute the increase in the incidence of JOCD in recent years in part to the growing number of youth involved in year-round competitive sports, the widespread use of MRI and the increased awareness of the pathology among more health care providers.[4,5,10]

JOCD of the knee occurs most frequently in the classic location of the posterolateral aspect of the medial femoral condyle, as it is reported in more than 70% of cases.[4-10] Lesions may also present in the inferior-central lateral condyle that account for 10 to 20% of cases, while femoral trochlear lesions account for less than 1% of cases. Typical locations of OCD presenting on the distal femur are illustrated in Figures 1A and 1B. Although patellar involvement is uncommon (less than 5% of cases), when present, it is often located on the inferomedial surface of the patella. The pathology is most often monoarticluar, but bilateral involvement has been reported in 15-30% of cases.[4,5] When bilateral involvement is present, it is often asymmetrical in terms of lesion size and clinical symptoms.

Etiology

König originally coined the term osteochondritis dissecans in 1887 to hypothesize an inflammatory process resulting in dissection of articular cartilage and subsequent fragmentation of subchondral bone leading to loose body formation.[5] However, numerous histological studies have been unable to support a theory of inflammation.[4,5,7] Recent histological studies have also failed to provide evidence for osteonecrosis of the OCD fragment (progeny bone) or a relative ischemic watershed at the lateral aspect of the medial femoral condyle.[4] Instead, it seems the necrosis found in OCD may be secondary to the ac-

Figure 3



Coronal T1 TSE and sagittal T2 SPAIR MR images demonstrating a stable osteochondral lesion in the right knee (solid arrow). Marrow edema (open arrow) is observed with high signal intensity on the sagittal view.

tual detachment of the lesion rather than an underlying pathology.[4,5]

There have been numerous theories proposed to explain the cause of JOCD of the knee. However there is insufficient evidence to support a single etiology.[4-7] Currently, most authors believe the condition is multifaceted and composed of several theories including repetitive microtruama, abnormal ossification, aberrant joint mechanics and genetic predisposition.[4-8]

With regard to the theory of genetic predisposition for acquiring OCD, two studies have suggested an autosomal-dominant inheritance pattern.[4,5,7] Other studies have suggested that a genetic component to this pathology is likely due to bilateral presentation in up to 30% of cases along with the fact that many individuals experiencing JOCD may have osteochondral defects in multiple joints.[5] Despite these findings, Petrie[14] found only one relative with the disease in a radiographic examination of 86 first-degree relatives of 34 patients with confirmed JOCD. Although there is a potential genetic role as discussed in the literature, the role remains elusive and unclear at this time.

In 1933, Fairbanks[15] proposed a traumatic mechanism where impaction of the tibial spine on the lateral aspect of the medial femoral condyle leads to the common presentation of JOCD. However, this mechanism can only explain the development of lesions in the classic site of the medial femoral condyle, and does not support those occurring in other areas, such as the lateral femoral condyle and patella.[4] The most current accepted theory on the etiology of OCD at the present is repetitive microtruama, predominantly due to the increasing prevalence of this condition in young athletes. Although there is general acceptance, the exact nature of the mechanism is still unknown.

In 1999, the European Pediatric Orthopedic Society published a multicenter study that examined a total of 509 OCD lesions in a total of 452 knees. They found that approximately 55% of the young patients with confirmed JOCD were regularly active in sports and performed strenuous athletic activity.[16] It has been well recognized that children and adolescents are more prone to sport-related injuries, in part due to the lack of fully developed motor skills, temporary declines in coordination and balance at puberty, as well as changes in limb length versus limb mass.[7] These factors ultimately result in increased strain on the musculoskeletal system, including the more vulnerable areas such as the epiphyseal plates and apophyses. With the growing number of youth athletes involved in early, year-round sport specialization, it is thought that repetitive loading can lead to stress reactions that can progress to fracture of the underlying subchondral bone.[5-7] Persistent loading, particularly at high axial loads to the knee joint, may exceed the healing capacity of the progeny segment and lead to nonunion.[5] However, this mechanism does not explain asymptomatic lesions or those developing in sedentary individuals.

Theories such as aberrant joint loading and issues with epiphyseal endochondral ossification have also been suggested to contribute to the proposed multifaceted etiology of JOCD of the knee. Associations have been found between discoid meniscus and lateral femoral condyle lesions, and with the development of lesions in cases of mechanical axis malalignment.[4,5,7] Knees with medial femoral condylar lesions have been positively associated with varus malalignment, while those with lateral condylar lesions are associated with valgus mechanical malalignment.[5,7] Recent research has provided new MRI findings to support previous theories regarding JOCD formation through aberrant development of only a portion of the epiphyseal growth plate. Abnormal epiphyseal endochondral ossification may occur after a particular acute or repetitive insult, leading to a slowly evolving lesion as the patient ages. Evidence from T2 fat saturation sequences has helped describe two potential scenarios. The first is a permanent cessation of ossification after insult that leads to a completely cartilaginous OCD lesion without endochondral ossification. The second scenario involves temporary cessation of ossification that allows for future partial or complete normal ossification with time.[4]

Although there has been more than a century from the first discovery of this pathology, the relationship between the juvenile and the adult forms of OCD remains uncertain. Despite cases that have supported a de novo mechanism in the adult form, many experts believe that the adult lesions represent acute injury or are a persistent form of JOCD.[4-10] Further confounding this debate is the potential overlap of both presentations during mid or late-adolescence to adulthood.

Clinical Presentation

Since early recognition of JOCD is critical in the management, and ultimately the prognosis of the pathology, awareness of the subtle clinical symptoms and a high degree of suspicion in young individuals with non-specific knee pain are important.

The clinical presentation of JOCD of the knee is heavily dependent on the stage of pathology, including the size and stability of the lesion. Typically, in the early stages of this condition, a young patient may present with non-specific knee pain with or without a history of trauma.[5] In active youth with a symptomatic presentation, pain is exacerbated by periods of rigorous exercise or activities such as climbing hills or stairs.[4,5,8,9] These patients may have an observable limp after these periods of high activity and in less than 20% of cases, present with local knee effusion and swelling.[4] More advanced stages of the condition may present in a similar fashion to adult OCD of the knee, with symptoms of catching, locking, instability (giving way), and more obvious signs of atrophy and joint effusion. These signs are characteristic of unstable lesions or loose intraarticular chondral or osteochondral bodies.[6,10]

As stressed above, it is imperative for JOCD to be detected in an early stage so that adequate time is reserved for growth plate fusion, to increase the likelihood of more complete healing and a better prognosis. The issue for the clinician is that many of the earlier signs and symptoms are similar to other typical causes of knee pain in the adolescent. In order to increase clinical suspicion for osteochondral lesions, the patient history, particularly the ongoing temporal pattern of the condition, must be recognized. Furthermore, in the athletic population, the type of sport and specific movements that exacerbate the condition should be noted.[2,5] Although these injuries are most common in sports involving high axial loading and jumping, participation in other activities that do not encounter as much axial loading should not be dismissed as a possible provocative factor.[5,7]

Cahill and Ahten[6] reported characteristic trends observed in patients diagnosed with JOCD. Their findings may help clinicians identify historical findings to increase awareness for JOCD. Several trends support a theory of repetitive overuse or fatigue phenomenon as only 10% of patients have a history of acute trauma. Many of the individuals in their study were involved in more than 3 sports, and participated in year-round vigorous training programs. They also noted that 80% of these patients had symptoms for an average of 14 months before detection.[6] As noted above, the challenge with a vague and poorly localized knee pain in young patients is often difficult and must include other systemic and musculoskeletal diagnoses, as highlighted in Table 1.

Physical examination can also be vague, although tenderness is most often elicited over the anteromedial aspect of the femoral condyle with varying degrees of knee flexion.[9] Knee range of motion is often unremarkable in early stages of the pathology, but may have limitations in passive extension due to pain or mechanical obstruction in progressive stages with loose body formation. Knee effusion has been reported in less than 20% of cases on initial examination and atrophy of the quadriceps muscles in the effected limb may be noted only in advanced or long-standing lesions.[4] Orthopedic testing for ligament stability and meniscal involvement should be completed to rule out competing differential diagnoses.[5] In the case noted, examination of the knee failed to demonstrate any obvious signs of meniscal involvement or laxity for both cruciate and collateral ligaments. Wilson's sign has been a traditional orthopedic test designed to aid in the diagnosis of JOCD, as the test attempts to impinge the tibial spine into the lesions at the classic location of the posterolateral aspect of the medial femoral condyle. A positive test is thought to produce a painful reproduction of symptoms at the anteromedial joint line while the knee is flexed to 30^{o} with maximal internal rotation of the tibia. A positive finding is confirmed if symptoms dissipate once the knee is placed into external rotation at the same range of motion. Several authors have questioned its usefulness for clinical diagnosis as recent findings suggest poor sensitivity and specificity of this test.[4,5,7-9] Despite these recent results, the test may have an application as an outcome measure in patients that have positive findings on initial examination.[17] In the case presented, Wilson's test was deemed negative on physical examination even with the presence of OCD at the posteriolateral aspect of the medial femoral condyle.

Imaging

Due to the nonspecific nature of the clinical signs and symptoms of this pathology, diagnosis and characterization of JOCD is dependent on imaging. Among its use in diagnosis, imaging is significant for management as it is used to monitor progress and overall prognosis.[17] In the initial stages of assessment, conventional radiography, bone scans, computed tomography (CT), CT arthrography, magnetic resonance imaging (MRI), and magnetic resonance arthrography have been utilized.[17,18,19] Despite the use of several imaging techniques and diagnostic criteria, there is no single modality that reliably predicts nonsurgical healing capacity.[5,7,11] Furthermore, there is no single system that has gained wide acceptance since determining the stability of JOCD lesion is difficult to ascertain. The most accepted predictive factors for instability are skeletal maturity, the size of the lesion, and articular continuity. [4-7,17-20]

Most authors agree that conventional radiography should be the initial step for the diagnosis of JOCD and other osseous differentials in the knee as it allows determination of the location and size of the lesion as well as the skeletal maturity of the patient.[4-10,17-21] Most lesions can be identified through radiographs, which typically consist of four views, including anteroposterior (AP), lateral, tunnel, and merchant or sunrise views (see Figure 1).[5,17] Since JOCD can present asymptomatically and bilaterally in up to 30% of patients, several authors' believe it is clinically relevant and acceptable to obtain a contralateral knee series, especially if symptoms are present.[17,19] JOCD lesions typically present as a well-circumscribed area of subchondral bone separated by a crescent-shaped radiolucent outline of the fragment as demonstrated in Figure 2. Although this modality aids in initial assessment, the inability of radiographs to accurately describe size, stability, as well as the overlying articular cartilage of JOCD lesions, limits their ability in determining prognosis or making therapeutic decisions.[17]

Nuclear medicine, specifically technetium-99m methylene disphosphonate bone scans, has been used for assessment of JOCD lesions. This modality was initially thought to be useful for determining cases of operative management due to its superior sensitivity over conventional radiography in detecting increased activity in the bone and predicting stability of the lesion.[5] However, due to its poor specificity to distinguish JOCD lesions from other joint abnormalities and the lack of quality evidence for reliably determining the stability of the lesion, this imaging modality has not been used extensively in determining management.[17]

Another commonly employed imaging study is computed tomography (CT). However, this modality has also been of limited use in providing information on JOCD lesion's stability or healing potential as its ability to assess the non-calcified aspect of the joint, which is necessary to determine prognosis, is poorly visualized.[17] Although CT arthrography is more useful as it can assess the cartilaginous aspect of the joint as compared to the conventional CT, its increased exposure to ionizing radiation, especially in young patients has made it less favourable.[5,20]

Currently, magnetic resonance imaging (MRI) is the preferred imaging modality for both diagnosis and the assessment of healing potential of JOCD of the knee due to its ability to provide excellent anatomical detail of both the bone and soft tissues structures with the absence of harmful ionizing radiation.[5,7,17,18,20,21] MRI has been reliable in differentiating abnormal ossification from true OCD lesions, and more importantly, assess stability of a lesion. Determining lesion stability is the greatest prognostic factor to assess the likelihood of a lesion healing with non-operative management.[17,18,21] True JOCD lesions on MRI are viewed as defects in the posterior femoral condyles with intercondylar extension and significant edema (Figure 3).[17] The most common MRI criteria for determining instability of JOCD lesions were originally described by De Smet et al [21] and include:

(1) A rim of high signal intensity surrounding an OCD lesion on T2-weighted images
(2) Cysts surrounding an OCD lesion
(3) A fracture line of high T2 signal intensity extending through the articular cartilage overlying an OCD lesion
(4) A fluid-filled osteochondral defect.

However, studies have found that in immature patients there might be different criteria for determining stability as compared to the adult presentation. It has been noted the presence of a T2 signal intensity surrounding the JOCD lesion only indicates instability if it has the same signal intensity as the adjacent joint fluid, is surrounded by a second rim of low T2 signal intensity, or has multiple breaks in the subchondral bone plate.[17] Cysts surrounding JOCD lesions were only indicative of instability when the lesion size was greater than 5 mm or multiple lesions were present.[17] Despite these findings, to date, there are no current consensus on the MRI criteria, which support the definition of JOCD instability.[11,17,18] Incidentally, MRI is commonly used to assess healing. Typically, signal intensity and subchondral bone marrow edema will return to normal after a period of 12 months.[17]

Management

Management of JOCD still remains a controversial topic and has been traditionally divided into non-operative and/or operative care. The American Academy of Orthopaedic Surgeons (AAOS) [22] published a recent guideline with respect to the diagnosis and treatment of OCD of the knee. Although there were 16 recommendations, 10 were inconclusive, 4 were consensus statements, and 2 were supported with low quality evidence. Furthermore, the body of literature surrounding the diagnosis and management of JOCD of the knee is limited to retrospective case series, reports, and expert opinions, which inherently have poor internal validity and biases, which limits firm conclusions to be drawn from the current literature. However, the guidelines from the AAOS and recent literature being published from organizations such as the Research in Osteochondritis of the Knee (ROCK) have made it possible for both manual practitioners and surgeons to select the most appropriate courses of management for patients based on the current state of the literature.[5] These principles were deemed to be the best available evidence and guided management of the current case.

Treatment of JOCD of the knee is dependent on multiple factors. Two critical components that play a large role in initial management strategies are the skeletal maturity of the patient (time until growth plate closure) and the characteristics of the lesion (size and stability).[2-10,23] Non-surgical management is often the first line of treatment for stable lesions in patients with an open physis, which has at least 6 – 8 months of growth, prior to plate closure.[4-6,17,22] Immobilization and activity modification are the mainstays of conservative treatment. However there is controversy regarding the duration and timing of these interventions. Traditionally, immobilization via casting, bracing, or the use of a knee immobilizer was implemented before partial weight bearing with crutches for patients undergoing conservative care.[2-5,23] These methods have had less attention in recent years due to potential detrimental effects to the joint and muscles, such as quadriceps atrophy.[9,10] Several authors agree that the current non-surgical management should focus on restricting sport and high-impact activities for a course of 6-8 weeks, but allow for normal weight bearing activities in a compliant patient.[4,5,10] Light activities such as walking, cycling, and swimming have been suggested during the first 3-4 months with return to normal activities and sport activities in about 4-6 months.[2-5,10] Recent findings regarding the success of non-operative healing rates of JOCD lesions in patients with an open physis are approximately 65% within a 6-month period.[24] Failed conservative therapy and poor compliance are cited as predominant factors for poor healing success.[6,22] Several authors[5,6,17] stress the critical role of the practitioner to educate both the patient and parents involved so that compliance is maintained for optimal success with conservative management.

Surgical management is reserved for patients after 6-9 months of failed conservative care, those with detached or unstable lesions, those approaching physeal closures within 6 months, or when there is evidence of full-thickness loss of overlying articular cartilage as identified on MRI.[8-10,17] The goal of surgical intervention is to preserve the congruity and integrity of native articular cartilage. There are several surgical interventions that may be considered based on the characteristic of the lesion and stage of the disease. In stable lesions that have failed nonoperative care, surgical approaches such as arthroscopic drilling (transarticular or retroarticular) are used to stimulate revascularization and encourage healing.[5,10] In unstable lesions, approaches involving internal fixation with or without debridement are necessary to stabilize the lesion. When the lesion has progressed and is not repairable, restorative techniques such as microfracture and osteoarticular transfer systems (autologous chondrocyte implantation or osteohondral allograft) may be initiated.[5,10,17,25] A recent systematic review by Aboussaly et al [11] stated that there are numerous surgical techniques for stable and unstable lesions. However, regardless of the surgical intervention, the vast majority of lesions (94%) were judged to have healed post-operatively. These authors also highlight the paucity in this body of literature and cautioned the interpretation of their data since all studies lacked control groups, had variable sample sizes, and had a high heterogeneity in study methodology and baseline characteristics.[11]

On reviewing the case presented, there were several clinical challenges that had to be addressed. Although the lesion was stable, the greatest issue was the time until growth plate closure. The patient was approximately 10 months to growth plate closure making the decision for conservative management more uncertain. To undergo such management, compliance was critical to ensuring optimal physiology for healing. An initial restriction from rigorous activity and soccer participation was prescribed for the first 6 months. This included no running or jumping, with the patient being permitted to do light activities such as walking, cycling, and swimming. Upon demonstration of healing of the lesion with imaging at 6 months, a progressive lower limb rehabilitation program incorporating multiplanar and axial loading was initiated.

Although there is limited high quality literature surrounding the management of juvenile OCD of the knee, the current case demonstrated how utilization of the current guidelines and cooperation from the patient and his parents with regard to activity restriction, resulted in a favourable outcome. However, future research involving more rigorous prospective methodology to address the lack of current consensus in imaging and treatment options will be required. As experts in musculoskeletal health, chiropractors can provide patient education to ensure compliance to activity modification and apply rehabilitation principles to optimize joint function in addressing juvenile OCD.

Conclusion

Juvenile osteochondritis dissecans of the knee is the most common cause of loose intraarticular bodies in adolescence and the prevalence of these lesions seem to be increasing in active populations. Considering the serious consequences of misdiagnosing osteochondritis dissecans, such as non-union, mobility of the fragment, and accelerated joint degeneration, a high degree of suspicion for OCD should be considered with young individuals presenting with non-specific, recurrent knee pain. Through understanding the epidemiological and etiological factors that are suggested to play a role in this condition, primary clinicians should have a high level of suspicion in cases of non-specific knee pain in adolescents. As always, a thorough history and physical examination would be required to help in diagnosing this condition. Imaging studies have a pivotal role in the diagnosis of these lesions and a rapid referral to an orthopedic surgeon is required to determine the stability of the condition and the need for either conservative or surgical management. Although the literature surrounding optimal management and consequent prognosis of such injuries is lacking, practitioners can draw upon current best practices outlined by the AAOS and ROCK organizations. Furthermore, chiropractors can play a critical role in the multidisciplinary approach to such cases through potential clinical detection and nonoperative management of these patients.

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Influence of MRI field strength on clinical decision making in knee cartilage injury – A case study

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Objective: *To increase clinicians' awareness of the differences in image resolution and potential diagnostic accuracy between small and large-field MR Scanners. To present an example of a clinical decision making challenge in how to proceed when knee MRI and clinical findings don't agree.*

Clinical Features: *A 38 year old female mountain biker presented with knee pain and clinical features strongly suggestive of a torn meniscus or loose bodies. An initial MRI using a small field strength (0.18T) scanner was reported as normal. Her clinical presentation was suspicious enough that a repeat MRI on a high-field (1.5T) scanner was ordered. The second MRI included high resolution 3D volumetric imaging which revealed cartilage damage and loose bodies.*

Intervention and Outcome: *The patient was treated with arthroscopic surgery which confirmed the presence of meniscal and chondral injury and resulted in notable improvement in the patient's symptoms.*

Conclusion: *Clinicians should consider scanner quality and diagnostic accuracy before discounting*

Objectif : *Sensibiliser les cliniciens aux différences de résolution d'image et de précision potentielle du diagnostic entre les petits et grands imageurs par résonnance magnétique (IRM). Présenter un exemple de difficulté de prise de décision clinique quant à la façon de procéder lorsque l'IRM du genou et les résultats cliniques se contredisent.*

Caractéristiques cliniques : *Une vététiste de 38 ans souffre d'une douleur au genou et les caractéristiques cliniques indiquent clairement une déchirure du ménisque ou la présence de corps étrangers. Une IRM initiale à l'aide d'un petit appareil (0,18 T) n'a rien révélé d'anormal. Son tableau clinique était assez suspect pour qu'un nouvel examen par IRM à l'aide d'un appareil de 1,5 T soit prescrit. Le deuxième appareil d'IRM comportait une imagerie volumétrique haute résolution en 3D qui a révélé des lésions du cartilage et des corps étrangers.*

Intervention et résultats : *Le patient a subi une chirurgie arthroscopique qui a confirmé la présence de lésions du ménisque et de lésions chondrales. Une amélioration notable des symptômes du patient a été enregistrée.*

Conclusion : *Les cliniciens devraient tenir compte de la qualité de l'imageur et de la précision du diagnostic avant d'écarter des antécédents cliniques fortement*

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strongly suggestive clinical history and examination findings when MRIs are reported as normal.

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KEY WORDS: MRI, diagnosis, accuracy, knee, injury

évocateurs et les résultats des examens « normaux » effectués par une IRM.

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MOTS CLÉS : IRM, diagnostic, précision, genou, blessure, chiropratique

Introduction

Diagnosis of knee cartilage injury begins with the history and physical examination but often relies on magnetic resonance imaging (MRI) to confirm clinical suspicions and inform the final decision as to whether patients require arthroscopic surgery. In cases where MRI results contradict clinical suspicions, it is not uncommon for clinicians to discard their initial clinical impression due to the general reputation of MRI for high accuracy. It has been our observation that the specifications of the MR scanner and thus the resultant image quality are sometimes overlooked when considering diagnostic accuracy of MRI for cartilage injury. The purpose of this paper is to present a case in which consideration of scanner quality did play a role in the clinical decision making pathway and, combined with history and physical exam, resulted in a favourable outcome for the patient.

Case Presentation

History

A thirty-eight year old female experienced sudden onset of left knee pain while downhill mountain biking as she was negotiating difficult terrain while standing in the pedals. She did not fall from her bike. She described the initial pain as a sudden severe ache which she felt in the posterior knee but did not recall feeling any associated pop or click at the time. The next day, she reported her pain was localized to the posterior knee and was associated with mild knee swelling. She was able to ambulate with a limp, was unable to fully extend her left knee and the pain was much worse when she attempted to twist or rotate on the injured leg while walking.

She was assessed by her family physician and physical therapist who suspected a torn meniscus. She was referred for magnetic resonance imaging (MRI) and a consultation with an orthopedic surgeon. Due to the prolonged waits for publicly funded MRI in British Columbia, the patient opted to pay privately to have her MRI taken. Due to the relatively low cost, she chose a private clinic which utilized a 0.18 tesla (T) low-field strength MR scanner. This MRI was reported as normal and specific comment was made regarding the normal appearance of the menisci, articular cartilage and the absence of loose osteochondral fragments. The patient was subsequently assessed by an orthopedic surgeon who indicated that, based on the lack of MRI findings; she was not a candidate for arthroscopic surgery. The surgeon also felt that the presence of patellar palpatory pain indicated she likely had chondromalacia patella. She was advised to continue with conservative treatment.

At eleven weeks post-injury she presented to the first author's clinic seeking options for conservative care. She continued to be frustrated by her pain which had become more generalized in the knee and was stiff and aching at night. She reported that her knee would occasionally lock in an extended position and would also catch or buckle which, on one occasion, had caused her to almost fall down the stairs. She continued to experience pain with bending or twisting on her affected leg.

Physical Examination

She was unwilling to squat past 50% due to pain and apprehension. Heel and toe walking was unremarkable. Passive knee flexion was limited by 15 degrees due to postero-lateral knee pain. Passive knee extension was full but caused deep lateral knee pain. Palpatory pain was present along the lateral and postero-lateral joint line and in the proximal lateral head of the gastrocnemius. She also had bilateral palpatory pain of the inferior poles of the patellae.

Orthopedic exam was notable for deep lateral and posterior knee pain with McMurray's test and Thessaly's test. Valgus knee stress produced lateral knee pain without any valgus laxity. No pain or laxity was present with varus stress, Lachmann's, posterior drawer or patellar apprehension tests.

Management

Her history, symptoms and physical exam findings were highly suggestive of internal derangement of the knee such as a meniscal tear or osteochondral fragment. Strong clinical indicators and the knowledge that the MRI was performed on an older low-field MRI scanner raised concern that the resolution may have been insufficient to detect the injury in this case.

The MR images were sent for a second-opinion with a radiologist specializing in advanced imaging who agreed with the findings of the first report but also commented on the relatively poor image quality. The patient was counselled in this regard and the recommendation was made to obtain a new private MRI on a 1.5 T scanner. The second MRI revealed marked irregularity involving the undersurface of the posterior horn of the lateral meniscus with multiple loose bodies. Chondromalacia patella was also present.

She was referred to a second orthopedic surgeon who performed arthroscopic surgery 5 months post-injury. Arthroscopy revealed: 1) a grade 3 osteochondral defect in the medial femoral condyle measuring 1 cm x 1.25 cm. There was no evidence of full thickness cartilage loss, 2) lateral meniscal damage, 3) grade 3 chondromalacia patella, 4) loose debris. The medial condyle defect was stabilized at its edge and the loose debris removed.

Results

One month post-surgery she reported feeling an obvious absence of catching or giving-way in her knee. Rehabilitation was undertaken including range of motion exercises, stretching, strengthening and soft tissue therapy for the hip, thigh and knee. For several months she continued to have pain on stairs and with exercise which limited her participation in some sports. This may have been related to residual synovitis or cartilage damage in the patella, condyle and meniscus. On follow-up one year post-surgery she had returned to mountain biking and skiing but still experienced some discomfort with running.

Discussion

MRI has become second only to arthroscopy in diagnostic accuracy for internal knee derangements such as meniscal damage. A systematic review by Crawford et al.[1] reported sensitivity and specificity as 91.4% and 81.1% respectively in diagnosing medial meniscal damage and 76% and 93.3% respectively in diagnosing lateral meniscal damage. Some authors[2,3] have reported that low-field MR scanners have similar accuracy to their high-field counterparts in diagnosing meniscal tears while a systematic review by Oei et al.[4], using receiver operating characteristic curves, demonstrated some superiority in accuracy of high-field versus low-field scanners for diagnosing knees. Sensitivity for diagnosing chondral lesions of the knee has been reported as being considerably lower (45%-69%).[5-7] Most notably, defects affecting less than 50% of the hyaline cartilage thickness (grades 1-2) are particularly difficult to resolve even with high-field strength MR scanners.[5,7] We would expect that for many conditions, diagnostic accuracy would be affected by the ability of an MR scanner to produce images with detailed resolution.

Physical examination is generally regarded to be lower in diagnostic accuracy compared to MR for torn menisci. In a meta-analysis by Hegedus et al.[8], pooled sensitivity and specificity values were 70% and 71% for McMurray's, 60% and 70% for Apley's, and 63% and 77% for joint line tenderness. Reported accuracy was reduced in ACL deficient knees. Less research is available for Thessaly test but sensitivity and specificity have been reported as approximately 90% and 97% respectively by two studies.[9,10] Thessaly test in ACL deficient knees is less accurate with sensitivity and specificity of 79% and 40%.[11] We are not aware of studies which assessed diagnostic accuracy of physical exam procedures for chondral injuries or loose bodies making the relative value of physical exam compared to MRI uncertain for these diagnoses.

Clinicians who refer for MRIs should be aware that variations in image resolution exist between various scanners. Magnet static field strength, gradients, coil elements and protocols all play a role in determining the ability of a particular scanner to provide sufficient detailed images and appropriate diagnostic information. Image resolution can be divided into spatial and contrast resolution. Contrast resolution is effectively determined by the types of sequences that are selected by the MRI facility. Most commonly T1, T2, and gradient based MEDIC sequences are employed. Often fat saturation (FS) is used to eliminate the bright signal from fat and to make edema apparent. No standard sequences have been defined for joint imaging and thus the selection of prescribed sequences, slice thickness, and qualitative appeal of image quality is usually derived by the reading radiologist, or more commonly by the technologist operating the scanner. The critical interplay between slice thickness (spatial resolution), and sequence selection is always offset by scan time. MRI scans, even with high-field scanners, are rarely three-dimensional (3D) image acquisitions and thus the selected image planes for acquiring each sequence is predefined by radiologist preference, with guidelines provided by experts in the field, and publications. For example, in one radiology text[12], the lateral meniscal thickness is described as being 3 to 4 slices thick on sagittal plane images and image slice thickness is described to be 4-5 mm thick. Thus orthogonal plane images are required to ensure adequate representation of all the tissue in question.

Comparisons of the slice and gap thickness, spatial resolution and sequence times for each scanner are presented in Table 1. The slice thickness and resolution can be seen to provide more images and detail on the higher field magnet. Resolution values are given in two dimensions but when multiplied by slice thickness they provide a pixel volume referred to as a voxel. Smaller voxels translate to more detailed resolution of the MRI. The highest detail created by the high-field scanner used in this case study was produced in the axial 3D high resolution sequence resulting in a voxel size of 0.18 mm^3. The resolution provided by this sequence was 8.4 times more detailed than the best resolution provided by the low-field magnet. The images of the low-field magnet have thicker slices which volume average together – giving more blur, coupled with gaps without any imaging, which can lead to important information being missed. Figure 1 visually compares two similar axial slices of the same knee taken from each scanner, the high-field image showing the loose debris missed by the low-field image. Scan times for the high-field scanner are also shorter for each sequence which is important because motion at any point during the image acquisition will result in the entire sequence being discarded. In this case presentation, the patient's initial normal reported study was performed on a low-field magnet, which took approximately 45 minutes to complete including non-imaging scanner preparation time while the repeat study took 25 minutes to complete.

As stated above, not all high-field scanners utilize 3D high resolution volumetric imaging. This technology allows equal image detail in every axis and was not available from manufacturers until approximately 2008. Among the scanners manufactured with this capability, not all imaging centres implement the 3D high-resolution protocols. Therefore, knowledge of scanners' capacity for high resolution 3D volumetric imaging may also aid clinicians in their decision making, particularly with regards to chondral injuries for which the reported diagnostic accuracy of MRI is known to be lower.

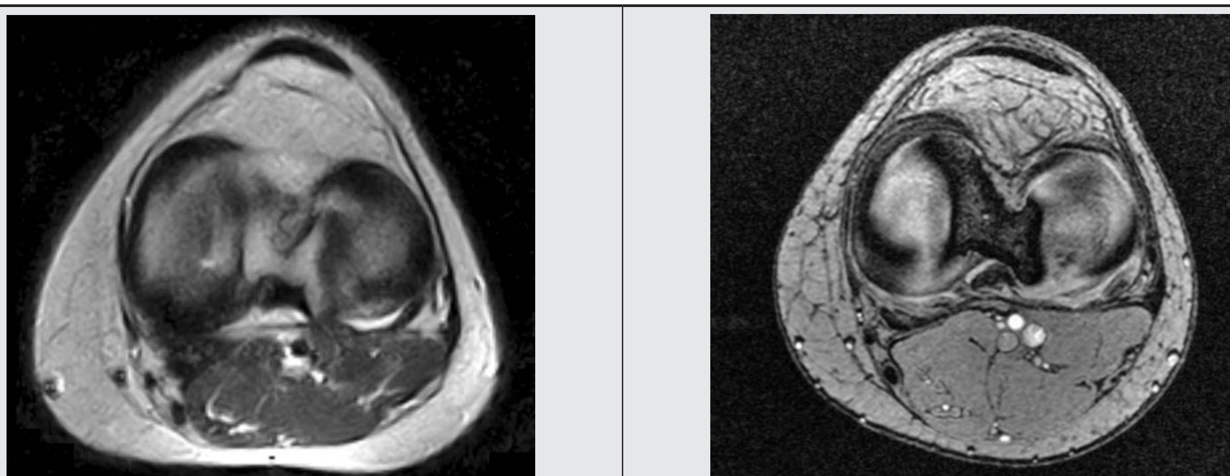
Table 1
Comparison of Spatial Resolution Between 0.18 T and 1.5 T MR Scanners

High-Field Scanner (Siemens Espree 1.5T)				
Sequence	**Slice Thickness (mm)**	**Slice Gap (mm)**	**Resolution (mm)**	**Acquisition Time**
Axial T2 Gradient	3.5	0	0.6 x 0.5	4:20
Sagittal PD Fat-Sat	3	0	0.6 x 0.5	4:24
Coronal T2 Fat-Sat	3	0	0.6 x 0.5	4:04
Coronal T2 Gradient	3	0	0.6 x 0.5	4:03
Sagittal T1	3	0	0.5 x 0.4	4:06
Axial 3D Hi-Res	0.6	0	0.6 x 0.5	4:11
Low-Field Scanner (ESAOTE Artoscan-C 0.18T)				
Sequence	**Slice Thickness (mm)**	**Slice Gap (mm)**	**Resolution (mm)**	**Acquisition Time**
Sagittal T1 Hi-Res	3	0.4	0.90 x 0.56	~7:51
Sagittal T2	3.5	0.9	0.83 x 0.80	~6:66
Coronal T2	4	0.4	0.83 x 0.83	~6:12
Coronal Fat-Sat	5	0.5	1.08 x 0.89	~7:07
Axial T2	4.5	0.9	0.78 x 0.78	unknown

Conclusion

We have presented a case in which meniscal damage and loose bodies in the knee were not detected on a low-field (0.18 T) MR scanner but were revealed by a higher field (1.5 T) magnet with superior contrast and spatial image resolution. The initial low-field MRI study which was reported as normal due to the lack of resolution led to discounting the patient's symptoms by an orthopedic surgeon and prolonged patient suffering.

Figure 1
Comparison of image resolution between 0.18 T and 1.5 T MRI.



ESAOTE Artoscan-C (0.18 T)	Siemens Espree (1.5 T)
These two equivalent images were taken of the same knee within two months of one another. The high-field strength MRI can be seen to provide greater detail. The white arrow indicates where loose debris in the posterior portion of the lateral compartment of the knee. Other differences in anatomic appearance are due to slice thickness and volume averaging.	

We hope this case will raise clinicians' awareness of variability in scanner resolution when making referrals for MRI and when considering diagnostic accuracy of an MRI. Consideration should be given to scanner quality before discounting strongly suggestive clinical history and examination findings when MRIs are reported as normal.

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Ulnar Impaction Syndrome: A case series investigating the appropriate diagnosis, management, and post-operative considerations

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Ulnar sided wrist pain is a common site for upper extremity disability. Ulnar impaction syndrome results in a spectrum of triangular fibrocartilage complex (TFCC) injuries and associated lunate, triquetrum, and ligamentous damage. Patients commonly present with insidious ulnar sided wrist pain and clicking, and a history of trauma or repetitive axial loading and rotation. In this case series, three patients presented to a sports chiropractor for evaluation and were subsequently diagnosed with ulnar impaction syndrome. Treatment strategies consist of conservative management, arthroscopic debridement or repair, arthroscopic wafer procedure, or ulnar shortening osteotomy. For the athlete, intervention should be

Une douleur cubitale du poignet est une manifestation courante d'un handicap de membres supérieurs. Le syndrome d'impaction cubitale entraîne une série de lésions du complexe fibrocartilagineux triangulaire (TFCC) et des lésions connexes de l'os semi-lunaire, du cartilage aryténoïde et des ligaments. Les patients souffrent habituellement d'une douleur insidieuse au poignet du côté cubital et de craquements de l'articulation, ainsi que de traumatismes ou de compressions et rotations axiales répétées. Dans cette série de cas, trois patients se présentant à un chiropraticien de sport pour une évaluation ont ensuite reçu un diagnostic du syndrome d'impaction cubitale. Les stratégies thérapeutiques comportent le traitement conservateur, le débridement ou la réparation arthroscopique, la résection arthroscopique de la partie distale, ou l'ostéotomie de raccourcissement cubital. Pour l'athlète, l'intervention doit être adaptée et

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individualized and sport-specific, considering athletic priorities, healing potential, return to play, and long-term health concerns.

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KEY WORDS: ulnar impaction, abutment, TFCC injury, athlete(s), management, chiropractic

indiquée pour son sport en tenant des priorités du sport, du potentiel de guérison, de la possibilité du retour au jeu et des problèmes de santé à long terme.

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MOTS CLÉS : impaction cubitale, soutien, lésions TFCC, athlète, traitement, chiropratique

Introduction

Hand and wrist injuries are common among athletes. Current literature reviews suggest a rate of 3-9% of all sports injuries involve the hand or wrist, with 25-50% recognized as overuse injuries.[1,2] Ulnar impaction syndrome, or ulnocarpal abutment, is a common degenerative condition causing ulnar-sided wrist pain.[3] Biomechanical changes causing excessive loading across the ulnocarpal joint are responsible for a spectrum of pathological changes involving the triangular fibrocartilage complex (TFCC) and articular surfaces of the ulnar head, lunate, and triquetrum.[4,5,6]

Ulnar-sided wrist stability is enhanced via the TFCC, an arrangement of ligaments and fibrocartilage originating from the sigmoid notch on ulnar border of the radius and inserting into the base of the ulnar styloid and fovea of the ulnar head.[7] It continues distally into the lunate, triquetrum, hamate, and base of fifth metacarpal, and connects with the ulnolunate and ulnotriquetral ligaments and extensor carpi ulnaris (ECU) tendon subsheath.[7,8] The lunotriquetral ligament, a weak intrinsic ligament of the wrist, is also commonly disrupted with progressive degenerative ulnocarpal impaction.[2,9] The TFCC is composed of a rich peripheral arterial supply at the outer 10-40% of the articular disc, and a near avascular central triangular articular disc lying between the ulnar head, lunate, and triquetrum.[7,10] The arterial supply of the TFCC guides subsequent treatment options, as the central and radial portions of the TFCC have significantly limited healing ability following injury.

The TFCC is responsible for stability across the distal radioulnar joint (DRUJ). Palmer and Werner (1981) demonstrated ulnar neutral wrists transfer approximately 18% of the total load applied, with the radiocarpal joint transferring 82% of the total load. A direct relationship between increasing ulnar length and increased force transmission across the TFCC exists. A positive variance of 2mm will increase the ulnocarpal load to approximately 40%.[3,11] Increased dorsal tilt due to previous injury of the radius can additionally increase the ulnar load to 65% of total load transferred.[11] Further, thinning of the articular disc has been shown to accompany increased ulnar variance, increasing risk of TFCC wear and perforation.[12] Although most commonly associated with congenital or acquired positive ulnar variance, ulnar impaction can also occur in ulnar neutral or negative ulnar variance wrists.[5,13,14] Dynamic variance can present with maximal grip and pronation, directly implicating athletes performing power-gripping tasks associated with axial loading and rotation.[15] Immature athletes under these demands are at a heightened risk for premature physeal arrest of the distal radius, and subsequent ulnar impaction.[4] The diagnosis relies heavily on clinical examination and secondary radiographic studies, and has been classified based on pathoanatomical change resulting from progressive deterioration of the TFCC, as well as degenerative changes within the dome of the ulnar head, lunate, triquetrum, and lunotriquetral ligament (LTIL).[11,15]

This case series illustrates the appropriate diagnosis and management of three patients presenting to a sports chiropractor with ulnar sided wrist pain. The report outlines pathophysiological changes occurring with ulnar impaction syndrome, and demonstrates the effective management strategies available based on individual considerations concerning healing, return to play, and long-term health.

Figure 1.
Radiographic imaging from case 1 revealing sclerosis with indentation of the ulnar side of the proximal articular margin on the lunate.

Case Series

Case 1

A seventeen year old student and competitive boxer presented to a sports chiropractor with a 6-month complaint of left sided wrist pain. The pain had come on progressively and he related it to "over-exertion/over training". Specifically the patient's complaint was aggravated by punching, standard push-ups and plyometric push ups repeatedly in training. In addition, tournaments with multiple fights in a few days also aggravated his complaint. The patient had seen his family doctor who diagnosed a sprain and prescribed the anti-inflammatory arthrotec and rest. The patient only used the medication for a short period and found minimal improvement. At the time of presentation the patient had been on 3 months relative rest excluding push ups and punching bag from his training. He did not complain of clicking or locking and had no difficulties with activities of daily living such as opening jars, doors etc. The patient stated his intention was not to come for treatment but a second opinion on why a sprain would take so long to heal.

Upon physical examination active, passive and resisted wrist range of motions were unremarkable for pain or deficits. Specific palpation over the distal ulna, pisiform, lunate and triquetrum were positive producing a jump sign. An attempt to do push-ups during the exam also caused the patient significant pain. Joint line palpation of the TFCC appeared to be less tender than bony palpation and ulno-carpal stress test was unremarkable.

Radiographs were ordered for the left wrist due to the positive exam findings despite three months of prolonged rest. The differential diagnosis included chronic ulnar impaction syndrome, ulnar styloid impaction, growth plate injury, and TFCC injury.

Radiographs shown in Figure 1 revealed neutral ulnar variance, and sclerosis with indentation of the ulnar side of the proximal articular margin of the left lunate, consistent with ulno-lunate impaction syndrome.

The patient was advised to continue his relative rest in training while referral to a sports medicine physician was initiated to consider further advanced imaging and management options. Further imaging was necessary for additional confounding factors such as TFCC injury or growth plate injury. The MRI showed intermediate to high signal on the T2 fat saturated sequence at the distal insertion of the triangular ligament on the ulnar styloid. A tiny partial tear of the TFCC 1-2mm could not be completely excluded. There was mild increased signal across the epiphyseal plate of the distal ulna. This could indicate a subtle Salter type 1 or 5 non-displaced fracture. Therefore continued relative rest and monitoring was indicated. The patient was encouraged to keep working out at his club but to specifically rest from punching the bag, sparring with opponents and to avoid push ups or other exercises where the hands and wrists become weight bearing.

Following eight months of relative rest the patient returned to his sports physician and his exam findings had returned to normal. He had recently initiated a return to full training including punching the bag and sparring. His case will require some additional clinical monitoring to determine if his wrist will handle full training and competition. Continued rest from push ups with the wrist extended position is recommended with a focus on allowing recovery following aggressive work outs or competition.

Figure 2 and 3:
Wrist ulnar deviation and PA views reveal positive ulnar variance of 5mm with incongruity of the DRUJ, as a sequela of previous distal radius fracture. An ossicle is also noted at the ulnar styloid process.

Case 2

A 26-year-old male chiropractic student presented to a chiropractor with a complaint of developing right wrist pain and stiffness following initiation of Mixed Martial Arts classes over a four-month period. The primary complaint was increased pain following repetitive punching at a stationary bag, and had increased in intensity over this period. Opening doors and weight bearing in extended positions would also aggravate his complaint. The pain was between 3/10 at rest and 8/10 when aggravated. The patient reported relief with rest. Previous trauma included a distal radius growth plate fracture and distal ulna fracture from a fall on an outstretched arm at the age of 13 years, in which the patient did not note long-term deficits. He also reported a history as a card dealer four years prior, where he occasionally experienced sharp ulnar sided pain while dealing. Further, two years prior to assessment, he received radiographic evaluation from his medical doctor, which was described to be unremarkable. During the current examination, minor swelling was noted at the distal radioulnar joint. Active, passive, and resisted wrist ranges of motion revealed discomfort during all movements involving extension, supination, and pronation. Upper limb closed-chain exercises were challenging, with the patient reporting apprehension during these exercises. The chiropractor requested radiographic imaging of the wrist, revealing a positive ulnar variance of 5mm with incongruity of the distal radioulnar joint, resulting from the previous radius fracture (Figure 2 and 3). The patient was referred for subsequent orthopaedic evaluation, where the surgeon suggested a right ulnar osteotomy shortening and TFCC debridement procedure (Figure 4 and 5). Following the operation, a splint was utilized for five days, after which gentle active and passive wrist range of motion exercises commenced. After a few weeks, gentle grip strength exercises at various wrist flexion and extension angles were used to replenish hypothenar atrophy resulting from the injury. Five months following the procedure, the patient

Figure 4 and 5:
Demonstrates successful ulnar osteotomy procedure, with ulnar variance decreased to neutral, and osteotomy procedure further increasing stability of the DRUJ joint.

reported mild ulnar sided wrist pain, when initiating his chiropractic career. Acupuncture (TH-4), with needle insertion on the dorsal ulnar aspect of extensor digitorum, relieved this complaint. Currently, 30 months following the operation, this pain has only recurred once and was again relieved with simple acupuncture therapy. Current limitations include minor restrictions in active and passive supination. There is occasional clicking near the TFCC and remaining apprehension during closed chain upper limb exercises with an extended wrist, such as planks and push-ups. The patient currently maintains working on shoulder centration exercises while maintaining quadruped position, with varying center of gravity. Concurrent grip strength exercises, Turkish get-ups, and Farmer carries are also significant positive influences in the rehabilitation process.

Case 3

A 27-year-old male chiropractic student presented to a chiropractor with 10 days of moderate to severe left ulnar sided wrist pain, which started when catching a rolling ground ball during a baseball game. The patient rated the pain at 9/10 following this incident, and could not use his left hand in the shower when attempting to wash hair. At presentation, the pain had decreased to 2/10, with increases in intensity following tobacco farming. He had a long history of tobacco farming, which consists of repetitive ulnar deviation, long days of physical work, and heavy lifting. He also reported an active history of hockey, volleyball, and golf, with repetitive minor wrist sprains bilaterally. Upon physical examination, no visible bruising or scarring was evident. Digital palpation of the distal left ulna and ulnar collateral ligament was very painful. Ranges of motion were full and pain free; except for ulnar deviation limited 50% due to increased pain at the ulnar aspect of the wrist. Grip strength was unremarkable. The patient was sent for radiographic studies and diagnostic ultrasound, in order to examine the integrity of the dis-

Figure 6 and 7:
PA left wrist (Figure 6) demonstrates presence of ulnar styloid fracture and ulnar styloid impaction syndrome, with ulceration and cyst formation depicted within the triquetrum pre-operative. PA left wrist (Figure 7) demonstrates imaging following subsequent ulnar styloidectomy.

tal radioulnar joint, ulnar collateral ligament and TFCC. Diagnostic ultrasound was unremarkable. Radiographs demonstrated a fracture of the ulnar styloid and signs of subchondral cyst formation within the triquetrum (Figure 6 and 7), consistent with ulnar impaction. At this time, the patient was referred to an orthopaedic surgeon, and a subsequent ulnar styloidectomy was performed, removing fractured pieces under anesthesia and shaving the ulnar styloid. The wrist was then casted for three weeks. Mild atrophy globally and severe stiffness was present throughout the wrist following casting, and the patient re-visited the chiropractic clinic, presenting with moderate swelling, tenderness, and redness at the excision site (approximately 4cm in length). Supination and pronation was decreased 50%, with flexion and extension decreased by 25%. The patient was treated with Graston Technique (GT)®, microcurrent, myofascial release techniques, and active and passive range of motion strengthening three times a week for eight weeks. At follow-up, he reported 90% strength and range of motion globally, and was able to resume normal working duties with only mild to moderate discomfort. The patient received intermittent GT® on scar tissue and passive range of motion exercises for another month, when he then returned to full working duties with great success. At 42 months follow-up, the patient is a working chiropractor, reporting no pain, and full strength and range of motion of his left wrist and arm. While exercising in a loaded closed-chain position, he focuses on maintaining neutral wrist position.

Discussion

Ulnar sided wrist pain is a common cause of upper extremity disability, a host site for many traumatic and chronic degenerative conditions.[16] Ulnar impaction syndrome is a progressive degenerative condition, most commonly resulting from repetitive abutment of a lengthened ulna, with the TFCC, lunate, triquetrum, and lunotriquetral ligament. The relative length of the ulna compared to

Table 1
*Palmer and Werner Classification of traumatic and degenerative conditions of the TFCC *L-T: lunotriquetral ligament*

Class I: Traumatic	
A	Central perforation
B	Medial avulsion (ulnar attachment) with or without distal ulnar fracture
C	Distal avulsion (carpal attachment)
D	Lateral avulsion (radial attachment) with or without sigmoid notch fracture
Class II: Degenerative (Ulnocarpal Impaction Syndrome)	
A	TFCC wear
B	TFCC wear + lunate and/or ulnar chondromalacia
C	TFCC perforation + lunate and/or ulnar chondromalacia
D	TFCC perforation + lunate and/or ulnar chondromalacia + L-T* ligament perforation
E	TFCC perforation + lunate and/or ulnar chondromalacia + L-T* ligament perforation + ulnocarpal arthritis

the radius is expressed as ulnar variance, where neutral variance is dictated by a difference of less than 1mm from the radius.[17] Although a wide distribution occurs within the population, developmental positive ulnar variance is cited to be relatively more common in Asian and black populations than Caucasians.[16, 18] Athletic events requiring repetitive compression and rotation demands on the upper extremity may also predispose a patient to ulnar impaction via traumatic development.[19] Distal radius fractures are the most frequent occurring fracture in children under 16 years of age[20], with shortening of radial length greater than 5mm considered to lead to long-term functional impairment[20, 21]. This was certainly involved in the development of ulnar impaction in case 2. Authors have reported TFCC tears in 43-80% of patients following distal radius fractures, with majority of peripheral TFCC tears demonstrating DRUJ instability.[22,23] Post-traumatic shortening of the radius following distal radial fractures is associated with lengthening of a previously asymptomatic, long, or beaked ulnar styloid; resulting in concomitant impaction of the ulnar styloid on the proximal aspect of the triquetrum and ulnar-side of the lunate.[14] This is referred to as ulnar styloid impaction syndrome, and may be present alone, or in combination with ulnar impaction syndrome, and commonly developing with repetitive ulnar deviation and dorsal flexion.[14] This was noted within the third case of this case series, likely due to repetitive rotational demands during tobacco farming. Further, in absence of distal radius fractures, submitting an immature wrist to prolonged compression and repetitive microtrauma has demonstrated premature arrest of radial growth plate and subsequent ulnar overgrowth.[17, 24-26] Our first case highlighted the need for appropriate prolonged rest periods in the adolescent athlete.

Ulnar impaction syndrome results in progressive degeneration and increased abutment of the distal ulna or TFCC against the ulnar carpus. Although a precise incidence of TFCC injury is unknown; gymnasts, boxers, racquet and stick sports are said to report “fairly common” injury of TFCC.[10, 20] These athletes generally present with a history of axial loading on a pronated wrist, and pain provocation during wrist rotation. Particularly, the load bearing attributes of the TFCC increases susceptibility towards acute traumatic injury, as well as secondary degenerative concerns implicated with ulnar impaction[8]. In the second case, distal radius trauma in combination with load bearing activity were factors in the progression of TFCC degeneration, and such necessary debridement during osteotomy procedure. The TFCC is exposed to a spectrum of acute and degenerative pathoanatomical changes, as originally described in 1981 by Palmer and Werner (Table 1). This classification system reveals the progressive and additive nature of degenerative TFCC injuries, as increased impingement occurs between the ulnar head on the triquetrum and ulnar aspect of the lunate.[24] Traumatic injury of the TFCC usually affects the peripheral disc, whereas degenerative tears most commonly impact the central disc.[2] The first case also showed signs of a small tear using MRI but it could not be confirmed with this image alone.

A detailed history and focused physical examination are critical components for diagnosing TFCC injury due to ulnar impaction in the athlete. Chronic pain caused by repetitive loading of the wrist, with painful clicking or locking during pronation and supination are often present[8], pain is aggravated with activity, and generally relieved with rest. As opposed to acute events generally associated with class I traumatic TFCC tearing, athletes present with insidious, progressive pain limiting range of motion, grip strength, and performance.[4] The history of the patient in case 1 and 2 was very similar to this expected athletic presentation.

Many provocative manoeuvres have been described to help diagnose TFCC injury. Ranges of motion should be evaluated, with ulnar deviation and pronation often pain-producing. Gripping motion also elicits pain subsequent to TFCC injury and grip strength is usually decreased compared with the unaffected wrist.[8] Tenderness of the TFCC during palpation distal to the ulnar styloid and proximal to the pisiform, between the tendons of the ECU and flexor carpi ulnaris (FCU) indicates a positive ulnar fovea sign.[2] The ulnocarpal stress test, originally introduced by Nakamura (1991) involves combined dorsiflexion, axial loading, and ulnar deviation or rotation of the wrist. In the authors' original study, 33 of 45 patients with positive ulnocarpal stress tests demonstrated positive ulnar variance of 1mm or more on the affected wrist during standard posterior-anterior (PA) views. Further, class II TFCC lesions resulting from ulnocarpal impaction were confirmed in 19 patients, or 57.8% of those demonstrating positive ulnar variance. The majority of these patients suffered a spontaneous onset of pain, and were diagnosed with class IIB lesions involving TFCC wear with lunate and/or ulnar chondromalacia. However, positive ulnocarpal stress testing is sensitive for a variety of intra-articular ulnar wrist pathology[16], and is not specific for the diagnosis of ulnocarpal abutment syndrome[4, 24]. A positive supination lift test, with patient "lifting" examination table with palms flat on undersurface of table, can further suggest peripheral dorsal tear of the TFCC[2]. During a positive piano key sign, the athlete forcefully presses palms into examination table while the clinician observes for increased dorsal-palmer translation of DRUJ, which may suggest instability. Impairment of the articular disc and longitudinal instability of the DRUJ occur simultaneously and must be investigated.[12] Overall, a detailed history of spontaneous ulnar sided wrist pain combined with provocative testing should prompt the astute clinician to further radiologic evaluation, as the chiropractor promptly ordered in all of the above cases.

When expecting possible ulnar impaction syndrome, radiographic series include standard zero rotation posterior-anterior (PA) and lateral views. Although ulnar positive wrists will demonstrate ulnar impaction, ulnar neutral and negative wrists are also at risk due to dynamic variance, in which forearm pronation and forceful gripping have been shown to increase ulnar variance.[15, 27] Therefore, in addition, a pronated grip PA view is often performed to best demonstrate increased ulnar variance. This is critical as the presence of ulnar variance impacts future treatment decisions for the athlete, and an accurate diagnosis can prompt appropriate management considerations, including further imaging. Conventional radiographs can detect the presence of positive ulnar variance, ulceration or cyst formation within the ulnar base of the lunate and/or triquetrum, and joint incongruency of the DRUJ.[16, 24] Further, the presence of a prominent ulnar styloid must be noted as this may affect surgical treatment, with wafer resections incapable of resolving ulnar styloid-carpal impaction.[4] MRI can be helpful to further detect radiologically occult lesions. MRI has reported 72-100% sensitivity, 90% specificity, and 92% localization capability of TFCC tears[28, 29], however detection of peripheral tears and experience of interpreting radiologist significantly influence the ability to detect and localize TFCC injuries[30]. Softening, fibrillation, or partial thickness defects within the articular cartilage are more difficult to detect, as well as degeneration within the lunotriquetral ligament.[14] The gold standard imaging for localizing TFCC injuries is considered to be wrist arthroscopy, which serves as treatment at time of diagnosis, and reports 88-100% sensitivity.[8,16,24] Arthroscopy also provides detailed information regarding ligamentous lesion size if present, while distinguishing partial and complete tears of the TFCC.[14, 24]

Treatment

Athletes may benefit from earlier intervention in an effort to return to play more rapidly, or may delay intervention based on athletic aspirations and timing.[4] Individualized treatment plans must be formulated with the surgeon, including potential postponement of surgical options following the season when injury is not disabling. Early diagnosis and intervention have been claimed to reduce the risk of long-term disability and injury progression[2,6,8,31], with early arthroscopy and peripheral TFCC repair recommended for cases of DRUJ instability[10,20]. During the athletic season, treatment typically begins with modified activities, non-steroidal anti-inflammatories, bracing, and physical therapy to decrease patient symptomology, with corticosteroid injections offered if extended rest is not effective.[4] Park and colleagues[32] reported 57% of patients with TFCC injury to achieve resolution of symptoms following four weeks of immobilization. Although effective for the general population, immobilization alone will not address altered biomechanical concerns in the athlete. Ultimately, in order to decrease load experienced across the ulnocarpal joint, ulnar variance must be adjusted with surgical treatment. Arthroscopic options include TFCC debridement and/or repair, or arthroscopic wafer technique. Open procedures include the ulnar-shortening osteotomy (USO) and more advanced techniques in presence of significant ulnocarpal arthritis present within class IIE lesions.[4]

Arthroscopic debridement or repair may be appealing for midseason athletes secondary to benefit of shorter recovery time.[33, 34] Central tears are often debrided due to lack of blood supply, whereas peripheral TFCC injuries warrant repair based on adequate vascular supply and increased symptomology.[2] Type IA lesions, tears within the central articular disc, and type IIC lesions, associated with articular disc perforations, are therefore commonly treated with debridement. The success rates in the literature range from 66 to 87%.[19,33,35] Generally speaking, arthroscopic repair of peripheral tears involves increased immobilization and delayed rehabilitation as compared to central tears due to the influence TFCC function on DRUJ stability.[19] USO remains a successful secondary procedure for persistent pain following debridement or repair of TFCC.[19] Following arthroscopic debridement alone, patients are immobilized for one to two weeks prior to initiating limited range of motion.[19] Strengthening begins when near normal active range of motion is obtained. Return to modified play can occur as early as three weeks following intervention, where 80% strength and motion gains are advisable.[9,10,20,36] Some athletes may return to modified sport tasks within four to five weeks, with the exception of those involving high axial loading, such as gymnastics and boxing.[8] In a specific evaluation of 16 National Collegiate Athletic Association (NCAA) athletes with a required high level of wrist function, McAdams and colleagues[37] reported an average return to play of three months with significant improvements in DASH (Disabilities of the Arm, Shoulder and Hand). All patients underwent six weeks immobilization, followed by six weeks of progressive range of motion and strengthening exercises with full return to sport permitted at three months. The two athletes unable to return to sport at three months had associated ulnocarpal impaction and DRUJ instability. Long-term follow-up studies are needed in order to document the durability of arthroscopic procedures, as well as evaluate long-term outcomes as related to pain and grip strength. Athletes with ulnar impaction syndrome must also recognize further surgical intervention to address ulnocarpal impaction is likely necessary, with debridement failure at 13-60% in the ulnar positive wrist.[6,16,19,33]

Arthroscopic wafer procedures, originally described by Feldon and colleagues[38], can be performed in combination with debridement, or at a later date. This procedure can be performed in type IA, IIC, and IID TFCC injuries demonstrating less than 2mm ulnar positive variance, and without associated lunotriquetral instability.[4,19] Arthroscopic wafer procedures include partial excision of the distal dome of the ulna until fluoroscopy indicates -1 to -2mm variance.[6, 27] The articular surfaces of the lunate and triquetrum are also evaluated, with loose cartilage resected.[19] The athlete is generally splinted for two weeks following intervention, with in-sport splinting and gradual range of motion encouraged.[8,19] Gradual range of motion is dictated by patient comfort, with strengthening initiated at four weeks.[19] A large percentage of patients report symptom free eight weeks following surgery[27,34], although return to full activity has been reported from six weeks to seven months[6,27,39]. Wafer resections may be preferred over USO in patients with concern for non-union or hardware irritation.[19] Rare complications such as postoperative tendonitis, and inadequate ulnar head resection with overzealous debridement of TFCC, leading to DRUJ instability, have been reported within the literature.[19]

USO are indicated when positive ulnar variance exceeds 2mm, with associated lunotriquetral instability, or the presence of ulnar styloid impaction.[4,14] This was indicated in case 1. Surgeons perform an oblique osteotomy at the distal ulna and complete fixation with a compression plate.[7] Historically, patients presenting with ulnar-positive and ulnar-neutral wrists suffering type IIA and IIB lesions of the TFCC are offered a USO to decrease the total load across the ulnar side of the wrist.[7] In type IID lesions, associated with lunotriquetral interosseous injury, USO is performed to increase stability via tightening of the extrinsic wrist ligaments.[40] Type IIE lesions are associated with ulnocarpal arthritis, in which wafer procedures and USO are contraindicated, requiring salvage procedures due to extensive damage and instability.[7] Multiple studies report improved pain, range of motion, and function following USO, with good to excellent results reported in 89-94% of patients.[41,42] Symptomology greater than six months prior to USO has been shown to dampen results, possibly secondary to irreversible pathological changes in the wrist.[41] Patients are immobilized for a week followed by casting for four to six weeks, with gentle forearm motion and grip strengthening encouraged immediately following surgery.[2,4] Passive range of motion begins as split is discontinued, with isometric strengthening initiating at eight to ten weeks, progressing to weight bearing and plyometrics.[2] Literature suggests that approximately 50% of patients may require hardware removal[6], causing further avoidance of contact sport and weight bearing. The patient in case 1 has not reported any concurrent hardware complaints at follow-up. The principal risk for non-union is reported at 0-5%, and is increased in the smoking population.[4,16] Baek and colleagues[43] investigated long-term results of USO in 36 patients, with excellent clinical outcomes in pain, range of motion, and function greater than five years postoperatively, even within 16% who demonstrated radiographic arthritic changes of the DRUJ. More recently, a retrospective case series of 33 patients following USO were assessed at average follow-up of 10 years, with 88% reporting satisfied to very satisfied with the procedure, accounting for 30% of patients who required hardware removal.[44]

A single prospective trial has investigated the effects of low-intensity pulsed ultrasound (LIPUS) on bone healing at osteotomy sites in 27 patients following forearm shortening for stimulating cellular biochemical events to promote bone formation.[45] Patients were randomized to LIPUS (1.5MHz and $30mW/cm^2$) or without LIPUS (control), with the intervention group receiving daily 20-minute treatments at one week post-operatively until at least 12 weeks post-operatively. Cortical union represented with disappearance of interruption of cortex with callus formation, and endosteal union with obliteration of osteotomy line with endosteal callus were assessed. Although all osteotomies achieved complete union, the LUPUS group demonstrated shortened time to cortical union by 27% ($P = 0.012$) and endosteal union by 18% ($P = 0.019$), providing opportunity for earlier return to activity and work, with no complications identified. No differences in pain, range of motion, grip strength, or functional status occurred between groups at time of radiographic union. These findings support previous research on distal radius fractures and accelerated tibial fracture healing[46, 47], and should be considered post-operatively following ulnar osteotomies. Further randomized, prospective controls demonstrating reproducibility of results are important to determine the efficacy of such treatment for promoting early return to play in athletes undergoing ulnar osteotomies.

Studies evaluating the results of arthroscopic wafer procedure for ulnar impaction syndrome have shown similar favourable results as compared to USO.[19] Contstantine and colleagues[48] compared clinical outcomes of USO and wafer procedure, finding similar results in pain relief and wrist function, with USO requiring more revision procedures and delayed healing. Bernstein and colleagues[6] concluded that combined debridement and wafer procedure provided similar results to USO in 27 patients with statistical differences in complications rate, favouring the wafer procedure. Papapetropoulos and colleagues[49] prospectively reviewed data in 51 patients up to 24 months postoperatively, reporting no statistical significant difference in range of motion, grip strength, and DASH and VAS scores between USO and wafer procedure. Although larger prospective trials are needed, the best available evidence supports wafer resection to be an equally effective treatment for ulnar impaction as compared to USO, while avoiding potential hardware complications, repeat procedures, and delayed healing risks.[5]

Conclusions

Ulnar impaction syndrome is a common cause of a spectrum of pathoanatomical changes to the distal radioulnar joint (DRUJ). Scientific data regarding the treatment of peripheral TFCC lesions and ulnar impaction syndrome are limited to relatively small sample sizes, in which the distinction between traumatic and non-traumatic lesions is unclear.[22] More prospective randomized evidence is required comparing duration of symptoms, immobilization, debridement and arthroscopic or USO repair. The ideal intervention strategy in the future must not only minimize symptoms and reoccurrence with operative procedures, but also better evaluate post-operative conservative measures available for improved healing, and sports performance. Future research evaluating long-term outcomes following operative care and subsequent injury management is crucial.

When dealing with ulnar impaction syndrome in the athlete, the diagnosis, treatment, and rehabilitation regimen should be individualised and sport-specific, considering age of the athlete, athletic priorities, healing potential, return to play, and long-term health concerns and well-being. Early detection is critical for the athlete, and clinical findings such as locking and clicking, as well as previous fractures, must be evaluated by the sports chiropractor, warranting imaging and early orthopaedic referral. Limited research has investigated conservative management of TFCC injuries, specifically within the athletic population. In season injury management consists of cortisone injections and TFCC debridement in hopes of awaiting off-season required surgical procedures.

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Guyon Canal Syndrome: lack of management in a case of unresolved handlebar palsy

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Objective: *To present the clinical diagnostic features including management of Guyon canal syndrome in a case with unresolved sensory deficits in a young female cyclist.*

Clinical Presentation: *After 14 days of cycling across Canada, a 23-year old female experienced sensory loss, followed by atrophy and a "claw" hand appearance of her left hand.*

Intervention and Outcome: *Treatment included cervical chiropractic manipulation, soft tissue therapy and the use of cycling gloves. Seven years after the initial injury a lack of sensation in the ulnar nerve distribution of her left hand has persisted.*

Discussion: *This case demonstrates that a lack of proper management can lead to permanent sensory loss and is worth highlighting. Various therapists evaluated the patient's symptoms and provided minimal care. No diagnosis was given, nor were appropriate measures taken for her to understand the risks of continuing to ride.*

Summary: *Although treatment for Guyon Canal Syndrome can be as easy as cessation from cycling until symptoms subside, other treatment options could be*

Objectif : *Présenter les caractéristiques de diagnostic clinique, dont le traitement du syndrome du canal de Guyon dans un cas de déficits sensoriels non traités chez une jeune cycliste.*

Tableau clinique : *Après 14 jours de vélo à travers le Canada, une femme de 23 ans a souffert une perte sensorielle, suivie par une atrophie et l'aspect d'une « main en griffe » à sa main gauche.*

Intervention et résultats : *Le traitement comportait la manipulation chiropratique cervicale, le traitement des tissus mous et le port de gants de vélo. Sept ans après la blessure initiale, un manque de sensation dans la distribution du nerf cubital de la main gauche a persisté.*

Discussion : *Ce cas démontre que le manque de traitement approprié peut entraîner la perte sensorielle permanente et mérite qu'on s'y attarde. Différents thérapeutes ont évalué les symptômes de la patiente et lui ont fourni des soins minimaux. Aucun diagnostic n'a été fait, ni des mesures appropriées n'étaient prises pour lui faire comprendre les risques de continuer à faire du vélo.*

Résumé : *Bien que le traitement du syndrome du canal de Guyon soit aussi simple que l'arrêt de la pratique du vélo jusqu'à la disparition des symptômes, d'autres options thérapeutiques pourraient être utilisées pour*

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utilized to help manage ulnar nerve compression injuries in cyclists.

aider à traiter les lésions de compression du nerf cubital chez les cyclistes.

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MOTS CLÉS : observation, paralysie du guidon, syndrome du canal de Guyon, chiropratique

Introduction

Ulnar nerve compression in cyclists, also known as Guyon Canal Syndrome (GCS), was first reported by Eckman et al in 1975.[1] Other common terms used in the literature include: ulnar tunnel syndrome, cyclist's palsy, or handlebar palsy. Stresses over Guyon's Canal in other sports including racket sports, karate and wheelchair activities can also lead to this type of ulnar nerve injury.[2,3]

The anatomic region of Guyon's canal is approximately 4–4.5 cm in length and can be subdivided into three zones: 1) proximal to the pisiform bone (the area where the ulnar nerve bifurcates); 2) a deep ulnar (motor) compartment; 3) a superficial (sensory) compartment (see Figure 1).[4,5] Guyon's canal is bordered by the pisiform medially and the hook of the hamate laterally, with the pisohamate ligament forming the floor of the canal and the roof composed of the palmar carpal ligament.[2,4-7] The ulnar nerve lies within the confines of this anatomic region and can be easily compressed by pressure of the extended wrist on the handlebars of a bicycle. Other common causes ulnar nerve compression at Guyon's Canal include but are not limited to the presence of ganglion cysts, lipomas, anomalous muscles, or a hypoplastic hamulus.[2,3] As the ulnar nerve courses through Guyon's canal, it divides into two terminal branches, the deep motor branch of the ulnar nerve and the superficial ulnar nerve (Figure 1). The deep ulnar nerve is responsible for motor control of intrinsic hand function through innervation of the dorsal and palmar interossei, the lumbricals of fourth and fifth digits, the hypothenar muscles (abductor, flexor and opponens digiti minimi), adductor pollicis muscle and the deep head of flexor pollicis brevis.[6] The superficial ulnar nerve supplies sensation over the hypothenar eminence and through two common palmar digital nerves over the palmar aspect of the fifth finger and the adjacent sides of the fourth and fifth fingers.[6] Authors have attempted to classify the type of Guyon Canal Syndrome into Type I (mixed motor and sensory loss), Type II (motor loss), and Type III (sensory).[8,9] This classification may not be important in guiding our treatment, however it can help to understand the anatomy involved and to monitor progress and outcomes. In this particular case, the cyclist experienced Type I GCS where both the superficial and deep branches of the ulnar nerve were compromised. The injury was likely more severe to the superficial ulnar branch since its function remained impaired.

A prospective study by Patterson et al in 2003, investigated the incidence of ulnar neuropathy in cyclists.[10] The authors investigated twenty-five cyclists (ages 20-60 years old) randomly chosen for the study, who underwent a 600km bicycle tour over the course of four days.[10] Using a questionnaire and physical examination, ulnar and median nerve function were assessed day 0 (the day before the ride began) and then re-evaluated on day 4 (within hours of completion of the ride).[10] Seventy percent of the participants experienced some form of neurological symptoms by the end of the ride.[10] Motor weakness was experienced by 36%, sensory loss was apparent in 10%, and 25% experienced both motor and sensory deficit.[10] Further results showed there was no difference between experienced riders compared to inexperienced riders regarding symptoms, and mountain bikers (9/25) had more sensory loss when compared to individuals who were using road bikes (16/25).[10] Results from this study highlight an area of research to be further explored. This particular study lacked strength due to its small sample size, multiple co-founding factors, and use of examination procedures with unknown sensitivity and specificity. The results, therefore, are difficult to generalize to the entire population of cyclists.

The actual incidence of GCS in the population is unknown due to difficulty in reporting the injury and a lack

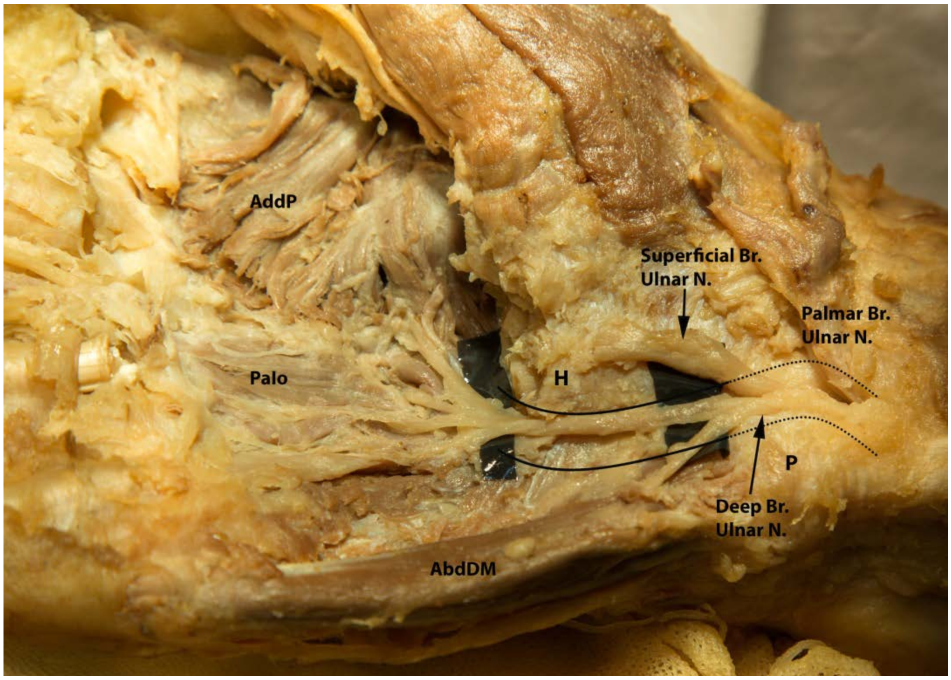

Figure 1.
Dissection of the right palm indicating Guyon's canal. The path outlined by the dotted and continuous lines indicates Guyon's canal. The dotted lines indicates the proximal zone (part 1) and the continuous lines indicates the deep ulnar compartment (part 2). AddP – adductor pollicis (transverse head), PaIo – palmar interossei, AbdDM – Abductor digiti minimi, H – hook of hamate, P – pisiform. (Superficial branch of palmar N. reflected laterally).

of a standardized definition.[1,10,11] Symptoms experienced are usually not severe enough to seek care, compared to injuries such as a fracture experienced from a traumatic fall.[12] Most of what we currently know about GCS exists from previous case reports that attempt to highlight the usual sign and symptoms, physical evaluation, diagnostic testing, and management of this condition. These case reports are important first steps in evidence-based medicine to introduce new concepts or ideas to guide case management and to present new ideas for future investigations.[1,10,11]

Although ulnar nerve compression injuries are fairly rare, there is a growing popularity in participation of large-scale long-distance bike rides, thus this condition may increase in prevalence. This article presents a case of GCS following in a young female cycling across Canada who continues to experience neurological deficits in the ulnar nerve distribution seven years after initial injury.

Case report

In the summer of 2007, a 23-year-old female cyclist experienced discomfort in the fifth digit of her left hand. This began approximately eight days (~325km) into a cycling trip across Canada. She described abnormal sensation in the fifth digit, with mild difficulty extending it completely. She was unable to clearly articulate her exact symptoms at that time. Over the course of the next six days, her symptoms progressed and became more distinct. After 408 km, the feeling of mild numbness progressed from the distal fifth digit (palmar surface) to include the entire fourth and fifth digits, and the entire hypothenar eminence. She also experienced extreme difficulty moving her fourth and fifth digits; she was unable to abduct or adduct her digits, extend the fifth digit, or adduct her thumb. Along with these neurological findings she had the ensuing physical deformities: complete atrophy of the left hypothenar eminence and adductor pollicis muscle, as well as the presentation of claw hand, which is a classic representation of an injury to the ulnar nerve. Furthermore, she was unable to perform any fine motor skills with her left hand, which resulted in severe difficulties in performing activities of daily living. Throughout the summer symptoms continually progressed such that she lost the ability to perform many gross or fine motor skills with her hand, and was unable to shift gears on her bike. She reported fear of permanent dysfunction in her left hand if she was unable to regain motor function.

Management of this patient's case was variable and lacking for the most part due to the nature of the trip. There was no consistent monitoring or follow-up that took place. The patient received occasional treatment that consisted of chiropractic manipulation of the cervical spine, and generalized soft tissue therapy of the upper limb musculature. No specific treatment was provided to help manage the distinct peripheral nerve injury that was occurring. Afraid of losing function of her hand and that it would remain in the "claw" appearance, the patient self-prescribed and performed passive abduction, adduction and extension of her fingers and adduction of the left thumb 100 times daily. Her bike fitting was re-assessed (without change). After approximately 4000 km of cycling, she was advised to wear foam-cushioned gloves.

Once full disability from GCS occurred, her symptoms no longer progressed; however, there was also no improvement over the next 55 days. Within a month of completing the ride, the patient's motor function returned, however she was still experiencing symptoms of residual sensory loss. The patient did not receive any form of chiropractic treatment after completing her ride, but continued to do passive range of motion exercises.

Unfortunately, seven years after the initial injury this individual continues to self-report residual symptoms of decreased sensation in the pad of the fourth digit, the entire palmar aspect of the fifth digit and hypothenar eminence. There is also mild decrease in size of the hypothenar eminence. The individual was not interested in addressing these issues with any diagnostic imaging or treatment.

Regrettably, this patient's case was not well managed or documented. The patient's evaluation and care were provided by various therapists and chiropractors encountered on her cycling journey across Canada. No specific treatment was provided, no diagnostic testing or laboratory procedures were performed, and no outcomes were documented using valid and reliable tools. This case accurately reflects the nature of an independent athletic event where consistent health care monitoring or provision was not available.

Discussion

Peripheral nerves can be injured in a variety of ways. In this particular case, the ulnar nerve sustained prolonged external compression and traction in the confines of the anatomical region of Guyon's canal by the handlebars. To better understand what occurred, it is important to look at three types of nerve injuries identified by Seddon in 1943.[13] The first type of nerve injury, neuropraxia occurs where there is transient mechanical trauma or ischemia to the nerve resulting in a signal conduction block.[13,14] Recovery of the nerve within days or weeks is possible because there is no disruption of the nerve or its supporting sheath.[13,14] This is one of the more common types of peripheral nerve injury that presents to a chiropractic practice. The second type of nerve injury, axonotomesis occurs when there is disruption of the nerve but the supporting Schwann cell sheath remains intact.[13,14] This can occur when there is prolonged compression or traction of the nerve often leading to Wallerian degeneration of the nerve and signs of denervation distal to the lesion.[13,14] If intervention to remove the insult to the nerve, such as long standing compression, is not removed at a reasonable time it can lead to end organ damage, or permanent loss of function.[13,14] This is likely the type of injury the young cyclist in this case experienced. Regeneration of nerve and recovery of function is possible given that the offending cause of injury is removed or avoided which can be accomplished by stopping cycling. The third type of injury is referred to as neurotemesis.[13,14] This involves serious injury or transection of the nerve and it's supporting sheath.[13,14] Partial recovery is generally achieved with surgical intervention. Chances for spontaneous recovery of nerve function diminish with continuous deformation or insult to the nerve.[13,14] Typically after a nerve undergoes Wallerian degeneration, the regrowth rate is typically 1-3mm/day.[13,14] This is important in order to educate our patients that recovery from a nerve injury typically a long gradual process.[13,14]

The clinical presentation of GCS is fairly straightforward. A clear history and physical examination will most often lead to the correct diagnosis without need for imaging or special tests.[15] Patients generally present to a health care practitioner complaining of sensory and/or motor loss in the ulnar nerve distribution of the hand beyond the anatomic region of Guyon's canal. These symptoms typically transpire after a long distance bike ride, a ride with a long downhill component or event after mountain biking where prolonged compression of the ulnar aspect of the hand and wrist is compressed and extended on the bike's handlebars. Occasionally, these neurologic symptoms may be accompanied by atrophy of the hypothenar eminence and adductor pollicis, claw hand presentation, and pain or tenderness, however these are not always present. At this point it is extremely important to ask the patient how long they have been experiencing symptoms as duration of insult to the nerve provides critical information for prognosis.[3,11,15]

A typical physical examination includes a screen of the cervical spine and upper limb, and a detailed upper limb neurological exam. Sensory loss (paraesthesia, numbness or tingling) over the hypothenar eminence and palmar aspect of the fifth digit and ulnar half of the fourth digit may be mapped out. If the deep ulnar nerve branch has been affected, motor testing will reveal the inability to abduct or adduct fingers, and/or inability to adduct the thumb, and a positive Froment's test may be present.[3,11,15] The following tests might also be positive in patients with GCS: upper limb tension test of the ulnar nerve, Tinel's test, or Phalen's test where tension, tapping and compression is focused on straining the ulnar nerve at the anatomic site of Guyon's canal. If required, or the clinician suspects an anatomical issue resulting in ulnar nerve compression, further diagnostic testing can be done including plain film radiographs, ultrasound, MRI, electromyogram, or nerve conduction velocity study (with acute injury).[3,11,15] However, the sensitivity and specificity of many of these tests for ulnar neuropathy at the wrist are unknown because existing studies are limited to a small number of patients with known neuropathy.[15] Furthermore, electrodiagnostic testing may be used to monitor extent of the injury, progression or improvement, however abnormal results are variable and normal results do not always rule out pathology.[15]

The classical clinical presentation of GCS is generally understood well by healthcare practitioners, however it is important to consider both external and internal factors, possibly associated with the development of this condition. This is especially important when an individual's symptoms persist over a long period of time. Important differential diagnoses include: cervical radiculopathy, thoracic outlet syndrome, cubital tunnel syndrome (which is more common than Guyon's Canal Syndrome), and fracture (traumatic) of the hook of the hamate.[3,11,15]

Treatment and recommendations

There is a gap in the literature regarding evidence-based information for the management of ulnar nerve compression injuries in cyclists. There are currently no systematic reviews or randomized controlled trials assessing the effectiveness of interventions to help inform or direct our treatment principles. In the absence of evidence-based information, expert opinion from a Delphi Consensus Strategy is often looked upon for guidance. To assist professionals in the management of patients with this condition, Hoogvliet et al, performed a Delphi Consensus strategy to provide recommendations for multidisciplinary treatment of GCS as part of the European HANDGUIDE study in 2013.[2] A total of 35 hand experts selected by their national membership associations were assembled as the panel, consisting of 18 surgeons, 13 therapists, and five physical medicine and rehabilitation physicians. A steering committee was formed to initiate and guide the Delphi process through rounds in order to reach consensus on the description, symptomatology, diagnosis and intervention for GCS.[2] Their role was to design sequential questionnaires for the expert panel, analyze their responses and then formulate feedback for the next Delphi round. A minimum of 70% agreement was required for consensus to be achieved among the experts. Questions in the 2nd and 3rd rounds were formulated by the steering committee based on the results from the previous rounds.[2] After three rounds consensus was achieved on the description of the syndrome, symptomatology and physical examination, diagnosis and classification coinciding with descriptions of GCS previously alluded to in this article.

The most commonly recommended intervention in the HANDGUIDE was instructions to avoid local pressure and/or limit mechanical overload including repetitive or static movements such as wrist extension or compression of the wrist.[2] This should not be used as the sole treatment, but always in combination with another form of treatment such as splinting the wrist in a neutral position in a fingers-free splint for one to 12 weeks at night, or when tolerated throughout the day.[2] These first two interventions were more common for mild-moderate symptoms of less than three months duration.[2] In patients who have more severe or chronic presentation, surgery is an option to explore anatomical causes of ulnar nerve compression in the canal.[2] Lastly, non-steroidal anti-inflammatory drugs (NSAIDs) use or corticosteroid injections can be considered. However, 94% of the panel agreed that NSAID were not useful for the treatment of GCS.[2] The HAND-GUIDE concluded that the main factors for choosing a particular therapeutic intervention included severity of symptoms, duration of symptoms and previous treatments received.[2] They also prepared a handout as a guideline for practitioners to follow to help guide their identification and treatment of this condition. The steering committee proposed to include the following note in the guideline based on suggestions by several experts: "Depending on the patient's situation and personal preferences, additional therapeutic modalities, such as ultrasound or nerve gliding exercises, can be added to the treatment"; however, no consensus was achieved to add this note to the guideline.[2] The inclusion of this note would have strengthened the idea that this guideline should not be considered as a rigid set of rules.

There is a lack of evidence-based recommendations regarding therapeutic interventions for the prevention and treatment of GCS. Slane et al in 2011 investigated the influence of glove and hand position on pressure over the ulnar nerve during cycling in an attempt to provide some concrete recommendations.[16] The study assessed a sample of thirty-six experienced cyclists from a local cycling group consisting of equal numbers of males (40.2 y, 180 cm, 82 kg) and females (37 y, 170 cm, 80 kg). These individuals were placed on a stationary bike adjusted to their individual specifications and underwent a typical one- to two-hour tempo ride.[16] Hand pressures over the handlebars were measured using a high-resolution pressure mat (peizo-capacitive pressure mat). These pressures were recorded in each participant over a series of trials where hand position (tops, drops, hoods) see Figure 2, glove type (foam, gel) and glove thickness (3mm, 5mm) were randomized in order to produce pressure profiles in different combinations. Pressure data was summarized over a standardized anatomical region of interest that overlies the ulnar nerve at Guyon's Canal.[16] Wrist posture was simultaneously monitored with a motion capture

Figure 2.
Hand positions when cycling

A) Tops
B) Drops
C) Hoods

system. Results of the study demonstrated that pressure and loading patterns experienced by cyclists was significant enough to induce ulnar nerve damage.[16] The highest pressure over the region of interest was observed in the drops hand position.[16] This was also the posture that produced the greatest wrist extension.[16] Riding in the tops hand position produce the greatest ulnar deviation.[16] In these cycling postures, sustained compression of the ulnar nerve ensues.[16] Severe conduction block within the nerves can occur within hours, and when the duration of insult to the nerve persist it can lead to the classic Wallerian degeneration which can take upwards of months to recover.[13,16]

Recommendations yielded from the study to reduce peak pressures included wearing padded cycling gloves, which reduce peak pressure by 10-29%, and the greatest reduction in peak pressure was achieved while wearing a glove made of thin compliant padding (3mm, foam).[16] Damage to the nerve can be minimized by additional countermeasures such as frequently changing hand position and ensuring proper bike-set up by a professional. The clinical relevance of the results of this study is unknown and recommendations are difficult to generalize. This study was done in a controlled steady-state laboratory environment, measuring pressure profiles on the dominant hand only and fitted with brand new gloves. Only the normal forces were considered, while pressure profiles of shear forces on the hand during an actual ride on varied terrain when steering is involved are likely different. Future studies should consider dynamic variations in hand pressure and wrist posture when cycling. Another major limitation of this study was that the authors commented on statistical significant finding, however did not provide any statistical information to justify these conclusions.

Prolonged pressure of the wrists on the handlebars during cycling could negatively affect nerve physiology and can lead to temporary or permanent neurological dysfunction as demonstrated in this case. Chiropractors should be aware of the clinical presentation of the condition and be able to advise their patients on prevention, self-care, and provide proper management strategies. Prevention strategies that can be utilized are essential to help reduce the negative effects of prolonged compression and traction on the ulnar nerve at Guyon's Canal. These include wearing cycling gloves (thin compliant padding of 3mm foam), padding the handlebars, changing hand and body position frequently as well as taking breaks to avoid prolonged compression, and having your bike fitted properly by a specialist.[3,10,11,17] However, even in the face of preventative strategies, the forces on the ulnar nerve are still high enough to sustain damage. Therefore, it is important to recognize when the ulnar nerve has been compromised and diagnose the condition early so that necessary adjustments can be made given the circumstances.[2,17] First and foremost the athlete should be advised to stop the activity and be made aware of the risks for permanent dysfunction if they continue. Instructions should be given to the athlete on how to avoid insult to the injury, and perhaps the athletes wrist and hand can be immobilized in a splint to help decrease the amount of mechanical load on the irritated nerve.[2.17] The support for different management techniques of ulnar nerve compression in cyclist's has yet to be investigated.

Even though direct evidence does not exist for the use of certain management strategies for GCS, chiropractors should utilize evidence regarding treatment of peripheral nerve injuries. This could include the use of low-level laser therapy that has been shown to accelerate the rate of recovery of injured peripheral nerves through modulating several neurotrophic factors and through its anti-inflammatory effect.[18] The use of therapeutic ultrasound has also been shown to modulate certain cellular and molecular responses involved in the healing process and improve the rate of recovery of peripheral nerve injuries.[19] Ebenbichler et al[20] demonstrated in clinical trials ultrasound can improve symptoms as well as median nerve conduction velocities in patients with a neuropraxic grade of injury, further supporting the clinical use of ultrasound to accelerate and improve functional recovery after a peripheral nerve injury.[19,20] Proper settings for the use of these modalities in treating a patient with GCS have yet to be determined and further research is required to prove their efficacy in the management of GSC.

Clinicians should always keep in mind weighing risk versus harm against patient preferences and goals and explore all options, as our goal is to improve on natural history. Future research should focus on the role of conservative management for the treatment of GCS.

Conclusion

Ulnar nerve compression injuries are common in the sport of cycling. We report a case of a 23-year old recreational cyclist who experienced severe ulnar nerve injury while cycling across Canada. This case highlights the necessity of all primary health care practitioners responsible for diagnosing and treating these athletes to be aware of the potential ramifications and long-term disability that can occur with prolonged insult to injury. A delayed diagnosis and inappropriate management may lead to prolonged neurological sequelae.

Chiropractors are well suited to offer a continuum of supportive care for their athletes and as in most sports it is important to consider the integrated team working with the athlete in order to benefit their performance. This case was not well managed or documented, hence is worth highlighting, as neurological symptoms remain unresolved. More attention should have been paid to the proper management of this patient in order to help prevent the severity of the injury. Perhaps by fitting with gloves at an earlier stage, as well as advice to stop immediately once hard neurological signs of ulnar nerve dysfunction presented may have prevented the progression and chronicity of the complaint. Nevertheless, despite the injury and dysfunction, the individual was able to complete the trip across Canada with only minor unresolved neurological deficits. This case accurately reflects the nature of an independent athletic event where consistent health care monitoring or provision was not available.

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Can injury in major junior hockey players be predicted by a pre-season functional movement screen – a prospective cohort study

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Background: *The Functional Movement Screen (FMS) is a tool that is commonly used to predict the occurrence of injury. Previous studies have shown that a score of 14 or less (with a maximum possible score of 21) successfully predicted future injury occurrence in athletes. No studies have looked at the use of the FMS to predict injuries in hockey players.*

Objective: *To see if injury in major junior hockey players can be predicted by a preseason FMS.*

Methods: *A convenience sample of 20 hockey players was scored on the FMS prior to the start of the hockey season. Injuries and number of man-games lost for each injury were documented over the course of the season.*

Results: *The mean FMS score was 14.7+/-2.58. Those with an FMS score of ≤14 were not more likely to sustain*

Historique : *L'évaluation du mouvement fonctionnel (EMF) est un outil qui est couramment utilisé pour prévoir les blessures. Des études antérieures ont montré qu'une note de 14 ou moins (avec une note maximale possible de 21) réussit à prévoir les blessures futures chez les athlètes. Aucune étude n'a examiné le recours à l'EMF pour prévoir les blessures chez les joueurs de hockey.*

Objectif : *Déterminer s'il est possible de prévoir les blessures chez les joueurs de la ligue de hockey junior majeur par une EMF avant le début de la saison.*

Méthodologie : *Un échantillon de commodité de 20 joueurs de hockey a été évalué par l'EMF avant le début de la saison de hockey. Les blessures et le nombre de joueurs perdus par jeu pour chaque blessure ont été enregistrés pendant la saison.*

Résultats : *La note moyenne d'EMF était 14,7+/-2,58. Ceux qui ont obtenu une note d'EMF ≤14 n'étaient pas plus susceptibles de subir une blessure, telle que*

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an injury as determined by the Fisher's exact test (one-tailed, P = 0.32).

Conclusion: *This study did not support the notion that lower FMS scores predict injury in major junior hockey players.*

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KEY WORDS: screen, movement, hockey, injury, chiropractic

déterminée par la méthode exacte de Fisher (unilatérale, P = 0,32).

Conclusion : *Cette étude n'appuie pas l'idée que les notes d'EMF permettent de prévoir les blessures chez les joueurs de la ligue de hockey junior majeur.*

(JCCA 2014; 58(4):421-427)

MOTS CLÉS : évaluation, mouvement, hockey, blessure, chiropratique

Introduction

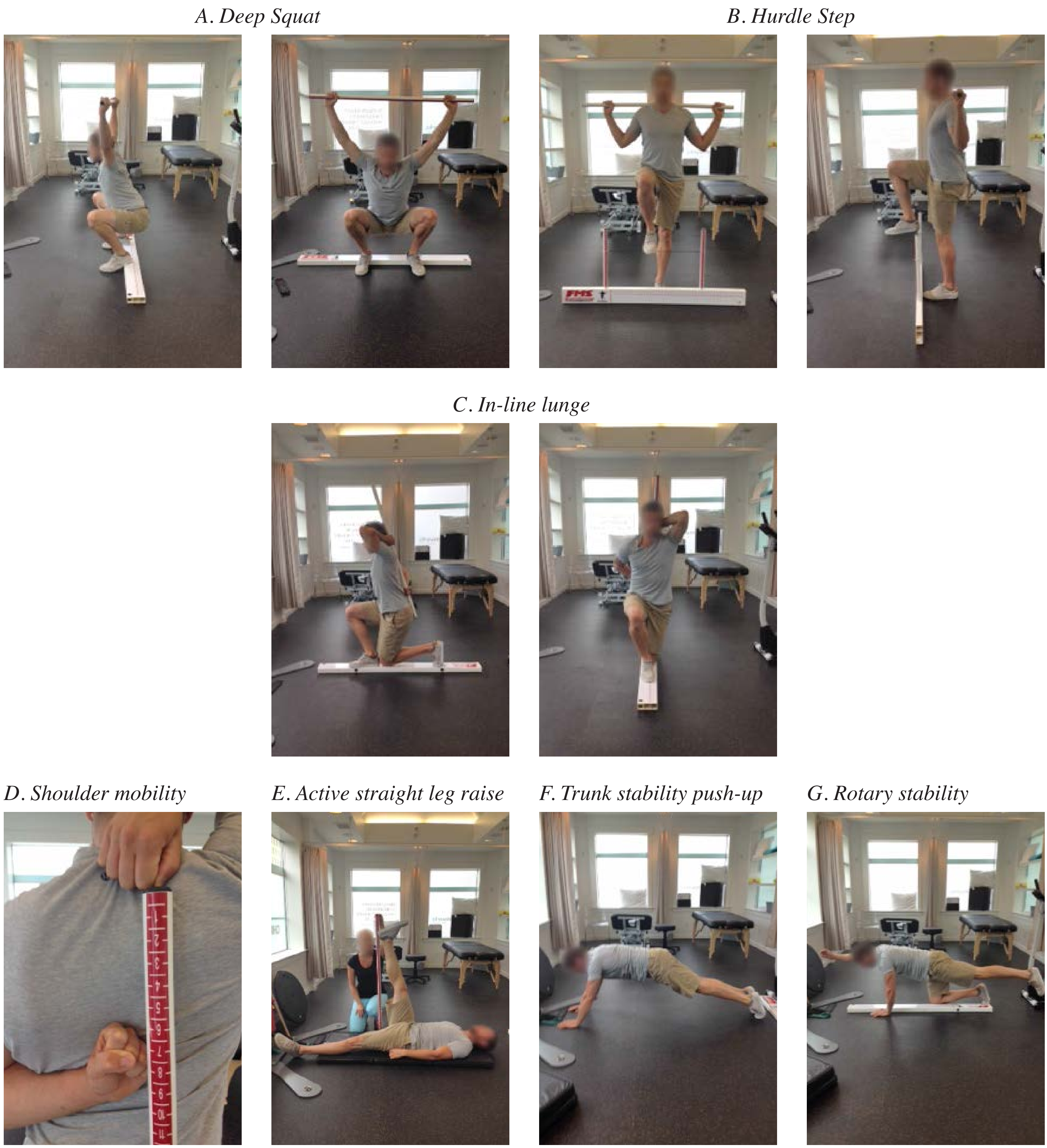
Participation in sports often results in traumatic and overuse injuries.[1,2] It has been estimated that 50 to 80% of these injuries are overuse in nature and affect the lower extremity.[3] Although, the risk of musculoskeletal injury is multifactorial[4-10], recently there has been increased recognition of muscular imbalances, poor neuromuscular control and core instability as potential risk factors for athletic injury[11,12]. It has also been demonstrated that previous injury is a prominent risk factor for future injuries.[13] Kiesel et al.[14] hypothesize that complex changes in motor control may result from injury which may be detected using movement oriented tests that challenge a multitude of systems at once. One of these assessment tools is the Functional Movement Screen (FMS).

The FMS is an assessment tool whose utilization has increased in popularity in recent years.[15] Its low cost, simplicity of administration and non-invasive qualities contribute to its use by organizations of professional and amateur athletes, military personnel and firefighters.[16] According to Cook et al.[17] the FMS bridges the gap between pre-participation medical examination and performance evaluation by testing the athletes' ability to perform functional multi-segmental movements. To perform the FMS, an assessor observes the subject perform seven fundamental movements in order to identify abnormal movement patterns. The assessor gives a score from zero to three based on the quality of movement. The FMS is intended to challenge stability and mobility and requires controlled neuromuscular execution.[17] It is thought that muscle imbalances can result in compensatory movement patterns, resulting in poor biomechanics and eventually a micro or macro injury.[17]

Figure 1 includes pictures for each of the seven subtests which comprise the FMS. The seven tests are: 1) the deep squat which assesses functional mobility of the hips, knees and ankles, 2) the hurdle step which examines stride mechanics, 3) the in-line lunge which assesses mobility and stability of the hip and trunk, quadriceps flexibility and ankle and knee stability, 4) shoulder mobility which assesses range of motion and scapular stability, 5) the active straight leg raise which assesses posterior chain flexibility, 6) trunk stability push-up, and 7) the rotary stability test which assesses multi-plane trunk stability.[17,18]

Few studies have investigated the use of the FMS to predict injury in athletes.[11,12,19,20] Kiesel et al.[19] demonstrated using an receiver operating characteristic (ROC) curve that a score of 14 or less on the FMS was associated with an 11-fold increase injury risk when they examined the relationship between FMS scores of 46 professional football athletes and the incidence of serious injury (injury lasting three or more weeks in duration).[12] They concluded that poor fundamental movement is a risk factor for injury in football players and that players with dysfunctional movement patterns, as measured by the FMS, are more likely to suffer an injury than those scoring higher on the FMS. Chorba et al.[12] found that a score of 14 or less on the FMS resulted in an approximate 4 fold increase in the risk of lower extremity injuries in female collegiate soccer, volleyball and basketball athletes. It was concluded that compensatory movement patterns in female collegiate athletes can increase the risk of injury and that these patterns can be identified by using the FMS. O'Connor et al.[21] looked at a population of US Marines and found that a score less than or equal to 14 on the FMS demonstrated a limited ability to predict all traumatic or overuse mus-

Figure 1 – Functional Movement Screen Tests



culoskeletal injuries (sensitivity: 0.45, specificity: 0.71), while the same cut-off value was able to predict injuries lasting more than three weeks in duration (sensitivity: 0.12, specificity: 0.94). Butler et al.[22] examined whether low FMS scores are predictive of injury in firefighters. Similar to Kiesel et al.[19], an ROC curve analysis illustrated that an FMS score of ≤14 discriminated between those at a greater risk for injury and those who were not.

If low FMS scores can predict injury, off-season conditioning might be used to restore dysfunctional mechanics to reduce risk. Kiesel et al.[14] found that 52% of players on a professional football team were able to improve their score from below to above the established threshold score for injury risk (≤14) in a seven week off-season conditioning program.[14] Similarly, Peate et al.[11] determined that firefighters enrolled in an eight week program to enhance functional movement reduced time lost to injury by 62% when compared with historical injury rates.

No studies to date have assessed FMS scores as a predictor of injury in hockey players. The purpose of this study is to see if injury in major junior hockey players can be predicted by a pre-season FMS. It is hypothesized that athletes with an FMS score below 14 will have an increased number of injuries compared to those with a score of 14 or above.

Methods

Study design and patient selection

In this cohort study, athletes from a major junior hockey team were assessed during the pre-season using the FMS, and injury incidence was documented over the course of the season. Subjects were invited to participate via email by their team's head athletic therapist one month prior to the pre-season medical evaluations. Players who were below the age of eighteen were required to obtain approval from a parent or guardian. All members of the team who attended the pre-season medical evaluation chose to participate in the study. Informed consent was obtained from all participants and ethical approval was received from the Canadian Memorial Chiropractic College Ethics Review Board prior to performing the study.

Data collection

FMS data was collected at the team's practice facility. The lead investigator, a chiropractor who is certified in FMS, performed the screen on each player individually. The administration procedures and scoring were consistent with the standardized version of the FMS test that was developed by Cook et al.[17,18] Each player was given three trials on each of the seven sub-tests and received a score from zero to three on each. Scoring criteria were as follows: 0) pain was reported during the movement; 1) failure to complete the movement or loss of balance during the movement; 2) completion of the movement with compensation; and 3) performance of the movement without any compensation. For each sub-test, the highest score from the three trials was recorded. For the sub-tests that were assessed bilaterally, the lowest score was used. Three of the sub-tests (shoulder mobility, trunk stability push-up and rotary stability) also have associated clearing exams that are scored as either positive or negative with a positive response indicating that pain was reproduced during the examination. Should there have been a positive result on a clearing sub-test; the score for that movement would be zero regardless of how well the subject could perform the movement. An overall composite FMS score with a maximum value of 21 was then calculated and participants were informed of their score. No attempt was made to alter the training routine of the players as a result of the FMS score obtained. Only the lead investigator had access to the FMS scores so as to not influence the player's level of hockey participation.

Injury data was collected from game one up to the end of the last game of the 2013-2014 play-offs for a total of 76 games. Over the course of the season, all injuries were brought to the attention of the team physician who provided a diagnosis for the injury. An injured player returned to hockey once the team physician provided clearance to play. The team's head athletic therapist recorded all injuries that occurred while playing in a hockey game or practice including the diagnosis, number of man games lost for each injury and whether the injury was from contact or non-contact. For the purpose of this study, injury was defined as a physical condition which occurred during a game or practice which resulted in the player missing at least one game. A contact injury was a subcategory of injury involving collisions with another body, ice or boards and/or contact with puck or stick. Non-contact injuries were all other injuries that did not fall into the contact category.

Data analysis

To maintain consistency with previous studies, a cut-off score of 14 on the FMS was used to assess differences in injury risk.[12,19] A 2 x 2 contingency table (Table 2) was created whereby the FMS score was split into groups less than or equal to 14 and more than 14 and the cohort was divided into groups who sustained an injury and those who did not. Sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, disease prevalence, positive predictive value and negative predictive value with 95% confidence intervals were calculated. Due to the intermediate sample size two different tests of association were performed: a Chi squared coefficient (Yates corrected) and a Fisher's exact test with a one-tailed p value of <0.05.

Results

A total of 31 male subjects were assessed using the FMS. Players were excluded from the study if they were traded to another team during the season or did not make the team following training camp. As a result, 20 subjects (ages 16-20) with a mean height and weight of 72 inches and 186lbs respectively were included in the study. Subject FMS scores are presented in Table 1. The mean FMS score and standard deviation (SD) for all subjects (n =20) was 14.7+/-2.58 (maximum score of 21). The mean FMS score for subjects who sustained an injury was 15.0 (+/- 2.21) and for those who were not injured was 14.4 +/- 2.99 respectively. Of the individuals who had an FMS composite score of ≤ 14 (n = 8), 62.5 % sustained an injury over the course of the season while 60.0% of subjects who scored ≤ 13 and 50.0% of subjects who scored ≤ 15 sustained injuries.

A total of 114 man-games lost were recorded during the season. Of those, 44 were associated with subjects with an FMS score of ≤14 compared to 70 associated with a score of ≥15 (Table 3). Seventeen injuries were recorded during the season, seven occurred in subjects with an FMS score of ≤14 and ten in subjects with an FMS score of ≥14 (Table 3). All of the injuries were a result of contact and no injuries were the result of non-contact.

Our results demonstrated a sensitivity of 0.5 (CI95 = 0.189 to 0.811); specificity of 0.7 (CI95 = 0.348 to 0.930); positive likelihood ratio of 1.67 (CI95 = 0.54 to 5.17); negative likelihood ratio 0.71 (CI95 = 0.34 to 1.50); Positive predictive value of 62.50% (CI95 = 0.25 to 0.91)

Table 1
Subject FMS scores

Athlete	Age (years)	FMS score (Max: 21)
A	19	17
B	16	16
C	17	17
D	17	14
E	17	13
F	16	12
G	17	15
H	18	7
I	18	15
J	18	17
K	17	13
L	18	15
M	20	16
N	20	17
O	20	16
P	20	14
Q	19	12
R	18	15
S	19	19
T	20	14

Table 2
2x2 contingency table for all subjects (N = 20).

FMS Score	Injured	Not Injured
≤ 14	5	3
≥ 15	5	7

Table 3
Nature of Injuries and Number of Man-games lost

FMS Score	Contact	Non-contact	Man-games lost
≤ 14	7	0	44
≥ 15	10	0	70

and negative predictive value of 58.33% (CI95 = 0.28 to 0.85). There were no significant differences found in injury incidence between the two FMS score groups using the Fisher's exact test (one-tailed, P = 0.32). Chi square test of association produced a value of 0.2.

Discussion

The results of this study do not support the hypothesis that low FMS scores (≤14) in hockey players predict the risk of incurring injuries over the course of a hockey season. A lower score on the FMS was not significantly associated with injury. There are several considerations regarding our operational definitions of injury which may have influenced our results. Previous studies have varied in terms of their definition of injury. Kiesel et al.[19] defined an injury as three or more weeks of time loss from football. Chorba et al.[12] defined an injury that met the following criteria: 1) the injury occurred as a result of participation in an organized practice or competition setting; 2) the injury required medical attention or the athlete sought advice from a certified athletic trainer, athletic training student, or physician. We chose to define an injury as one or more man games lost. It was believed by the authors that inability to play was the least ambiguous definition of injury severity as it had a clear impact to both player and team.

In this study, injuries were categorized as either contact or non-contact because the developers of FMS have hypothesized that repetitive microtrauma caused by aberrant movement patterns, predisposes athletes to overuse type musculoskeletal injury.[17,18] Kiesel et al.[19] did not define the nature of injuries sustained by the athletes in their study, whereas Chorba at al.[12] and O'Connor et al.[21] both specified if the injury was from trauma or overuse. We hoped that differentiating these injuries would improve our data interpretation.

All recorded injuries in this study were from contact. Injuries from slashing, collisions, hits, puck impact are unlikely to be affected by better functional movement of an athlete and therefore it is questionable if any of these particular athletes could have avoided injury. The lack of non-contact injuries in this study makes it impossible to compare risk of these injuries between the two groups. Our experience has shown us that, in fact, hockey players do experience non-contact injuries including repetitive strain injuries and while repetitive strain injuries may cause players to miss games, often they will not. From this perspective, our inclusion criteria of missing at least one game may have resulted in these injuries being excluded from our data. Nonetheless, the pattern of injuries recorded in this study illustrates that a majority of man-games lost in hockey are due to contact. It is therefore possible that in sports, like hockey, where collision, stick, and puck injuries are high that the FMS may have less utility in predicting risk.

There are several weaknesses with this study. The relatively short duration of this study limits our ability to see if the potential effects of cumulative microtrauma may eventually lead to pain or injury significant enough to cause a player to miss games. Although all subjects were wearing loose fitting clothing, (shorts and t-shirt) not all were wearing training shoes as they were not specifically instructed to do so prior to arriving for the FMS. As a result, the few participants that did not have training shoes performed the FMS barefoot. This may have produced a lower FMS score for these individuals as they may have had less foot and ankle stability barefoot. Inability to control hydration levels, prior sleep and nutrition at the time of screening reduced our ability to standardize testing conditions. This study did not account for player positions or ice time. We suspect that players with more ice time would have an increased likelihood of being injured. It has been shown that FMS scores are higher in individuals who are more physically mature.[24] Our study did not take physical maturity into account. This study used a relatively small sample based on convenience, limiting the statistical strength of our data.

To enhance experimental robustness, future studies should involve more teams and players. We would also suggest that those studies be more longitudinal in design. Age should be considered in data analysis if widely disparate age groups are being studied. Categorizing injuries as either contact or non-contact will continue to assist in determining whether FMS may be more useful for certain types of injuries. Overuse injuries such as tendinopathies are more prevalent in populations of increased age[23] and therefore, it is recommended that future research regarding repetitive strain may benefit by studying adult populations.

Conclusion

The results of this study do not support the notion that, when applied to junior hockey players, FMS can identify athletes who are more likely to suffer an in-season injury. Therefore, the FMS cannot be recommended as a pre-season screening tool for injury prevention in this population. Further study is warranted.

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A survey of Canadian Alpine ski racing coaches regarding spinal protective devices for their athletes

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Introduction: *Spinal protective devices are a recent addition to the protective equipment worn by competitive and recreational alpine skiers and snowboarders. Their rate of use is not documented at the time of publication. The objective of this study was to examine the current attitudes and recommendations of Canadian alpine ski racing coaches towards spinal protective devices.*

Methods: *A convenience sample of alpine ski racing coaches across Canada were contacted in each provincial sport governing body in the ski racing community. A ten question online survey was attached to the initial email. Descriptive statistical analysis was utilized.*

Results: *A total of 29 Canadian alpine ski racing coaches completed the study survey. All participants were familiar with spinal protective devices and 51.7% of respondents reported that they do not actively enforce spinal protective device use with their ski racing athletes. 80% of respondents reported that their Canadian ski racing club did not have guidelines or*

Introduction : *Les dispositifs de protection de la colonne vertébrale sont un ajout récent à l'équipement de protection porté par les skieurs alpins et planchistes amateurs tout comme professionnels. Leur fréquence d'utilisation n'est pas connue à la date de cette publication. Cette étude vise à examiner les attitudes et les recommandations actuelles des entraîneurs canadiens de ski alpin de compétition concernant le port de dispositifs de protection de la colonne vertébrale.*

Méthodologie : *Un échantillon de commodité d'entraîneurs de ski alpin de compétition de partout au Canada a été contacté dans chaque organisme provincial directeur du sport de ski de compétition. Le courriel initial a été suivi par un questionnaire en ligne comportant dix questions. On a eu recours à une analyse statistique descriptive.*

Résultats : *Un total de 29 entraîneurs canadiens de ski alpin de compétition ont rempli le questionnaire de l'étude. Tous les participants étaient familiers avec les dispositifs de protection de la colonne vertébrale et 51,7 % des répondants ont déclaré qu'ils n'imposent pas activement le port de dispositifs de protection de la colonne vertébrale à leurs skieurs de compétition. 80 % des répondants ont indiqué que leur club canadien*

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policies regarding spinal protective device use. 86.2% of respondents were unaware if their provincial sport organization had a policy regarding their use.

Discussion: *The majority of coaches reporting training athletes aged 10-15, which may help to explain why only half of those surveyed enforce the use of spinal protective devices. This group of athletes may not participate in speed events as frequently as older athletes, where the use of spinal protective devices is more common.*

Conclusion: *The majority of Canadian Alpine ski coaches report a belief that spinal protective device use is important, however, far fewer enforce their use, or work in an environment with a policy requiring it. Further research is required to determine the differences in beliefs and practice.*

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KEY WORDS: protective, spinal, Alpine, skier, coach

de ski de compétition n'avait pas de directives ou de politiques relatives au port de dispositifs de protection de la colonne vertébrale. 86,2 % des répondants ne savaient pas si leur organisme provincial de sport avait une politique concernant leur utilisation.

Discussion : *La majorité des entraîneurs ont déclaré entraîner des athlètes âgés de 10 à 15 ans, ce qui peut aider à expliquer le faible pourcentage de ceux qui imposaient le port de dispositifs de protection de la colonne vertébrale. Ce groupe d'athlètes ne participe pas nécessairement à des épreuves de vitesse aussi souvent que les athlètes plus âgés, chez qui le port de dispositifs de protection de la colonne vertébrale est plus fréquent.*

Conclusion : *La majorité des entraîneurs canadiens de ski alpin se disent convaincus que le port de dispositifs de protection de la colonne vertébrale est important, mais beaucoup moins font respecter leur port, ou font partie d'un milieu qui a une politique obligeant le port. D'autres recherches sont nécessaires pour déterminer les différences dans les convictions et les pratiques.*

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MOTS CLÉS : protection, colonne vertébrale, alpin, skieur, entraîneur, chiropratique

Introduction:

Spinal protective devices are available for international use, although research on their rate of use, effectiveness, and limitations are lacking.[1] These devices have been described as equipment that protects an athlete's back from external forces. Ski coaches help athletes of all ages with equipment and training decisions on a regular basis, and are required to stay familiar with the rules in place for safe activity and fair competition in order to maintain certification. This study aimed to explore the attitudes and actions of Canadian alpine ski racing coaches regarding spinal protective devices. It is our hypothesis that many, if not all, surveyed Canadian alpine ski racing coaches would be familiar with spinal protective devices but that fewer coaches surveyed will respond as enforcing their regular use.

Injuries

Among the competitive alpine ski racing population, Florenes reported that 81% of injuries occurring during the 2007-2008 World Cup competitive season were moderate or severe in nature, resulting in time loss of eight to 28 days or greater for those athletes.[2] In these athletes, anterior cruciate ligament injuries were most frequently reported, followed by concussions.[2]

Although the knee is the most commonly reported location of acute injury among World Cup alpine ski racers (representing 35% of injuries), lower leg and low back injuries are the second most common injuries reported (22% of reported injuries each). Only 4.5% of the reported low back injuries were regarded as severe, however, resulting in 28 days or more of missed skiing activity.[2]

Of these reported injuries, 45% occurred during official World Cup competitions, with the remaining injuries occurring during various forms of on-snow training; indicating that many accidents and injuries occur outside of competition events.[2] It has recently been reported that injury rates of elite alpine skiers are in fact higher than previously thought, suggesting an increased need to investigate this population of athletes.[2] Specifically, Franz reported that most severe spine injuries (fractures, dislocations, subluxations) occurred most often in skiers at the lumbar spine level and encouraged the promotion of back protection along with various other preventative measures.[3]

It has been found that injury rates increase with rates of speed among recreational and competitive populations.[4] As ski racers actively seek out increased rates of speed in all disciplines of competition, it is possible that this population is at greater risk of injury. It may be possible that the number of back injuries in competitive alpine ski racing has changed with the changes in snow preparation and increased speeds in all disciplines in recent years.[5] Recent high profile deaths of Canadian ski athletes in freestyle and ski cross disciplines highlight the need for more research and advocacy for change in safety measures in snow sports. Alpine Canada is attempting to develop policies to improve safety measures for all ski athletes as evidenced by the Alpine Ski Safety Summits held in 2011 and 2012.[6]

Protective Equipment

Helmet use in all disciplines is currently mandatory in all competitive disciplines by the Federation International du Ski (FIS).[7] Spinal protective devices are allowed for use under alpine ski racing downhill suits in competition for protective purposes but their use is not currently mandatory.

In its Specification for Competition Equipment (2012-2013 Edition), FIS defines back protectors as "an additional item of equipment, which protects the athlete's back against weather and external forces."[1] This section states "The use of back protections is recommended", but does not mandate the use of spinal protective devices, as it has for helmet use across all ages and competitions in all disciplines.[1] The rate of spinal protective device usage is currently unknown in competitive alpine skiing, but a survey conducted in Switzerland revealed that 40% of recreational skiers and snowboarders wore a protector designed for snowsports.[8]

According to Schmitt, hard shell spinal protective devices are likely more effective protecting against penetration injury as shown with the EN1077 standard test for snow sport safety.[8] Current spinal protective devices available for purchase vary in performance with mechanical testing that is designed to assess motorcycle protectors.[8] Impacts or accidents that result in spinal column or cord damage, however, are likely more severe than impacts involved in this common mechanical testing (drop test, EN1621).[8] It has been found that the beliefs of the effectiveness of spinal protectors to prevent spinal vertebral fractures does not match up with the theorized actions of spinal protective devices (hard or soft design) as they only dampen forces to the back and cannot decrease axial loads, such as those experienced in severe flexion.[8]

Alpine Ski Racing and Back Protection

Alpine Canada, the governing body of alpine ski competition in Canada, does not currently have a rule mandating back protection, and rather follows FIS guidelines on allowing spinal protective device use in competition as stated in its rules of competition.[1,9,10] Individual provincial sport organizations and independent clubs are permitted to introduce their own rules and regulations as decided by their members, permitting that these rules and regulations do not interfere or contradict the rules put forth by Alpine Canada and FIS.[1,9,10]

Canadian Coaches and Back Protection

Alpine ski coaches work closely with athletes and families to determine equipment choices. Further, they are often called upon to enforce mandatory and suggested equipment rules and regulations. Understanding the attitudes and beliefs of alpine ski race coaches towards spinal protective devices will provide an understanding of what educated and trained leaders of this sport think of these devices, and how to better educate and promote their use, if indicated, in the future.

Methods and procedures:

Design

This study used a cross-sectional survey design. A convenience sample of alpine ski racing coaches was selected. This study was approved by the Research Ethics Board of the Canadian Memorial Chiropractic College.

Sample Specification

A convenience sample of the target population composed of males and females, was used. The head coaches certified by Alpine Canada were contacted. In order to participate, subjects must self-report Canadian citizenship, be certified as an alpine ski racing coach, and actively coach at the time of survey completion. Subjects were excluded if they did not fit the sample specifications or did not provide consent.

Description of Experimental Maneuver

The survey and instructions for its completion were mailed electronically to the head coaching personnel certified by Alpine Canada. The survey (Appendix A) was provided in the English language only. A total of two identical emails were sent to 135 contacts, each one week apart, with a link to the survey. The email provided a brief outline of the research project being conducted in hopes to gain a better understanding of their current attitudes towards spinal protection.

A qualitative analysis on the survey results was completed.

Results

The breakdown for Canadian Alpine provincial contacts is provided in the table below. Contact information was not available for coaches or representatives in the North West Territories and Nunavut.

Table 1.
Contact breakdown of Canadian Alpine provincial coaches and representatives.

Province	Coaches	Representatives
Alberta	35	—
British Columbia	20	11
Manitoba	—	3
New Brunswick	4	1
Newfoundland/Labrador	1	2
Ontario	4	1
Nova Scotia	21	3
Quebec	—	8
Saskatchewan	—	9
Yukon	—	1
Prince Edward Island	—	1
National (Alpine Canada)	1	—

All 29 respondents were certified coaches through Canadian Ski Coaches Federation with experience ranging from 3-46 years (mean 24.5) and completed all ten questions. 79% of respondents were trained Development Level Canadian Ski Coaches Federation coaches or higher, with 41% of respondents being Performance Level coaches. Two respondents were CSCF High Performance Level coaches.

With respect to familiarity with spinal protective devices, 62.1% reported being "very familiar", and 37.9% reported being "familiar". There were no respondents that reported being "not at all familiar" with spinal protective devices (Table 2). The majority of coaches (65.5%) strongly agreed or agreed with the statement "[i]t is important for your athletes to wear a spine protector", while 13.7% disagreed or strongly disagreed (20.7% neutral) (Table 3). With respect to enforcement of their use, the majority (51.7%) of coaches were neutral (Table 4).

The majority of coaches (79.3%) reported there was not a policy regarding spinal protective device use in their club (Table 5), nor was the majority (86.2%) aware of a provincial policy regarding its use (Table 6).

Most coaches reported coaching athletes less than 15 years of age (Table 7). With respect to the frequency of spinal protective device use by athletes in competition, responses were distributed throughout the six potential responses (never, rarely, sometimes, often, most of the time, and all of the time) (Table 8).

Please see appendix B for tables.

Discussion

Safety, risk management, and protection in competitive alpine ski racing may be important issues for alpine ski coaches. Further, risks of injury to the athlete and the responsibility coaches to reduce foreseeable risks for injury are important discussion topics for the alpine ski racing community. Coaches may play a major role in moderating safety equipment purchases. Encouragement or limitation of safety equipment use by coaches, may affect athletes' decisions.

The majority of coaches reported that they worked with athletes ranging between ten to 15 years of age. It is possible that coaches who do not enforce the use of back protection with their athletes are coaching these younger athletes who do not spend much time in training for speed specific disciplines, in which protection may not be indicated.

Coaches are largely responsible, or at least relied upon for athlete safety considerations and equipment recommendation. All of the respondents reported being very or somewhat familiar with spinal protective devices, yet most reported that they are not aware of policies regarding their use at the club or provincial level. Given the lack of formal policies, it may be hypothesized information regarding spinal protective devices is distributed via the companies that produce these devices. Further investigation is required to determine how these coaches are receiving education regarding back protectors, whether it is from product brand marketing, equipment providers, or another source. Without policies, protocols or enforceable rules relating to spinal protective devices, it is possible that coaches may believe them to be an unnecessary cost. Interestingly, nearly one third of coaches surveyed report that they disagree or strongly disagree that the use of spinal protective devices are important for their athletes, and more than half do not enforce their use. Future studies should correlate these responses with the ages, region, and the discipline(s) participated in by their athletes. Also, in future studies, it would be interesting to better understand the demographic characteristics of the coaches to determine if trends related to recommendation and enforcement of use may be related to the age, gender, or geographic region of the coach. It would also be useful to determine why these coaches believe spinal protectors are beneficial or not for their athletes, and future studies could inquire specifically to this question.

Limitations

With the lack of research specifically targeting the attitudes of alpine ski coaches towards spinal protection, this research is preliminary and the sample size is small (n=29). A total of 135 individuals were contacted via email. It is uncertain if recipients sent the survey to others, therefore, a response rate cannot be calculated. Furthermore, some Canadian provincial websites provided direct coaching staff contact emails, thus proportionately more coaches were contacted directly in Alberta and British Columbia. This may have produced demographic bias depending on whether or not these provinces have been previously exposed to spinal protective devices for alpine skiing or whether they are even accessible in sporting good stores in that particular province.

It must also be recognized that this survey was only able to gather information regarding the beliefs of coaches, and may not be reflective of athletes' practices. It is possible that coaches are unaware of the use of spinal protective use in their athletes. Future studies should address athlete behaviours rather than simply relying on coaches' reports.

Unfortunately, the survey question that asks respondents of their familiarity with spinal protective devices does not identify what aspect of spinal protective devices they are familiar with. Given the FIS description of spinal protective devices is currently vague[1], the survey did not provide an explicit definition of these devices in order to gather as much information as possible from respondents in this pilot study. It may be possible coaches are familiar with the fact spinal protective devices exist and are available to buy, they are allowed by FIS rules, or that they are commonly recommended and used in speed events for older athletes. Spinal protective devices are prevalent on the higher-level ski circuits worldwide (without being mandatory or verified for proper fit or specific type). It must be considered, however, that this decision may have led to difficulties with interpretation on behalf of the coaches and future studies should address various devices specifically.

With regards to the survey demographics, this preliminary survey did not obtain information regarding the respondent as gender, age, whether the coaches were certified and licensed under the new CSCF coaching levels pathways (necessary to coach currently), the region in which they coach, if the respondents coached more than one specific or multiple age groups of athletes, if the respondents worked exclusively with female or male athletes, if the coach ever worked during speed discipline events or training camps, and if the coach has any personal experience dealing with a traumatic spinal injury while coaching. It was not the aim of this study to collect large amounts of data and demographic details, but rather discover some preliminary information regarding attitudes and actions regarding spinal protective devices by Canadian ski racing coaches. This highlights the potential topics for future studies beyond this preliminary and exploratory research.

Conclusion

This study sought to examine the rates that Canadian alpine ski coaches recommend and enforce the use of spinal protective devices by their current athletes. This rate was surprisingly low, considering the response of coaches believing that spinal protection was important for their athletes. Very few coaches reported knowing of any current policy in place regarding spine protection use by their respective ski club employer or provincial sport organization. Future studies could explore what clubs do have policies regarding back protection, how they were implemented, and how they are enforced regularly using their coaching staff. Further investigation is required to determine why coaches are implementing spinal protection use for their athletes or not. There are many factors contributing to these attitudes towards spinal protection in Canadian alpine skiing and future research will help to better understand these attitudes.

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Appendix A.
SURVEY

1. The purpose of this study is to assess the current attitudes of Canadian Alpine ski racing coaches towards spinal protective devices for athletes. Two students in their third year at Canadian Memorial Chiropractic College (CMCC) will be conducting this research project.

   Your participation in this research study is voluntary and is not mandatory. At any point in time during the survey, you may withdraw without penalty. This online survey will take approximately 5 minutes. We will not be collecting your name or any other identifying information at any point during the survey. Thus, your responses are completely confidential.

   This research project has received research ethics approval from the CMCC research ethics board. Please contact Dr. Brynne Stainsby with any questions or concerns you may have at bstainsby@cmcc.ca.

   Clicking on the "agree" button below indicates that:
   - you have read the above information
   - you voluntarily agree to participate

   - Agree
   - Disagree

2. What age group do you coach?
   - < 10 years of age
   - 10-15 years of age
   - 15-20 years of age
   - 20-25 years of age
   - 25-35 years of age
   - 35+ years of age

3. What are your coaching certifications?

4. How many years have you been coaching?

5. Are you familiar with spinal protection devices for Alpine Skiing?
   - Very
   - Somewhat
   - Not at all

6. It is important for your athletes to wear a spine protector:
   - Strongly Agree
   - Agree
   - Neutral
   - Disagree
   - Strongly Disagree

7. Do you enforce the use of back protectors for your athletes?
   - Yes
   - No
   - Neutral

8. Does your ski club have a back protection policy currently in place?
   - Yes
   - No
   - I do not know

9. When competing in alpine ski competitions, your athletes wear back protectors:
   - All of the time (100%)
   - Most of the time (75-100%)
   - Often (50-75%)
   - Sometimes (25-50%)
   - Rarely (0-25%)
   - Never (0%)

10. Are you aware of a provincial back protection policy for alpine skiers in your province?
    - Yes
    - No

Appendix B

Table 2.
Familiarity with spinal protective devices for Alpine Skiing

Answer	Response Percent (%)	Response Count
Very	62.1	18
Somewhat	37.9	11
Not at all	0.0	0

Table 3.
Coaches' response to the statement: "It is important for your athletes to wear a spine protector"

Answer	Response Percent (%)	Response Count
Strongly Agree	37.9	11
Agree	27.6	8
Neutral	20.7	6
Disagree	10.3	3
Strongly Disagree	3.4	1

Table 4.
Enforcement of spinal protector use

Answer	Response Percent (%)	Response Count
Yes	34.5	10
No	51.7	15
Neutral	13.8	4

Table 5.
Frequency of club level spinal protection policies

Answer	Response Percent (%)	Response Count
Yes	10.3	3
No	79.3	23
I do not know	10.3	3

Table 6.
Awareness of provincial policies regarding spinal protective devices for Alpine Skiers

Answer	Response Percent (%)	Response Count
Yes	13.8	4
No	86.2	25

Table 7.
Athlete age demographic

Answer	Response Percent (%)	Response Count
< 10 years of age	10.3	3
10-15 years of age	62.1	18
15-20 years of age	20.7	6
20-25 years of age	0.0	0
25-35 years of age	0.0	0
> 35 years of age	6.9	2

Table 8.
Percentage of athletes wearing spinal protectors in competition

Answer	Response Percent (%)	Response Count
All of the time (100%)	17.2	5
Most of the time (75-100%)	24.1	7
Often (50-75%)	10.3	3
Sometimes (25-50%)	17.2	5
Rarely (0-25%)	24.1	7
Never (0%)	6.9	2

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Meniscal allograft transplant in a 16-year-old male soccer player: A case report

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Meniscal allograft transplantation (MAT) is a relatively new procedure that has gained popularity in the last couple of decades as a possible alternative to a meniscectomy to provide significant pain relief, improve function, and prevent the early onset of degenerative joint disease (DJD). As of present, evidence is limited and conflicting on the success of such procedures. In this case, a 16-year old male athlete underwent numerous surgical procedures to correct a left anterior cruciate ligament (ACL) rupture with associated medial and lateral meniscal damage that occurred as a result of a non-contact mechanism of injury. Following multiple procedures, including repair of both menisci and follow-up partial meniscectomy of the lateral meniscus, the patient continued to experience symptoms on the left lateral knee, making him a candidate for MAT. This case is used to highlight what a MAT is, what makes someone a candidate for this type of procedure, the current evidence surrounding the success of this intervention, and some rehabilitation considerations following surgery. The role of chiropractors and primary

L'allogreffe méniscale (AM) est une procédure relativement nouvelle qui s'est répandue au cours des dernières décennies comme une solution de remplacement possible à une méniscectomie afin de soulager de façon significative la douleur, d'améliorer la fonction, et d'empêcher l'apparition précoce de l'arthrose. À l'heure actuelle, il y a peu de données probantes, qui sont d'ailleurs contradictoires, sur le succès de ces procédures. Dans ce cas, un athlète de 16 ans a subi de nombreuses interventions chirurgicales pour corriger la rupture d'un ligament croisé antérieur (LCA) gauche ainsi que les lésions associées au ménisque médial et latéral qui se sont produites à la suite d'un mécanisme de blessure sans contact. Après plusieurs procédures, y compris la réparation des deux ménisques suivie d'une méniscectomie partielle du ménisque latéral, le patient a continué à ressentir des douleurs latérales au genou gauche, ce qui a fait de lui un candidat pour l'AM. Ce cas est utilisé pour mettre en évidence ce qu'est un AM, ce qui rend quelqu'un un candidat idéal pour ce genre de procédure, les preuves actuelles relatives à la réussite de cette intervention, et certains enjeux liés à la réadaptation après la chirurgie. Le rôle des chiropraticiens et des médecins traitants est d'assurer que les jeunes athlètes subissent une

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clinicians is to ensure that young athletes undergo early intervention to offset any degenerative changes that would be associated with sustained meniscal lesions.

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KEY WORDS: meniscal, allograft, transplantation, chiropractic

intervention rapide pour compenser les changements dégénératifs qui seraient associés à des lésions méniscales soutenues.

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MOTS CLÉS : méniscal, allogreffe, greffe, chiropratique

Introduction

Increased athletic participation among youth and adolescents has been on the rise.[1] This has lead to an increase in sports related injuries. Trauma and sports related injuries are common and have been cited to account for upwards of 40% of all injuries experienced by youth.[2] The knee is one of the most commonly injured joints accounting for 15.2% of all injuries among high school athletes.[3] Trauma to the meniscus accounts for up to 23% of all reported knee injuries.[3] These numbers are highly dependent on age, as it has been demonstrated that the incidence of meniscal and intra-articular disorders increase with age, likely being related to morphological changes in tissue elasticity.[4] Meniscal injuries are common among athletes from amateurs to professionals, typically resulting from a non-contact mechanism of injury when sudden rotational forces coupled with acceleration and deceleration impinge meniscal fibers between the tibia and femur resulting in tearing.[5,6] However, due to the complexity of forces associated with meniscal tears, concomitant anterior cruciate ligament (ACL) rupture or damage is possible, dramatically changing the overall presentation and prognosis of the clinical case. Surgical studies have indicated that concomitant meniscal injuries occur in 69-78% of all ACL cases.[7,8]

Degenerative changes associated with meniscal pathology are well documented in the literature and are of particular concern for adolescents where developing early onset osteoarthritis (OA) can lead to premature joint replacement.[9] This apparent correlation has generated a significant amount of attention in the importance of meniscal preservation to prevent degeneration. Over the years, various techniques have been implemented to offset these degenerative changes associated with meniscal lesions and traditionally involve one of the three common interventions: (1) conservative management (leave-alone), (2) excision (partial or complete menisectomy), or (3) repair.[10] However, in the past decade with advancements in technology and surgical procedures meniscal allograft transplantation has become a viable alternative to prevent the long-term sequelae in lesions that are not amendable through repair or partial-excision and would traditionally result in complete-excision.[11]

This case report focuses on concomitant ACL and meniscal injuries in adolescents and highlights the importance of early recognition and intervention to prevent premature degenerative changes. This report also outlines that in the presence of unsuccessful primary management, meniscal allografts could provide significant pain relief and functional improvement.

Case

A 16-year-old male presented to a sports chiropractic clinic with severe left knee pain that occurred during warm-up before a soccer match. He reported that it occurred as he was running across the pitch and as he went to change directions (plant and pivot) his left foot was placed in a divot causing him to collapse. He described that following the incident swelling occurred immediately. During initial presentation he had difficulty localizing pain and bearing weight, as well as, significant global knee range of motion deficits. Orthopedic examination was unable to be completed due to rigidity and swelling. Follow-up MRI revealed a full thickness ACL rupture with associated medial and lateral complex bucket handle tears of the left menisci.

Upon diagnosis, the patient underwent ACL reconstruction (June 2003), where a procedure producing an autograft using the semitendinosus tendon was implemented. At the time of the surgery the patient was informed that the tears in the menisci were not addressed and would be corrected at a later date. Following surgical intervention, the patient was treated in accordance with ACL rehabilitation and a sports-specific return to play protocol. Successful intervention had the patient developing full ROM and good joint proprioception. However, in lieu of this progression the patient still experienced recurrent/persistent pain with a sensation of instability (i.e., "giving way"). Additionally, the patient continued to report left knee joint line tenderness (medial and lateral) and swelling, leading to the second surgical intervention to repair both menisci six months (December 2003) following the initial surgery. Again, rehabilitation was provided by a sports chiropractor to facilitate return to play, but was impeded by continued symptoms (i.e., joint line tenderness and swelling) of the lateral knee, resulting in a third surgical procedure to perform a partial lateral menisectomy four months later (April 2004). The patient was able to return to play by September, but despite a return to full strength, good agility, and adequate proprioception the patient complained that the knee never quite felt "right" and sought the opinion of a second orthopedic surgeon in hope of an improved outcome. As a result, the patient received a lateral meniscal allograft in January of 2005 and returned to competition in July.

As a result of the final procedure, upon return to competition the patient only required periodic treatment over the next three years. Following the final procedure there was a significant reduction in pain and feeling of instability, resulting in improved patient satisfaction. Currently, the patient is 26-years old and continues to have the ability to participate in all of the sports he desires, but has started to demonstrate clinical signs and symptoms of early degenerative joint disease (DJD). These symptoms include increased joint stiffness and audible crepitus, as well as, decreased flexibility at the knee.

Discussion

The menisci are a complex dynamic type-1 collagenous structure situated between the femoral condyles and the tibial plateau.[12] It has been well documented that the menisci serves to stabilize the tibiofemoral joint particularly in ACL deficient knees, dissipate loading, increase joint congruency all while aiding in the lubrication of the articular structure.[13-15]

The medial meniscus is significantly less mobile then the lateral meniscus as a result of it being firmly attached to the medial joint capsule through both the meniscotibial and coronary ligaments. This consequently limits posterior translation of the medial meniscus to about 2.5mm during knee flexion.[16-18] In comparison, the lateral meniscus covers approximately 70% of the lateral tibial plateau, where the anterior horn attaches anterior to intercondylar eminence of the tibia, just lateral and posterior to the ACL.[16-18] Attaching in the general proximity is the posterior horn, which in 84% of people will divide into either anterior or posterior meniscofemoral ligaments (Humphrey or Wrisburg). The lateral meniscus has no connection to the popliteal hiatus or the lateral collateral ligament, which explains the increased excursion (up to 11mm) with knee flexion.[16-18]

The menisci are mostly avascular, suggesting limited capability to undergo natural healing. The meniscus can be divided into three zones transitioning from an avascular region of the central meniscus to an area of increased vascularity on the periphery. The central portion is termed the white-white zone, indicating an area void of blood, relying on diffusion from synovial fluid to provide nourishment.[11] Progressing laterally a region known as the "red-white" zone, which can be viewed as an area of high variability in blood supply to the meniscus. By the age of ten the meniscus beings to take on the adult morphology, vascularity will begin to recede confining blood supply to the peripheral one-third or "red-red zone" of the meniscus (Figure 1).[19] Specifically, it has been observed that vascu-

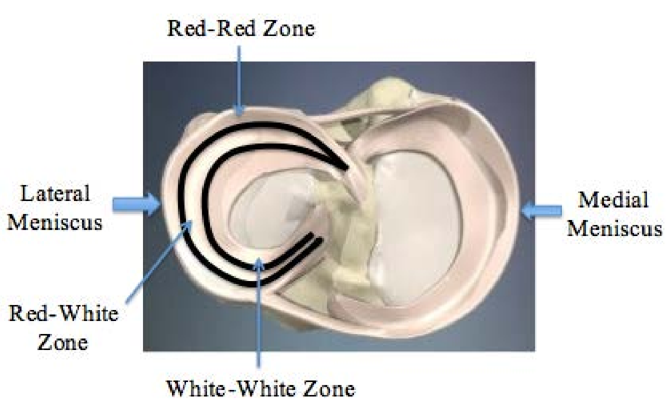

Figure 1
Superior tibial plateau with intact menisci demonstrating the 3 zones of vascularity (courtesy Primal Pictures Ltd. www.primalpictures.com)

larity in an adult meniscus can range from the peripheral 10-30% of the medial meniscus to 10-25% in the lateral meniscus.[19,20] Blood supply for the meniscus arises from a plexus of capillaries that comprise both superior and inferior branches of the lateral and medial genicular arteries.[19,20] The understanding of meniscal blood supply continues to be important, because an area high in vascularity has an increased potential to form a fibrovascular scar, crucial in the initiation of the reparative process. This has lead some to believe that younger individuals who sustain meniscal damage in the red zone have an increase propensity for healing.[19]

Surgical Management

Traditionally, surgical interventions of the meniscus involve excision of the damaged tissue (partial or complete meniscectomy) or attempted repair. The capacity of the meniscus to undergo healing is limited in the central portion (the red-white zone) and greatest in the menisco-synovial portion (red zone). It has been suggested that adolescents with tears confined to vascular zones (red/red and red/white) should undergo surgical repair to approximate damaged tissue and facilitate healing, through the formation of a fibrovascular scar.[17] However, in the circumstances that a tear is recognized in the avascular region (white/white zone), typically partial excision is recommended. It has now been recognized that such procedures can alter joint mechanics, increasing loading characteristics at the knee predisposing individuals to early DJD.[17] In a study by Baratz et al. it was described that following partial-menisectomies that the contact area would be reduced by 10% thus increasing point pressure by up to 65%, resulting in an increased rate of degenerative changes.[21] Full-menisectomies on the other hand would consequently reduce the contact surface by 75% increasing the associated joint contact pressure by 235%, resulting in the rapid onset of degeneration.[21] Due to this, full-menisectomies are now rarely performed and reserved for special circumstances, while not being recommended in youth.

In light of the negative side effects associated with menisectomies, attention has been directed at preserving functional meniscal tissue through repair to prevent continued catching, clicking, locking, instability ("giving way"), and to offset degenerative changes. Meniscal repair is the primary intervention prescribed in youth to facilitate healing and return to play in athletes, but may not be satisfactory in all circumstances.[22]

Current evidence suggests that early surgical management of meniscal tears is important in the long-term prognosis and the prevention of early onset OA in the knee.[22] Venkatachalem et al. demonstrated a 91% success rate with meniscal lesions repaired within three months of the initial injury, compared to only 58% in those after this period.[23] Additionally, other contributing factors to successful surgical repair include tear location, orientation, patient age, and concomitant ACL reconstruction.[22] Tear location speaks to vascular supply previously discussed with tears in the red zone likely to respond to surgical repair compared to those in the white zone.[22] Westin et al. performed a systematic review of the clinical healing rates of meniscus repairs in the red-white zone suggesting that repair is an acceptable intervention when appropriately indicated and should be considered before a meniscectomy is performed. It has also been suggested that future studies assessing healing rates in the red-white zone adequately report findings based on zone and type.[7] Additionally, it has been advised that authors separate findings from tears located in the red zone from the red-white zone because of the vastly different vascular characteristics of these areas.[7] Additionally, is has been suggested that tear orientation and type can affect healing following meniscal repairs. Vertical circumferential tears are likely to respond positively to surgical intervention, as these do not cause tearing of the circumferential collagen fibers, reducing the forces experienced by the lesion.[22] Comparatively, radial and complex multiplanar tears can cause significant disruption of collagenous fibers leading to a decreased propensity for tissue healing.[10]

In our case the MRI confirmed presentation of a full thickness ACL tear and associated medial and lateral complex bucket handle tears of the left menisci, which demonstrates the complexity of the lesion sustained by this athlete. Based on the available literature this could have warranted immediate surgical correction in hopes of protecting both the remaining meniscal tissue and the underlying articular structures.

When discussing meniscal injuries it is important to address associated ACL sequelae as concomitant injuries have been demonstrated to be associated with an increased risk of developing OA. In chronic ACL-deficient knees, increased instability leading to excess anterior translation and medial rotation of the tibia can predispose an individual to degenerative medial meniscal tears and early DJD.[24] Typically, it has been suggested that knee injuries resulting in concomitant ACL and meniscal lesions be repaired together producing significantly better outcomes.[22] It has been theorized that increased success is a result of increased intra-articular bleeding that supports fibrin clot formation and may provide the necessary vascular nutrition required to promote meniscal healing if repaired at the same time.[10]

When looking back at the case, it can be observed that these principals were not applied as ACL reconstruction was performed in isolation of meniscal repair. This is the result of determining during surgery that the meniscal lesions were in an area of high vascular supply and likely to respond to non-surgical repair. However, continued symptoms associated with both medial and lateral meniscal tears remained evident forcing multiple surgeries in attempt to repair and remove damaged tissue. This lead to many of the principals associated with successful meniscal repair not being addressed including: (1) not providing early surgical intervention on the meniscus to prevent degenerative changes (< 3-months), (2) progressive degeneration of the meniscus due to laxity associated with ACL reconstruction likely affected the type and location of the tear, resulting in a worse prognosis for this patient, leading to a drastic and relatively new procedure.

Meniscal Allograft Transplant (MAT)

After numerous failed surgical interventions the patient in this case report underwent a relatively new procedure involving a meniscal transplant from a cadaveric specimen (allograft). Meniscal transplants are highly involved surgical procedures requiring successful anchoring of meniscal tissue to the tibial plateau. Currently, there is a very limited number of orthopedic surgeons worldwide with a significant amount of experience in performing meniscal transplants. However, increased popularity as a result of a growing body of evidence demonstrating significant pain relief and functional outcomes has resulted in more procedures annually.[11]

In regards to meniscal allografts there are four primary procedures that are used including cryopreserved, fresh-frozen, fresh, and freeze-dried.[11,25] Each procedure comes with definitive pros and cons, which are unique to the histochemical and preservation method of the graft and is likely a concern for the operating surgeon.[11] Recently, most procedures are preformed using a fresh-frozen graft as they have become synonymous with elevated success rates, decreased risk of disease transmission, and maintenance of structural integrity preventing further degenerative changes to the knee.[26]

The indications for meniscal allograft transplantation (MAT) still remain vague and controversial, but recommendations have been established to suggest when this intervention is likely to have beneficial results.[11,26] First, it has been suggested that the ideal candidate is between the ages of 20-50 with a previous history of meniscectomy. Appropriate considerations should be taken to ensure skeletal maturity of the patient, as MAT procedures are not likely to be performed on subjects prior to closure of the epiphyseal plates.[11,26] Additionally, the patient should present with a stable knee joint, have minimal degenerative changes, no lower-limb radiographic misalignment, and no localized pain or swelling over the meniscus-deficient compartment.[11,26] Next, ACL-deficient patients who have previously had a medial meniscectomy are likely to yield positive results and improve joint stability if ACL reconstruction is performed in conjunction with MAT.[11,26] Finally, though not routinely performed, prophylactic MAT could be performed in young, athletic patients who have previously received a complete meniscectomy to prevent future DJD. This is not routinely performed because current evidence has not demonstrated significant evidence in the prevention of long-term joint arthrosis and is not void of surgical complications. However, some supporters have suggested that early intervention may significantly improve the surgical outcomes associated with MAT, likely making this conversation to be had between the patient and surgeon.[11,26] These recommendations have been suggested because like any invasive procedure there is associated risk beyond those commonly associated with surgeries and need to be actively discussed. Such surgical complications can include immunological concerns (i.e., host rejection), as the bone plug (an immunogenic substance) used to attach the meniscal graft has the potential to cause an immune reaction.[11] Further, concerns regarding disease transmission, primarily of Hepatitis C and HIV can occur even when appropriate sterilization procedures have been performed.[11] These risks are considered small but must be discussed with the patient prior to intervention.[11] Potential complications following MAT include detachment of the meniscus or bone plug, meniscal allograft failure, and arthrofibrosis.[11]

Conversely, contraindications include severe degenerative cartilaginous changes, resulting in ulceration and bone exposure. Radiographic evidence of advanced DJD (i.e., osteophyte formation, joint space narrowing, flattening of the femoral condyles) has been demonstrated to be associated with poor results during MAT. Additionally, it has been advised that patients over the age of 50 are not ideal candidates to receive MAT, while other negative prognostic factors include obesity (BMI>35), skeletal immaturity, and systemic diseases (e.g., synovial chondromatosis, inflammatory arthritis, and infection).[11,26-27]

Much of the initial evidence focusing on MAT, like many surgical procedures, has its roots in both cadaveric and animal studies providing limited translation into the active bipedal weight bearing human. However, recent studies have begun to look at the success of these procedures in humans, demonstrating various results both in the short-term and long-term. A study by Noyes and Barber-Westin revealed that 62 of 96 grafts (65%) were intact 2-years post surgical.[28] Similarly, Verdonk and colleagues demonstrated success rates to be 74.2% and 69.8% for medial and lateral MAT respectively, with a mean follow-up of 7.2 years.[29] However, a couple of studies have looked at long-term follow-up (> 10 years) of MAT, reporting conflicting evidence. Wirth and colleagues performed a follow-up (14 years) analysis of an original series, demonstrating that all allograft and articular cartilage underwent degenerative changes.[30] In contrast, Verdonk et al. suggested that MAT has a potential chondroprotective effect at follow-up (minimum 10 years, mean 12.1 years) by demonstrating that there was no joint space narrowing in 52% of patients.[31] The relatively young field of meniscal transplantation is characterized by a limited body of retrospective cohort literature, suggesting success rates between 12.5-100%.[26] However, it is important to note that these studies are limited in the capacity that they fail to provide a control group undergoing conservative management following a meniscectomy.[11]

Rehabilitation is an important component in the success of many orthopedic surgeries, but very little research has been conducted on the most appropriate method when dealing with MAT. This has led there to be confusion and a lack of consensus among professionals with regards to tissue loading and progression. Lee and colleagues have suggested a progressive approach to facilitate functional return without compromising the healing tissue.[26] It has been proposed that within two months post-surgery a patient should have the progressive ability to bear weight while achieving full ROM to allow for return to sport in 6-9 months. ROM exercise should begin immediately post-operatively focusing on full extension while limiting flexion to 90 degrees for the first 6-weeks as increased flexion has been associated with elevated stress on the meniscus, particularly at the posterior horn.[32] Further, pivoting and weight bearing should be minimized to prevent compression and shearing of meniscal tissue during the initial stages of rehabilitation.[26] During the first 4-weeks, initial rehabilitation is characterized by progressive closed kinetic chain exercises (i.e. standing toe-touch with full knee extension or passive knee extension) and patellar mobilizations to promote functional tissue loading (Figures 2-4).[26,32] Early open kinetic chain exercises, such as seated leg curl, are not advised. It has been suggested that knee flexion increases activation of the semimembranosus and popliteus cause posterior translation of both the medial and lateral meniscus respectively, potentially dislodging meniscal tissue.[26,32] Recommendations suggest that gentle jogging can begin between 4-6 months, but running is not advised before 6-months post-surgical.[26,32] Finally, return to play is likely to occur between 6-9 months.[26] In the case that concomitant ACL reconstruction occurs, rehabilitation protocol should be modified to address the meniscus

Figure 2
Standing toe-touch with full knee extension

Figure 3
Passive knee extension

Figure 4
Patellar mobilization

as the primary concern. Typically, ACL rehabilitation is characterized by progressive strengthening of the hamstrings through either concentric or eccentric loading to prevent anterior translation of the tibia during dynamic movements. The principals addressed during ACL rehabilitation if addressed too early are likely to have detrimental effects on the success of a meniscal transplant.[32] In this case an appropriate rehabilitation protocol for both the ACL and meniscus was followed. The rehabilitation program was carefully developed based on suggestions from the surgeon, while taking into consideration patient tolerance and mastery of previous exercises before progression could take place.

Conclusion

Meniscal injuries are a common injury among the athletic population, resulting from a non-contact mechanism of injury where rapid acceleration and deceleration in conjunction with twisting causes meniscal tissue to become impinged between the tibia and femur. The menisci serve to dissipate loading, increase joint congruency and aid in lubrication of the femorotibial articulation.[13-15] It has been well documented in the literature that significant trauma or excision of the menisci are associated with degenerative changes in the knee, suggesting that preservation of the menisci is of crucial importance in the prevention of early DJD. Traditionally, meniscal lesions have been addressed through surgical correction or removal, with less emphasis on conservative management as early surgical repair are associated with better outcomes. However, not all surgical procedures are successful leading to continued symptoms and disability. Meniscal allograft transplants have become a recent surgical innovation in the management of meniscal injuries. This relatively new procedure is characterized by meniscal transplantation using one of four forms of an allograft (cryopreserved, fresh-frozen, fresh, freeze-dried), with most success coming from those using fresh-frozen specimens.[11,25] Currently, due to the limited amount of surgeons performing these surgeries worldwide literature regarding the chondroprotective effects is limited, suggesting that this intervention should remain a last resort when patients have continued symptoms. Future research should be focused on the long-term success as well as the chondroprotective effects of meniscal allograft transplants, while addressing rehabilitation protocols that could promote return to function following surgery.

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The clinical and biomechanical effects of fascial-muscular lengthening therapy on tight hip flexor patients with and without low back pain

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Background: *Many patients have tight hip flexors with or without low back pain. Manual fascial-muscular lengthening therapy (FMLT) is one commonly used treatment for this population.* Objective: *Investigate the clinical and biomechanical effects of manual FMLT on tight hip flexor patients with and without low back pain.*

Methods: *A nonrandomized trial, before-and-after experiment with multiple baselines conducted on two different patient populations: 1) Mechanical low back pain patients with tight hip flexors (n = 10) and 2) Asymptomatic group with tight hip flexors (n = 8). Four treatments of manual FMLT were performed on the hip flexor of the two groups of patients over a two-week period. Primary* ***o****utcome measures over the two-week period were 1) Maximum voluntary trunk flexor and extensor moments, 2) Disability (Roland Morris Disability Questionnaire) and pain (10-cm Visual Analogue Scale), 3) Passive hip extension mobility.*

Results: *Primary outcome analysis involved within-*

Historique : *De nombreux patients ont des muscles fléchisseurs de la hanche serrés, avec ou sans douleur lombaire. La thérapie manuelle d'allongement musculo-facial (TMAMF) est un traitement couramment utilisé pour ces personnes. Objectif : Étudier les effets cliniques et biomécaniques de la TMAMF sur les patients dont les muscles fléchisseurs de la hanche sont serrés, qu'ils souffrent ou non de douleurs lombaires.*

Méthodologie : *Un essai non randomisé effectué avant et après l'expérience avec plusieurs références sur deux groupes de patients différents : 1) des patients souffrant de douleurs lombaires de nature mécanique et dont les muscles fléchisseurs de la hanche sont serrés (n = 10) et 2) un groupe asymptomatique dont les membres ont des muscles fléchisseurs de la hanche serrés (n = 8). Quatre séances de TMAMF ont été réalisées sur le muscle fléchisseur de la hanche des patients des deux groupes pendant deux semaines. Les principaux critères d'évaluation au cours des deux semaines étaient : 1) couple maximal volontaire des muscles fléchisseurs et extenseurs du tronc, 2) handicap (questionnaire sur les handicaps de Roland Morris) et douleur (échelle visuelle analogique de 10 cm), 3) amplitude d'extension passive de la hanche.*

Résultats : *L'analyse des principaux résultats*

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groups comparisons. Maximum voluntary trunk extension demonstrated increases for the low back pain patients. The low back pain patients demonstrated a small, but significant, reduction in disability and pain. Both groups demonstrated an increase in passive hip extension measurements.

Conclusion: *This preliminary study demonstrated interesting results from manual FMLT on two tight hip flexor patient populations with and without low back pain. However, there were several significant limitations from this study, which restrict the ability to generalize the results.*

(JCCA 2014; 58(4):444-455)

KEY WORDS: biomechanics, rehabilitation, back pain, iliopsoas, stretching, fascial-muscular, myofascial, hip flexor

comportait des comparaisons entre les groupes. L'extension maximale volontaire du tronc a augmenté chez les patients atteints de lombalgie. Ces patients ont démontré une réduction faible, mais significative, de l'invalidité et de la douleur. Chez les deux groupes, on a enregistré une augmentation des mesures d'extension passive de la hanche.

Conclusion : *Cette étude préliminaire a produit des résultats intéressants de la TMAMF sur deux groupes de patients dont les muscles fléchisseurs de la hanche sont serrés, à savoir ceux qui souffrent de douleurs lombaires et ceux qui sont asymptomatiques. Cependant, l'étude comportait plusieurs lacunes importantes qui limitent la possibilité de généraliser ses résultats.*

(JCCA 2014; 58(4):444-455)

MOTS CLÉS : biomécanique, réadaptation, douleur lombaire, iliopsoas, étirement, musculo-fascial, myofascial, muscles fléchisseurs de la hanche, chiropratique

Introduction

Low back pain is a significant health problem in developed countries.[1] Trunk muscle force in the low back pain population has been previously investigated.[2] A longitudinal study that was conducted with 215 adult males found a significant difference in baseline isometric trunk strength between healthy subjects and subjects with low back pain.[2] We also know that low back pain injuries can lead to pain, muscular tightness and adaptation.[3] Supporting the spine is crucially important to reducing injury and subsequently decreasing pain.[3] Trunk muscle moment production has been shown to be one of the best ways to protect the spine (the other two is muscle timing and muscle coordination).[3,4]

According to Bogduk et al. (1992) and Juker et al. (1998) the iliopsoas serves as a major compressor of the lumbar spine, and contributor to spine stability due to its comprehensive nature as it spans from the thoracolumbar region, across the lumbar spine and pelvis, to the femur attachment.[5,6] Spinal stability required iliopsoas activity even though it can only produce small moments in the sagittal plan.[7]

In most cases, the stabilizing potential of the iliopsoas has been attributed to the spinal compression it produces. Cholewicki & McGill (1996) suggest that compression from the psoas will create segmental stiffness.[8] They used a biomechanical model of the lumbar spine to estimate the lumbar spine stability. Individual muscle forces and their associated stiffness estimated from the EMG-assisted optimization algorithm, were combined with external forces to calculate the relative stability index of the lumbar spine for three subjects. They found that there was a stability safety margin during tasks that demand a high muscular effort and that the iliopsoas is one of the important muscles that assist in developing spinal stiffness. In addition, bilateral contraction of the iliopsoas majors provides equal and opposite moments about the lateral bend and axial rotation. These equal and opposite muscle actions have been described as acting like guy wires (i.e. psoas major muscles) to stabilize the mast (i.e. the lumbar spine) during various movements such as lifting.[7]

However, too much compression, clinically through iliopsoas tightness, can have a detrimental effect on the spine's health.[9] Kendall et al. defined hip flexor muscle tightness as the inability to achieve full hip extension when in the modified Thomas test position.[10] Further to this point many patients with low back pain experience a loss of hip extension due to hip flexor tightness.[11] One study by Licciardone et al. (2014) suggested that remission of psoas syndrome may be an important and previously unrecognized mechanism explaining clinical improvement in patients with chronic LBP following Osteopathic Manipulative Therapy.[12] To manage low back pain some clinicians and researchers have reported correcting the tightness of hip flexor muscles through stretching.[11,13-15]

An array of procedures have been described to improve muscle flexibility including passive stretching, active stretching, manual fascial-muscular lengthening therapy (FMLT) (i.e. Active Release Technique®) and proprioceptive neuromuscular facilitation stretches.[15-18] Active and passive stretching of the hip flexor group in low back pain patients has been shown to increase hip extension.[15]

Another common method of increasing hip extension is through manual FMLT. However, to our knowledge, no one has reported the muscle force, pain, disability and hip extension effects of a manual FMLT on tight hip flexor patients with and without low back pain. The purpose of this study was to examine the clinical and biomechanical effects of FMLT on tight hip flexor patients with and without low back pain.

Methods

Subjects

The study performed was an un-blinded intervention study with two different populations, a before-and-after experiment with multiple baselines that involved participation in five sessions over a two-week period. We estimated the standard deviation to be approximately 25% of the mean, based on both the control group (mean = 156.72, SD = 37.66) and patient group (mean = 133.77, SD = 33.05) of Suzuki and Endo (1983).[19] We also expected to consider mean differences of 25% to be significant. Thus, we calculated the sample size required to be n = 8. Twenty-seven subjects responded to flyers distributed through the University athletic centre. All twenty-seven respondents were assessed for inclusion into the study. Eighteen male patients met the study's requirements for tight hip flexors (a positive value on the Modified Thomas Test) with or without low back pain (Figure 6). They represented a homogeneous group with respect to age (undergraduate students), health and fitness level (University varsity athletes). During session one all subjects were evaluated by a clinician and placed into one of the following two groups: 1) Low back pain with bilateral tight hip flexors (LBP-THF). These patients were examined by a chiropractor to ensure that they had mechanical or nonspecific, episodic or constant, low back pain, for more than three months, and for safety had no history of serious underlying pathology, nerve root compromise, structural deformities, genetic spinal disorders or previous spinal surgery, or 2) Asymptomatic subjects with bilateral tight hip flexors (A-THF). Both groups were required to have bilateral tight hip flexors which was determined by a Modified Thomas Test (described below).[20]

Experimental Procedures and Protocol

Subject Orientation. During session one (S1) participants that met the inclusion criteria for the experiment were given a brief orientation to the experimental protocol. Specifically, subjects were given an opportunity to try the maximum trunk flexion ($Flex_{Max}$) and extension moment (Ext_{Max}) protocol prior to commencement of the study.

At this point, the subjects were allowed to ask questions or voice concerns that they might have had regarding the study and their participation. All recruited subjects agreed to participate in the experimental protocol. All subjects that participated in the study were asked to continue their usual sports training. All subjects in this study did not receive any other forms of therapy or treatment immediately prior to or during the two week study participation. This study was approved by the McMaster Research Ethics Board and all participants signed an approved consent form for participation in the study.

Study Design. During S1, outcome measures were collected (passive hip extension angle, Modified Thomas Test, 10-cm Visual Analogue Scale (VAS) and Roland-Morris Disability Questionnaire (RMDQ)). Subjects performed a series of maximum voluntary isometric contractions (MVICs) of the trunk extensor and trunk flexor muscle groups. Maximum isometric trunk extension and flexion were chosen as one of the outcome measures as many patients rely on trunk strength performance. For each $Flex_{Max}$ and Ext_{Max} trials, the subjects performed three repeated isometric exertions, for three seconds each, with one-minute rest between efforts (Figure 1).

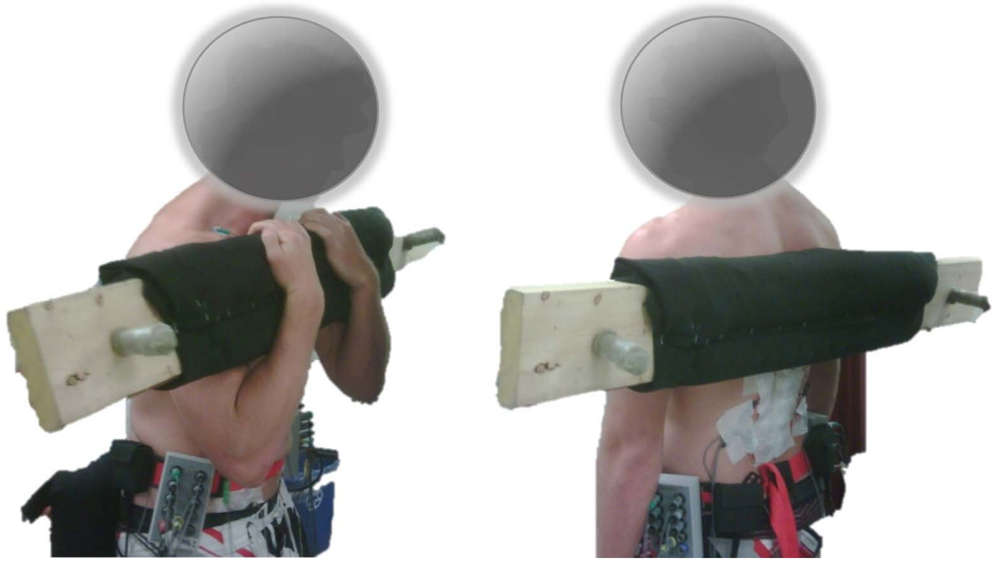

Figure 1.
MVIC apparatus: Subject performing $Flex_{Max}$ and Ext_{Max} efforts.

The $Flex_{Max}$ and Ext_{MAX} trials were performed against a padded restraint attached to metal chains in series with the force gauge. The vertical moment arm from the L4/L5 joint to the wood harness was measured so that the isometric forces could be converted into moments.[21] The data collected were termed the 'Pre' data from S1.

Following this data collection, the FMLT (described below) was performed on the subject's right and left iliopsoas. After this passive hip extension values were recorded, a new VAS pain scale was completed and repeated trunk flexor and extensor MVICs were completed, in a randomized order. Measures made immediately following the treatment were termed 'Post' in S1.

During Session two (S2), Session three (S3) and Session four (S4), Pre- and Post-FMLT measurements were only taken from the VAS-pain scale, trunk flexor and extensor MVIC trials. S1 and S2 were completed in the first week of testing with 24 hours of rest in between sessions. S3 and S4 were completed in the second week of testing with 24 hours of rest in between sessions. Session five (S5) was completed at two weeks of the initial testing day and 48 hours between S4 and S5. S5 consisted of replicating one complete set of outcome measures from S1's Pre condition, with no treatment following.

This timeline was chosen to replicate a common clinical scenario in which a patient receives two treatments per week for two weeks with a follow-up at the conclusion of the four treatments. The 24 hour period between S1/S2 and S3/S4 was used ensure consistency between subjects.

Outcome Measures

The primary outcome measures for this study were chosen to address the multitude of factors that are important for a patient in daily clinical practice (trunk muscle force, hip extension, pain and disability). Therefore, the primary outcome measures analyzed for the Modified Thomas Test and isometric maximum trunk flexion / extension were between S1:Pre and S5.[2,20] The primary outcomes measures analyzed for the low back pain population, pain and disability, were examined through the VAS and RMDQ between S1:Pre and S5.

Secondary outcome measures were analysed for all of the data from the multiple time points (for Pre/Post S1, S2, S3, S4, and S5) for the isometric maximum trunk flexion / extension and VAS. Since RMDQ was only collected at S1:Pre and S5, while hip extension data was only collected at S1:Pre, S1:Post and S5, a secondary outcome measure analyses was performed for these times.

Figure 2.
Manual FMLT of the iliopsoas complex.

The same investigator measured these variables for all subjects in all sessions.

Disability and Pain. Disability and pain were measured using: 1) Roland-Morris Disability Questionnaire (RMDQ) and 2) 10-cm Visual Analogue Scale (VAS) for low back pain.[22,23]

Flexibility Tests. The Modified Thomas Test was used to test for a tight iliopsoas complex. A simple long-arm goniometer (Orthopedic Equipment Co., Bourbon, USA) with a 360° scale marked in one degree increments was used. For each test the goniometer was placed with the axis over the greater trochanter. The test was considered "positive" if a tight iliopsoas complex existed when the hip flexion angle was greater than 0° and knee was bent. Three measurements were taken on both sides and the average of each side was recorded. For further details about The Modified Thomas Test please see Clapis et al. (2008). The Modified Thomas Test has been shown that there is a high intrarater and a high interrater reliability for the measurement of hip extension flexibility with a goniometer.[20]

Trunk Flexion and Extension Strength Trials. For the maximum voluntary isometric contractions (MVICs) of the trunk flexor and extensor muscles, forces were measured with a unixalial strain gauge (MLP-500-C0, A-Tech Instruments, Scarborough, Canada). All signals were collected with customized LabView software (National Instruments, Austin, TX.) using a PC compatible computer. Analog signals obtained from each instrument were converted to digital signals using a 12-bit A/D card (National Instruments, Austin, TX.). All signals were sampled at 2000 Hz.

Intervention

Treatment. The subjects from both groups received FMLT from the same practicing clinician (three years of clinical experience) with the goal of increasing the extensibility of the fascial-muscular iliopsoas complex. FMLT was administered with the subject in the side-lying position and the hip was flexed to place the iliopsoas complex at a shortened length (Figure 2). The fingers of the clinician were placed on the targeted treatment area. The finger contact was light compression and tension in the superior direction. The muscle was subsequently lengthened, moving the hip into extension until the end of the subject's range of motion, while the clinician maintained tension in the opposing direction. This was considered to be one pass. Three locations were used for the FMLT protocol in-

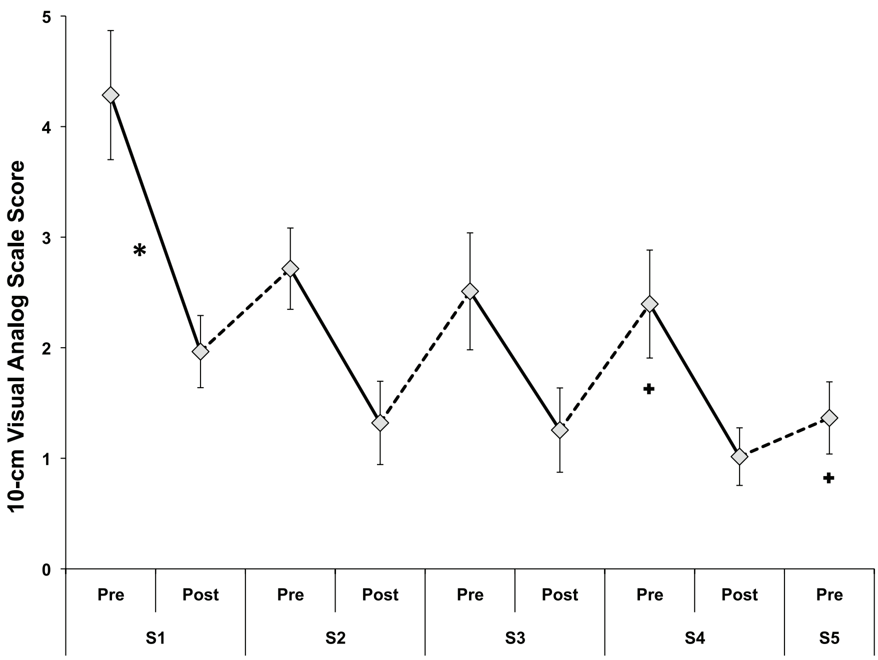

Figure 3.
*Mean LBP-THF group pain scores (10-cm VAS) over the course of the treatment program (n = 10). Solid lines indicate changes within a session (primary outcome measure); dotted lines indicate changes between sessions (secondary outcome measure). Standard error bars are shown. Significant decreases within a session shown with *; significant decreases from S1:Pre shown with a +.*

cluding: 1) Next to navel, 2) On the inside of the iliac crest and 3) Half way between the anterior superior iliac spine and the pubic bone (just below the inguinal ligament and medial to the Sartorius).[24] Three passes were performed at each location. After the nine passes, the subject was asked which location provided 'the most benefit.' The chosen location received an addition three passes. Subject received treatment bilaterally. Subjects were instructed not to receive any other types of treatment during participation in the study. The subjects were asked to continue with their normal day-to-day activities without deviation and without performing any additional exercises or stretches.

Data and Statistical Analysis

Averages were calculated across the three repeated trials, bilaterally for the hip extension flexibility tests.

The force records from each $Flex_{MAX}$ and Ext_{MAX} trial were smoothed with a one second moving average. The maximum force from each smoothed trial was recorded, and the highest force from the three trials was determined to be the maximum value for both $Flex_{MAX}$ and Ext_{MAX} for each subject. These values were multiplied by their respective moment arms to calculate the maximum strength as a moment of force for both directions.[21]

The A-THF group had their VAS recorded for the S1:Pre/Post through S5 (n = 9) and RMDQ scores were recorded at S1:Pre and S5. Since they were recorded as 0 for all subjects in that group (no disability and no low back pain) statistics for the VAS and RMDQ were only run with the LBP-THF group. A paired t-test was run with the RMDQ disability data from S1:Pre and S5. A one-way ANOVA with repeated measures was run for the VAS pain scores, with time as the independent variable (n=9, S1, S2, S3 and S4:Pre and Post and S5).

For the flexibility measurements, the dependent variable was passive hip extension. For each of these dependent variables, a three-way mixed ANOVA was run and the independent variables were time (S1:Pre, S1:Post, S5), side (right and left) and group (LBP-THF and A-THF). Given that side was not an independent variable for the trunk strength trials, a two-way mixed ANOVA was run for both the $Flex_{Max}$ and Ext_{Max} strength data, with the independent variables being (LBP-THF and A-THF) and time (n=9).

For all statistical analyses with significant main or interaction effects, a Tukey's post hoc pairwise comparison test was performed to determine the significance of individual mean differences in time. Significance was set

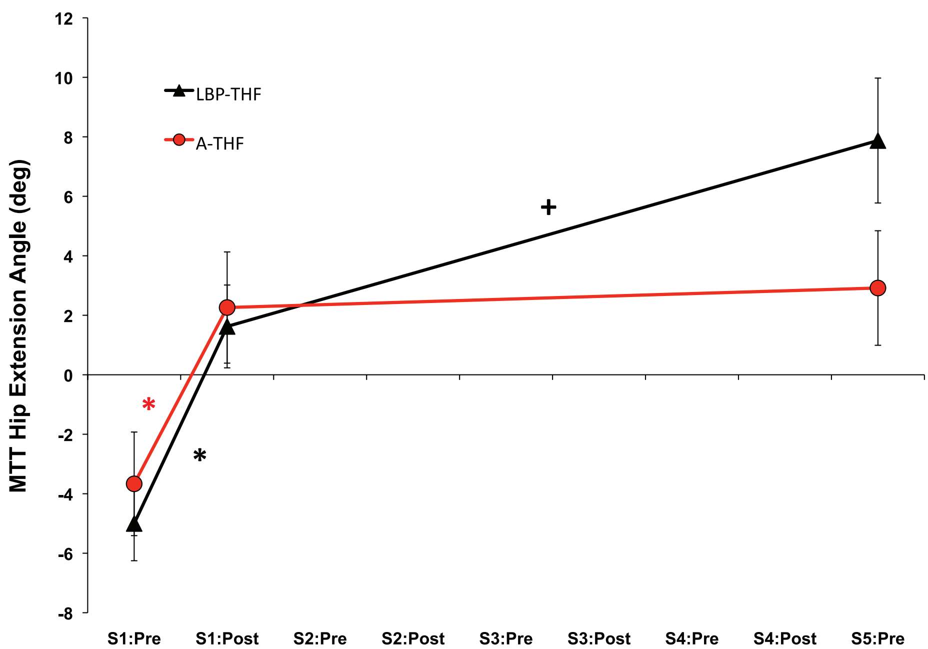

Figure 4.
*Modified Thomas Test hip extension angle (deg) for the low back pain, tight hip flexor (LBP-THF) and asymptomatic THF (A-THF) groups at S1:Pre, S1:Post and S5. Values are pooled across the right and left side (n = 20 for LBP-THF and 16 for A-THF). Standard error bars are shown. Significant decreases within a session shown with *; significant increases from S1:Pre to S5:Pre shown with a +.*

at $p < 0.05$. The Statistical Package for the Social Sciences (SPSS) statistical software package was used for analysis.

Results

This study involved 18 male University varsity athletes that were subdivided into two groups: 1) Low back pain with tight hip flexors (n = 10, age = 22.2±4.3 years, mass = 85.9±19.1 kg), or 2) Asymptomatic subjects with tight hip flexors (A-THF): asymptomatic subjects having bilateral tight hip flexors but no LBP (n = 8, age = 22.5±2.1 years, mass = 84.0±11.0 kg) (Table 1). No injuries occurred during treatment and testing of the study. There were no significant differences in age, height, weight or training hours per week between groups. There were no participant dropouts and there was full compliance with each subject for this study.

Disability and Pain

Primary Outcome Measure

The average LBP-THF group disability score (RMDQ) demonstrated a significant decrease (p<0.05) 5.1±2.8 (out of 24), before treatment in S1:Pre, to 2.3±1.1 in S5 (after four treatments).

There was a significant main effect of time on pain over the course of the treatments (p<0.0001). The average LBP-THF group VAS score decreased4.2±1.8 cm (out of 10 cm), before treatment in S1:Pre, to 1.4±1.0 cm in S5.

Secondary Outcome Measure

When comparing Pre values for the VAS score, the post hoc analysis revealed a significant decrease in pain from S1:Pre to both S4:Pre and 5:Pre. There was no significant decrease in pain from S1:Pre to both S2:Pre and S3:Pre. Comparing the Pre and Post values within each session, there was a significant decrease in pain only within S1 (Figure 3 & Table 2).

Flexibility Tests

Primary Outcome Measure

In all cases, the right and left hip extension flexibilities were very similar on the right and left sides (always within two degrees), so the data were pooled bilaterally. The Modified Thomas Test resulted in a significant main effect of time (p<0.0001) and a significant interaction between time and group (p<0.05). For the LBP-THF group, the post hoc analysis revealed a significant increase from S1:Pre to S5 (p<0.05). For the A-THF group, there was a significant increase from S1:Pre to S5 (Figure 4). There

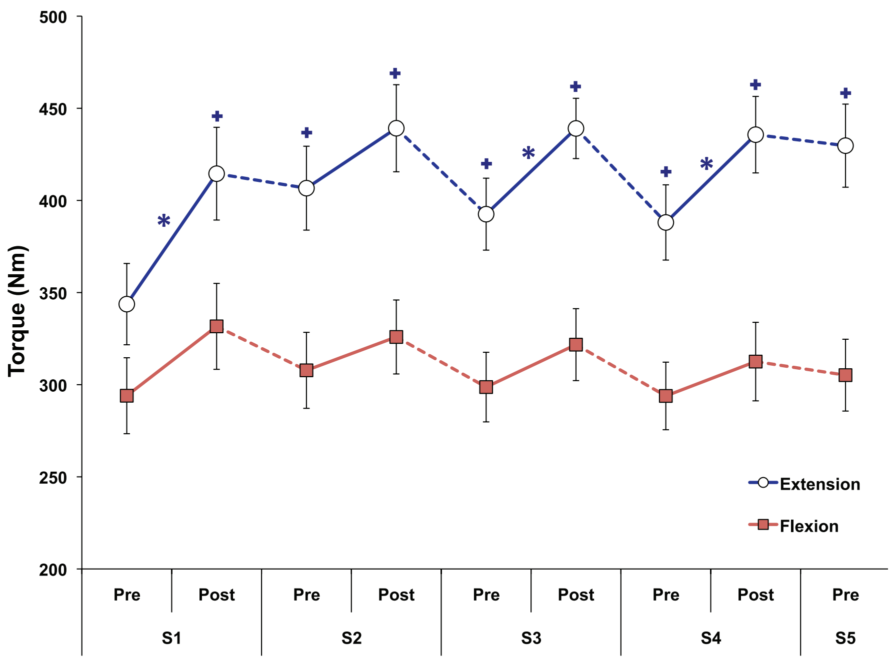

Figure 5.
*Trunk flexion and extension strength (Nm) of both THF groups over the course of the treatment sessions (n = 10 for LBP-THF and 8 for A-THF). Solid lines indicate changes within a session (primary outcome measure); dotted lines indicate changes between sessions (secondary outcome measure). Standard error bars are shown. Significant decreases within a session shown with *; significant increases from S1:Pre shown with a +.*

was a significant increase in passive hip extension over the course of the treatment program, from S1:Pre to S5, for the LBP-THF and A-THF groups by 13.1° (±1.1°) and 8.0° (±1.0°) respectively.

Secondary Outcome Measure

The Modified Thomas Test resulted in a significant effect for time for the LBP-THF group from S1:Pre to S1:Post ($p<0.05$). There was no significant effect for the A-THF group between S1:Pre and S1:Post.

Trunk Flexion and Extension Strength Trials

Primary Outcome Measure

There was a significant main effect of time on Ext_{Max} ($p<0.0001$) (Figure 5 & Table 3). Over the course of the treatments (S1:Pre to S5), the LBP group increased their Ext_{Max} values an average of 34% compared to 14% for the A-THF group (Figure 5).

Secondary Outcome Measure

There was a significant increase in Ext_{Max} when comparing S1:Pre to all tests performed after the first treatment. When comparing the Pre and Post values within each session, there was a significant increase in Ext_{Max} within S1, 3 and 4.

There was a significant main effect of time on $Flex_{Max}$ ($p<0.001$) (Figure 5 & Table 4). There were no significant main or interaction effects of group. Comparing the Pre and Post values within each session, there was a significant increase in $Flex_{Max}$ only within S1.

Discussion

Over the course of the treatment program, the disability and pain scores for the LBP-THF group were reduced compared with their baseline values. The minimal important difference for change in the RMDQ score has varied in the literature.[25,26] A recent study, taking the baseline score into account, suggested that a 30% improvement was considered a useful threshold for identifying clinically meaningful improvement on each of these measures.[27] In this study, prior to treatment, the average RMDQ score for the LBP-THF group was 5.1 out of 24 (±2.8). After four treatments the average RMDQ score was 2.3 (± 1.1). This result falls within the minimal important difference change in the RMDQ literature. The 2.8 point change is not large change but is an encouraging result that would suggest further investigation for this type of therapy on the LBP population with THFs.

The minimally important change for the VAS within-person has been suggested to be 15 out of 100 (or 1.5

Table 1.
Descriptive statistics (average and standard deviation) of A-THF (n = 8) and LBP-THF (n = 10) groups.

Group		Age (yrs.)	Height (cm)	Weight (Kg)	Training/Week (Hrs.)
A-THF (n = 8)	AVG	22.5	172.7	84.0	12.3
	SD	2.1	17.1	11.0	4.3
LBP-THF (n = 10)	AVG	22.2	181.3	85.9	11.8
	SD	4.3	11.3	19.1	5.8

Table 2.
Mean and standard deviation of the LBP-THF group pain scores (10-cm VAS) over the course of the treatment program (n = 10).

LBP–THF	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS	10-cmVAS
(n=10)	D1-Pre	D1-Post	D2-Pre	D2-Post	D3-Pre	D3-Post	D4-Pre	D4-Post	D5
AVG	4.29	1.97	2.72	1.32	2.51	1.26	2.40	1.02	1.37
SD	1.85	1.03	1.16	1.19	1.67	1.21	1.54	0.82	1.03

Table 3 & 4.
Mean and standard deviation of trunk flexion and extension strength (Nm) data of both THF groups over the course of the treatment sessions (n = 10 for LBP-THF and 8 for A-THF).

Maximum Trunk Extension Strength (Nm)			
Group	**Time**	**Mean**	**SD**
A-THF	S1:Pre	353.2	53.6
A-THF	S1:Post	405.0	47.3
A-THF	S2:Pre	395.5	50.3
A-THF	S2:Post	412.6	52.2
A-THF	S3:Pre	371.9	55.0
A-THF	S3:Post	427.1	52.4
A-THF	S4:Pre	378.1	68.2
A-THF	S4:Post	418.9	54.4
A-THF	S5	404.0	64.6
LBP-THF	S1:Pre	336.2	119.0
LBP-THF	S1:Post	422.2	140.1
LBP-THF	S2:Pre	415.6	124.3
LBP-THF	S2:Post	460.4	125.4
LBP-THF	S3:Pre	409.0	99.6
LBP-THF	S3:Post	448.6	82.0
LBP-THF	S4:Pre	396.0	102.0
LBP-THF	S4:Post	449.2	109.1
LBP-THF	S5	450.3	114.0

Maximum Trunk Flexion Strength (Nm)			
Group	**Time**	**Mean**	**SD**
A-THF	S1:Pre	295.4	30.7
A-THF	S1:Post	319.0	37.4
A-THF	S2:Pre	283.7	32.3
A-THF	S2:Post	298.3	42.7
A-THF	S3:Pre	277.8	33.0
A-THF	S3:Post	299.9	32.8
A-THF	S4:Pre	266.1	19.4
A-THF	S4:Post	290.3	36.5
A-THF	S5	278.2	21.3
LBP-THF	S1:Pre	292.9	117.1
LBP-THF	S1:Post	341.8	130.9
LBP-THF	S2:Pre	327.1	112.8
LBP-THF	S2:Post	348.0	105.1
LBP-THF	S3:Pre	315.5	102.9
LBP-THF	S3:Post	339.2	106.6
LBP-THF	S4:Pre	316.2	99.5
LBP-THF	S4:Post	330.3	116.7
LBP-THF	S5	326.8	106.7

out of 10) from baseline scores.[27] At the conclusion of the two week treatment period, there was an average change of 2.9 out of the 10 cm on this scale.

One hypothesis for decreased disability and pain scores in this population may stem from decreasing excess compression on damaged structures of the spine. The LBP population will generate co-contraction to stiffen and stabilize the lumbar spine.[8,26,28] Compression on the spine that exceeds the necessary requirements to create spine stiffness can compromise spine stability.[29] This excess joint stiffness can damage the spine's surrounding tissues.[3] Therefore, theoretically relieving pressure on the spine, by increasing hip extension, may decrease the sensitivity to the irritated structures.

Through a variety of hip flexibility tests, this study demonstrated a significant increase in passive hip extension in both THF patient groups over time, particularly the LBP-THF group. Previous research has shown that individuals with LBP displayed less passive hip extension than people without LBP.[30] Clinicians and researchers have postulated that low back pain patients can have tight hip flexors.[13-15] Stretching treatment of the iliopsoas complex has been shown to increase hip extension, reduce pain and aid the return to normal activity for patients with low back pain.[31,32] It is proposed that improving the extensibility of the hip flexor complex in low back pain patients can help alleviate stress on the spine, decrease the pain experienced by these individuals, increase hip range of motion and possibly facilitate improved performance.

One theory, that may explain the mechanism behind the short term and sustained improvements in both trunk extension and flexion strength, is related to possibly returning the hip flexor muscle group to a more normalized muscle length. Increasing hip extension has been shown to remove inhibitory influences on antagonistic muscle groups.[33-35] This improved fascio-muscular extensibility has the potential to decrease its inhibitory effect on the antagonist and surrounding trunk musculature. This will likely allow the antagonist and surrounding trunk muscles to function closer to their full potential. The change in strength has a limitation as both groups could have improved from familiarization of the test. However, the symptomatic group may have improved because of pain reduction.

It would seem sensible to speculate that FMLT, a type of fascio-muscular lengthening therapy, might have decreased the iliopsoas tightness and increased hip extension. The iliopsoas complex is an integral contributor to spine health.[7] Altering the function of a key trunk muscle, such as the iliopsoas complex, would change the relative contribution of the antagonist and supporting trunk muscles contribution to spine stability. The central nervous system will choose the best muscle activation patterns in order to optimize the relationship between spine loading and spine stability.[36] Normalizing the iliopsoas complex might decrease the inhibition of other trunk stabilizing muscles and give individuals the ability to produce greater moments during MVIC trials.

Study Limitations

It is important to note that there was no control group in this study. Therefore, the outcomes from this study cannot be isolated to the treatment alone. The results might be attributable to time, as many LBP patients feel better after 2 weeks without any treatment.

A potential learning effect may have occurred during this study. Repetitive testing may induce learning effects and may have lead to the higher trunk flexion and extension strength.

There was a very brief follow-up period beyond the last treatment session (S4:Post to S5). Therefore, it is not clear how long the effects of the intervention are likely to last. More importantly, figure 3 and 5 demonstrate a quick deterioration of the post-treatment measurements back towards the baseline pre-treatment level shortly after each session, with no evidence of a sustained benefit over time. Perhaps this type of treatment is best suited for a specific population that requires quick, short-term results, such as an athlete with tight hip flexors and back pain prior to their sporting event. More research in this area may help elucidate these results.

Another study limitation was the sample size collected for the two groups. The LBP-THF group only had 10 subjects while the A-THF group only had 8 subjects. Future studies investigating FMLT on tight hip flexor groups would merit from including a larger sample size.

Finally, this study consisted of four treatments over a two-week period. Typically, treatment programs, particularly for low back pain patients, will be more than four sessions, include other forms of therapy (such as active exercise) and will progress over a significantly longer period than two weeks in duration. There was no long-

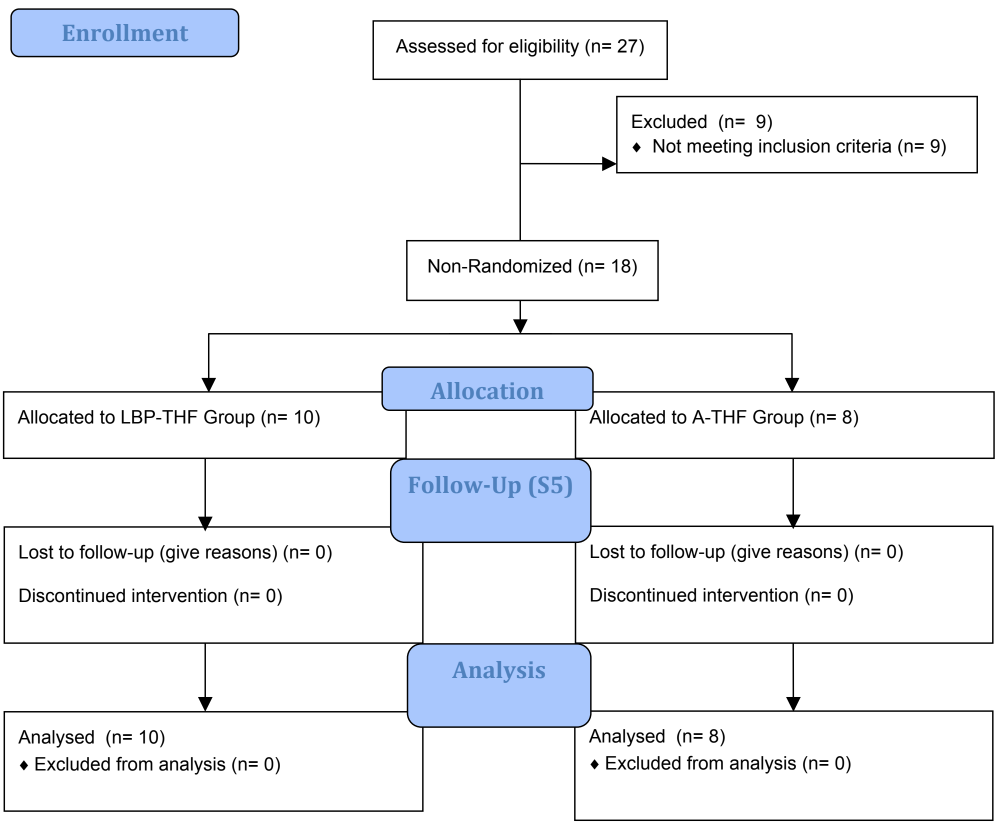

Figure 6.
Participant flow diagram.

term follow-up in this study. Therefore, these limitations restrict the ability to generalize the results.

Conclusions

This preliminary study demonstrated interesting results from manual FMLT on two tight hip flexor patient populations with and without low back pain over a two-week period. Maximum voluntary trunk extension demonstrated increases for the low back pain patients. The low back pain patients demonstrated a small, but significant, reduction in disability and pain. Both groups demonstrated an increase in passive hip extension measurements. However, there were several significant limitations from this study, which restrict the ability to generalize the results.

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Effects of spinal manipulation versus therapeutic exercise on adults with chronic low back pain: a literature review

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Background Context: *Chronic low back pain (CLBP) is a prevalent disorder that has a significant burden to society in terms of loss of work time and increased economic cost. Two common treatment choices of intervention for CLBP are spinal manipulation and prescribed exercise.*

Purpose: *The purpose of this systematic review was to examine the effectiveness of spinal manipulation vs prescribed exercise for patients diagnosed with CLBP. Studies that compared head-to-head spinal manipulation to an exercise group were included in this review.*

Methods: *A search of the current literature was conducted using a keyword process in CINAHL, Cochrane Register of Controlled Trials Database, Medline, and Embase. The search was conducted on, and included studies available up to August 29th 2014. Studies were included based on PICOS criteria 1) individuals with CLBP defined as lasting 12 weeks or longer; 2) spinal manipulation performed by a health care practitioner; 3) prescribed exercise for the treatment of CLBP and monitored by a health*

Historique : *La lombalgie chronique est un trouble fréquent qui devient un lourd fardeau pour la société, en perte de temps au travail et en augmentation du coût économique. La manipulation vertébrale et la prescription d'exercices représentent deux choix de traitement courants pour la lombalgie chronique.*

Objectif : *Le but de cette analyse systématique était d'examiner l'efficacité des manipulations vertébrales par rapport aux exercices pour les patients atteints de lombalgie chronique. Les études qui ont comparé directement la manipulation vertébrale à un groupe suivant des exercices ont été intégrées dans cette analyse.*

Méthodologie : *Une recherche des publications scientifiques actuelles a été réalisée en utilisant un procédé de mots-clés dans CINAHL, Register of Controlled Trials Database, Medline et Embase. La recherche a été effectuée le 29 août 2014 et a englobé les études disponibles jusqu'alors. Les études ont été incluses en fonction des critères PICOS 1) personnes souffrant de lombalgie chronique, définie comme subsistant 12 semaines ou plus; 2) manipulations vertébrales effectuées par un professionnel de la santé; 3) prescription d'exercices pour le traitement de la lombalgie chronique et suivi par un professionnel de la santé; 4) résultats cliniques mesurables pour réduire*

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care practitioner; 4) measurable clinical outcomes for reducing pain, disability or improving function; 5) randomized controlled trials. The quality of included articles was determined by the author using the criteria developed and used by the Physiotherapy Evidence Database (PEDro).

Results: *Three randomized controlled trials met the inclusion criteria of this systematic review and were included in this review. The outcomes used in these studies included Disability Indexes, Pain Scales and function improvement scales. The results included a mix of effects with one study finding spinal manipulation as more effective and another finding the exercises more so. The third study found both interventions offering equal effects in the long term.*

Conclusion: *Based on the findings of this systematic review there is no conclusive evidence that clearly favours spinal manipulation or exercise as more effective in treatment of CLBP. More studies are needed to further explore which intervention is more effective.*

(JCCA 2014; 58(4):456-466)

KEY WORDS: back pain, chronic, spinal manipulation, exercise, chiropractic

la douleur, l'invalidité ou améliorer la fonction; 5) essais cliniques randomisés. La qualité des articles retenus a été arrêtée par l'auteur à partir des critères développés et utilisés par la base de données factuelles de physiothérapie (Physiotherapy Evidence Database – PEDro).

Résultats : *Trois essais cliniques randomisés répondaient aux critères d'admissibilité à cette analyse systématique et donc ont été inclus dans cette analyse. Les résultats utilisés dans ces études comprenaient des indices d'invalidité, des échelles de la douleur et des échelles d'amélioration de la fonction. Les résultats comprenaient un mélange d'effets, une étude montrant l'efficacité supérieure de la manipulation vertébrale alors qu'une autre concluait que les exercices étaient plus efficaces. La troisième étude a conclu que les deux interventions offraient les mêmes effets à long terme.*

Conclusion : *En fonction des résultats de cette analyse systématique, on ne peut pas déduire de façon concluante et claire si la manipulation vertébrale ou les exercices sont plus efficaces dans le traitement de la lombalgie chronique. Il faut mener d'autres études pour explorer davantage laquelle des interventions est plus efficace.*

(JCCA 2014; 58(4):456-466)

MOTS CLÉS : lombalgie, chronique, manipulation vertébrale, exercice, chiropratique

Introduction

Chronic low back pain (CLBP), defined as pain lasting 3 months or more, is a major cause of disability in industrialized societies and more than 80% of the health care resources for back pain are utilized on these patients.[1,2,3] CLBP can arise from a variety of anatomical structures or can be part of an array of pathologies of the spine and therefore require different treatments depending on its cause.[4] It is estimated that 80-90% of patients are diagnosed with low back pain arising from non-specific mechanical reasons.[4,5] Most patients suffering with CLBP are treated non-operatively with a variety of conservative treatments.[4]

The rehabilitation health care professionals treating CLBP patients often employ a variety of modalities including therapeutic exercise and spinal manipulation.[4,6,7] Some studies have found that the treatment of CLBP with spinal manipulative therapy may significantly decrease pain and improve function.[4,6,7] Therapeutic exercise has also been shown to provide improvement on pain and functioning.[4,6] There have been many studies assessing the benefits of either treatment on patients with CLBP, however the majority of these studies have focused on investigating each treatment on their own. There are significantly fewer studies that have investigated and compared both treatments head-to-head in the treatment of CLBP.

To the author's knowledge, there has been only one previous systematic review that has examined studies comparing head-to-head the effectiveness of spinal ma-

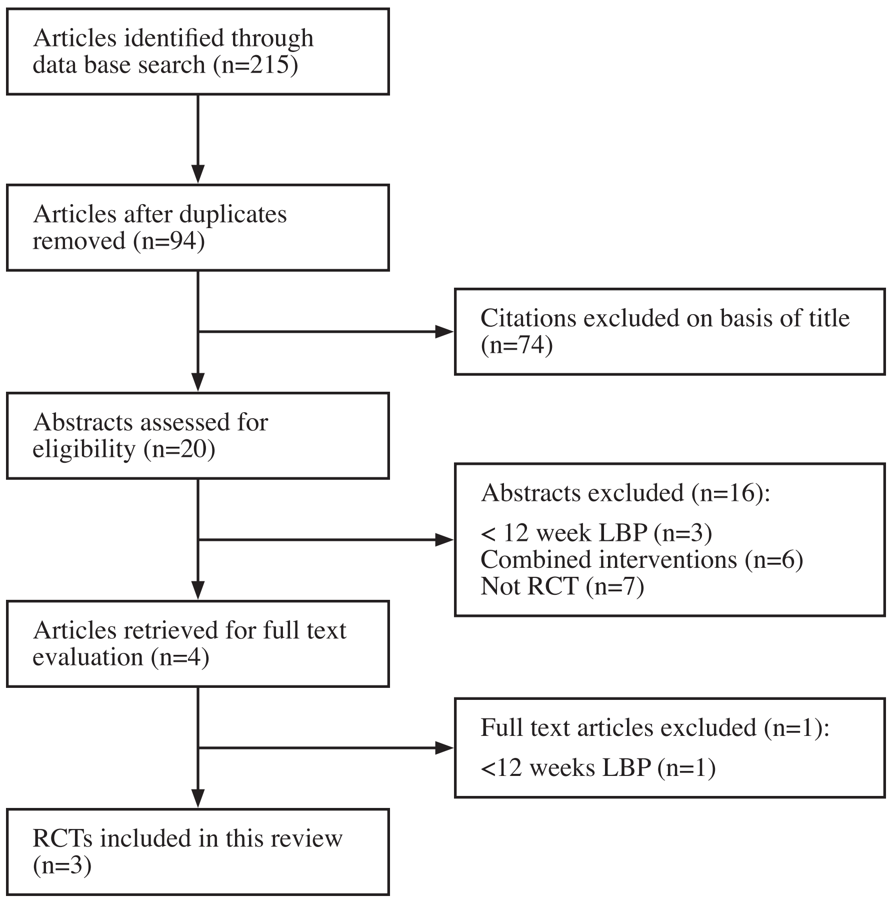

Figure 1.
Study flow diagram

nipulation and exercise in treating CLBP.[8] However, that systematic review defined CLBP as 6 weeks or more in duration where as in the current review it is defined as 12 weeks or more in duration.

Spinal manipulation and exercise are important modalities that play a central role in the treatment of CLBP.[9] This paper aims to summarize the available research evidence comparing the effects of spinal manipulation and therapeutic exercise [on disability or pain] related to chronic low back pain in adults.

Methods

Study Design

The author used Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA).[10] PRISMA can be used to report systematic reviews of various forms of research but is most appropriate for randomized controlled trials.[10]

Eligibility Criteria

Decisions for inclusion of published studies were based on the following Population, Intervention, Control, Outcomes, and Study design (PICOS) criteria[11] defined for this systematic review as:

Inclusion criteria:

Patients: human adult participants (18 years of age or older) with low back pain persisting 12 weeks or longer.

Intervention: spinal manipulative therapy, defined as high velocity and low amplitude thrust and/or manual mobilization of vertebral joints, must be performed by a health care practitioner (chiropractor, physiotherapist or other manual health care practitioner).

Comparison: exercise must be prescribed specifically for the treatment of CLBP and monitored by a health care professional.

Outcome: pain, disability or quality of life scores, not limited to one specific measure. No restriction on length of follow up.

Study Design: published randomized controlled trials

Additional inclusion criteria: Studies must be published and in the English Language (due to limited resources to translate from other languages). The search was not restricted by publication date to avoid exclusion of relevant studies.

Exclusion criteria:

- Studies that used CLBP subjects diagnosed with spinal stenosis, spondylolisthesis (2nd degree or more), lumbar scoliosis (>20' or more), previous vertebral fractures, systemic causes of CLBP (rheumatoid arthritis), psychiatric or cognitive co-morbidities.
- Studies that used CLBP patients diagnosed with specific spinal pathologies including malignancies, inflammatory joint disease and bone disease and/or disc prolapsed or herniations with or without neurological compromise.

Search Strategy

A keyword search in CINAHL, Cochrane Register of Controlled Trials Database, Medline, and Embase was conducted on August 29th 2014. The keywords used were manipulation, exercise, and chronic low back pain. The search was completed by combining the keywords with AND. Limits applied were human and English language.

In addition to the above primary database search, the reference lists of included studies and systematic reviews of similar topics were screened for relevant studies that were not produced by the database search.[8,12] This was done to ensure that no relevant study was missed in the search.

Study Selection

The review process was completed systematically as follows 1) title search, 2) abstract search, and 3) full text search for relevance. The reason for excluding articles at step 2 and 3 are described.

Risk of Bias

Each of the included articles was reviewed by the author and scored with the Physiotherapy Evidence Database (PEDro) quality assessment tool.[13] This retrospective quality assessment tool was designed to evaluate the internal validity and statistical reporting of randomized controlled trials. The PEDro scale consists of 11 items that pertain to the quality of RCTs. The highest score of 11/11 represents the highest possible quality and the lowest risk of bias whereas 0/11 is the lowest possible quality.

Results

Risk of Bias Within Studies

Risk of bias within the individual studies was assessed using the PEDro scale and results are as follows. One study scored 9/11[14], the second study scored 8/11[9], and the third study scored 9/11[15]. None of the three studies met criteria five and six (blinding of all the subjects and of all therapists administering therapy respectively).

One study[15] carried a participant selection bias risk. All of the participants were recruited through public hospitals, were unemployed and from low socioeconomic status. Studies show that CLBP patients from low socioeconomic status may be harder to treat.[16] This may put the external validity of the study to the general population into question.

Another study[9] may have a participant selection bias. All the participants were recruited at a public national health service at their physiotherapy department. These participants were all referred to this department and had not sought other choices such as private care or other health care practitioners that provide spinal manipulation such as chiropractors, osteopaths, or other practitioners trained in spinal manipulation. Thus, the external validity of the results might be questionable.

Risk of Bias for all Studies

The main bias in all the studies is that reporting of the outcome by subjects is done in a self-report and subjective manner. Recollection and self-reporting of data from subjects inevitably carries the risk of self-report bias and possible inaccurate outcomes. Furthermore, the design of all studies did not account for possible spontaneous recovery of CLBP by the subjects under either intervention.

A total of three relevant studies were located and cat-

Table 1.
Characteristics of Individual Studies

Author (year)	Participant Details	Intervention Investigated [details]	Comparison Intervention [details]	Outcome Measures	Findings
(Cecchi et al. 2012)	n= 210 ages 59±14 Inclusion: >6 months Non-specific LBP Exclusion: Neurological signs or symptoms, spondylolisthesis >2nd degree, spinal stenosis, lumbar scoliosis >20 degrees, rheumatoid arthritis or spondylitis, previous vertebral fracture, psychiatric disease, cognitive impairment, or pain-related litigation	Spinal manipulation [Mobilization and manipulation (patient specific) of spine, and soft tissue manipulation. 4-6 treatments (as needed) weekly, 20 minute sessions, 4-6 weeks of treatment.]	Back school [education, relaxation techniques, postural and individually tailored back exercises. 15x 1h sessions, 5 days per week, 3 weeks] Individual physiotherapy [Mobilization, active exercise, massage, PNF, education. 15 x1h sessions, 5 days per week, 3 weeks.]	Roland Morris Disability Questionnaire (RMDQ) (scoring 0-24) Pain Rating Scale (scoring 0-6)	Spinal manipulation showed the highest functional improvements when compared with BS and IP.
(Ferreira et al. 2007)	n=240 Inclusion: >3 months Non-specific LBP Ages 18-80 yrs Exclusion: Serious pathology, neurological signs, malignancy, inflammatory bone or joint disease	Spinal manipulative therapy [Joint Mobilization or manipulation, up to 12 treatments completed by physical therapists]	General Exercise [Supervised by physical therapists on Stretching and strengthening, 12 treatments, 8 weeks] Motor Control Exercise [Supervised training of transversus abdominis and multifidus muscles by physical therapists)	Patient-Specific Functional Scale (PSFS), Visual Analogue Scale (VAS), Roland Morris Disability Questionnaire (RMDQ)	Spinal manipulative therapy and motor control exercise produce better short term outcome than general exercise, but there was similar effects between all three groups mid and long term.
(Goldby et al. 2006)	n= 346 Inclusion: >12 weeks LBP read and write English Ages 18-65 yrs Exclusion: non-mechanical LB, Spondylolisthesis >grade II, recent fracture, significant neurological signs, inflammatory joint disease, lower limb pathology, metastatic disease (past or present), medically unsuitable for exercise, Chronic Pain syndrome, >1 back surgery, anxiety neurosis, pregnancy	Manual Therapy [3 hour back school, exercise (not stabilization exercises), and manual procedures. Max 10 interventions.]	Minimal Intervention [3 hour back school, Educational Booklet.] Spinal Stabilization Program [# hour back school, Stabilization exercises for the spine and education (educational booklet). 10 x 1 hour classes]	LBP intensity, disability (Oswestry Disability Index), handicap, medication and quality of life.	Statistically significant improvements for spinal stabilization group (at 6 months for pain, at 1 year in medication, dysfunction and disability),

egorised as shown in Table 1 based on Levels of Evidence (Centre for Evidence Based Medicine, 2011).[17] These studies met all the PICOS criteria. The other studies that did not meet all the PICOS criteria were excluded. There were no additional relevant studies identified by searching the reference list of the three chosen studies.

One study[14] reported that spinal manipulation is more effective than individual physiotherapy or back school in reducing disability as measured by RMDQ at discharge time. More importantly, this improvement held consistently on all the follow-ups. Pain relief was also reduced at discharge time and maintained over the 3, 6, and 12 months follow ups. Furthermore, the spinal manipulation group also experienced a lower use of pain related medication during the period of follow-ups. Interestingly, in the follow ups it was found that after discharge, the spinal manipulation group sought care more frequently than the individual physiotherapy group or back school. This occurred despite their pain reduction at discharge, 3, 6, and 12 months follow ups.

The back school and individual physiotherapy provided similar results in the short term when compared to baseline however the individual physiotherapy subjects experienced more recurrences of frequent constant low back pain in the follow-ups and this difference became significant at 3 and 6 months from the baseline. Thus, back school appears to have provided better results than individual physiotherapy when it comes to promoting active treatment as the subjects experienced significantly less recurrences on all the follow-ups.

The second study[15] reported the motor control exercise group and the spinal manipulative therapy group had slightly better outcomes than the general exercise group at 8 weeks but all three groups had similar outcomes at 6 and 12 months follow-ups. The results show that in the short term the motor control exercise and spinal manipulative therapy groups have better function and perception of effect than the general exercise group but this does not hold on the long term.

The third study[9] reported that a spinal stabilization program is significantly more effective than manual therapy in all of the outcomes. It reduced pain intensity, disability, dysfunction, medication intake and improved the quality of life in patients with CLBP. Manual therapy was significantly more effective than a spinal stabilization program or minimal intervention in one outcome, pain. However this was only significant with patients with the highest intensity.

Discussion

Three randomized controlled trials were reviewed in order to determine the effectiveness of spinal manipulation and therapeutic exercise on disability or pain related to CLBP in adults.

Cechi et al (2012) found that spinal manipulation showed the best improvement when compared with individual physiotherapy. Spinal manipulation appears to have produced the best results in both outcomes, pain reduction and improved function, however this has not been able to promote active self-treatment. This implies that spinal manipulation therapy depends on the availability of a specialist in spinal manipulation.

Ferreira et al (2007) found that spinal manipulation therapy and motor control exercise are better at reducing pain and disability than general exercise in the short term but not in the long term. All three interventions produce similar results in the long term. These results suggest that spinal manipulation therapy is an appropriate treatment modality for CLBP patients with high intensity pain. However, it should be utilized in conjunction with other modalities in order to have the best results in reducing disability, handicap and improving the quality of life.

Goldby et al (2006) found that spinal stabilization exercises were more effective than manual therapy in reducing pain intensity and disability and dysfunction. Interestingly, manual therapy was more effective in reducing pain in patients with the highest intensity.

These studies offer a glimpse of the literature available in general and suggest that there does not appear to be clear answers or conclusive evidence as to which treatment, spinal manipulation or exercise, is more effective in treating CLBP.

Perhaps the difficulties in finding conclusive evidence may lay in the entity of CLBP itself. It is by nature a heterogeneous entity that comprises a myriad of clinical signs and symptoms to offer different clinical scenarios in which a practitioner chooses an algorithm to diagnose CLBP. Then, the treatment choices are also a multitude of components that comprise exercise, manual therapy and spinal manipulation or any permutation of these.[12,18]

Furthermore, spinal manipulation or spinal manipulation therapy is not necessarily clear and uniform across the literature on what it exactly entails. In many cases it may include high-velocity thrust techniques or manual mobilization of the involved anatomical structures. In other cases, such as in one of the studies included in this review[9] it did not provide sufficient detail on what manual therapy procedures are.

Another difficulty when dealing with spinal manipulation or spinal manipulation therapy, is that it is not an exact science and it cannot be measured directly, and as such it offers variability on its delivery and therefore the potential for error in measurement of effects. This is made more so by the fact that it is delivered by a variety of health care practitioners that have different training and different modes of delivery. This may make the study of the effects of spinal manipulation on CLBP more challenging especially when comparing studies in a systematic review.

This is in fact a major limitation of this review that the variables of spinal manipulation and exercise differ and vary significantly from each of the studies. This non-uniformity of variables makes it difficult to compare the studies or generalize on the results.

More comprehensive studies are required with more rigorous design, better defined sub-groups of CLBP patients, clearly defined interventions including cost-effectiveness in order for us to provide better evidence to guide practice.

Uncovering the evidence is crucially important for the chiropractic profession as spinal manipulation therapy and LBP have been the corner stone of our existence and will likely play as crucial a role in our future.

Conclusion

It is evident from the literature review that there is no conclusive evidence favouring either exercise (of various forms) or spinal manipulation as treatment of choice to provide effective improvements on patients with CLBP.[9,12,14,15,18] For patients diagnosed with CLBP, joint mobilization and/or manipulation does not appear to provide better results than lumbar stabilization exercise programs. In this review, three studies offered different evidence as to which treatment is more effective.[9,14,15] In one study[9] prescribed therapeutic exercise provided significant improvements to CLBP patients when compared with spinal manipulation therapy where as in another study[14] spinal manipulation offered the most improvements.

It is also evident from the literature review that the nature of CLBP is heterogeneous in terms of the cause, and as such, it is no surprise that the treatment choices are not definitive in their effectiveness in improving all CLBP.

Further research that compares both treatments is required to definitively identify the most effective choice of treatment for individuals suffering from CLBP.

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Appendix A
Search Strategy and Search Results

Database: Embase, 1974 to 2014 August 28, 2014

1 manipulation.mp. (77551)
2 exercise.mp. (329457)
3 chronic low back pain.mp. (5254)
4 1 and 2 and 3 (51)
5 limit 4 to (human and english language) (45)

Database: Ovid MEDLINE(R), 1996 to August 28, 2014

1 manipulation.mp. (44646)
2 exercise.mp. (151252)
3 chronic low back pain.mp. (2880)
4 1 and 2 and 3 (48)
5 limit 4 to (english language and humans) (45)

Database: CINAHL, 1982 to August 29, 2014

Search ID#	Search Terms	Search Options	Results
S5	S1 AND S2 AND S3	Limiters – English Language Search modes – Boolean/Phrase	43
S4	S1 AND S2 AND S3	Search modes – Boolean/Phrase	44
S3	"chronic low back pain"	Search modes – Boolean/Phrase	1,875
S2	"exercise"	Search modes – Boolean/Phrase	78,372
S1	"manipulation"	Search modes – Boolean/Phrase	8,814

Cochrane Central Register of Controlled Trials searched August 29, 2014

There are 47 results from 800283 records for the search on 'manipulation in Title, Abstract, Keywords and exercise in Title, Abstract, Keywords and chronic low back pain in Title, Abstract, Keywords in Trials'

PUBMED, searched August 29 2014

There were 35 results for the search manipulation AND exercise AND chronic low back pain searched in all fields with the filters clinical trials, humans, English language applied.

Appendix B
Final Articles Eliminated

1. Aure OF, Nilsen JH, Vasseljen O. Manual therapy and exercise therapy in patients with chronic low back pain: a randomized, controlled trial with 1-year follow-up... including commentary by Lindström I. Spine. 2003; 28(6): 525-532.
2. Balthazard P, et al. Manual therapy followed by specific active exercises versus a placebo followed by specific active exercises on the improvement of functional disability in patients with chronic non specific low back pain: a randomized controlled trial. BMC Musculoskeletal Disorders. 2012; 13:162 DOI: 10.1186/1471-2474-13-162.
3. Bronfort G, et al. Evidence-informed management of chronic low back pain with spinal manipulation and mobilization. Spine J. 2008; 8(1): 213-225.
4. Bronfort G, et al. Supervised exercise, spinal manipulation, and home exercise for chronic low back pain: a randomized clinical trial. Spine J. 2011; 11:585-98 DOI: 10.1016/j.spinee.2011.01.036.
5. Brox JI, et al. Is exercise therapy and manipulation effective in low back pain? Tidsskrift for den Norske lægeforening: tidsskrift for praktisk medicin, ny række. 1999; 119: 2042-50.
6. Cecchi F, et al. Spinal manipulation provides better short and long-term reduction in pain and disability for patients with non-specific chronic low back pain. Focus on Alternative and Complementary Therapies. 2010; 15(2): 137-138.
7. Cecchi, F, et al. Spinal manipulation compared with back school and with individually delivered physiotherapy for the treatment of chronic low back pain: a randomized trial with one-year follow-up. Clinical Rehabilitation. 2010; 24:26-36 DOI: 10.1177/0269215509342328.
8. Cecchi F, et al. Predictors of functional outcome in patients with chronic low back pain undergoing back school, individual physiotherapy or spinal manipulation. Eur J Phys Rehab Med. 2012; 48: 371-8.
9. Cuesta-Vargas AI, et al. Exercise, manual therapy, and education with or without high-intensity deep-water running for nonspecific chronic low back pain: a pragmatic randomized controlled trial. Am J Phys Med Rehab. 2011; 90:526-34; quiz 535-8 DOI: 10.1097/PHM.0b013e31821a71d0.
10. Dvorak H, Kujat C, Brumitt J. Effect of therapeutic exercise versus manual therapy on athletes with chronic low back pain. J Sport Rehab. 2011; 20(4):494-504.
11. Ferreira ML, et al. Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: A randomized trial. Pain. 2007; 131:31-7 DOI: 10.1016/j.pain.2006.12.008.
12. Geisser ME, et al., A randomized controlled trial of manual therapy and specific adjuvant exercise for chronic low back pain. Clinical J Pain. 2005; 21(6): 463-470.
13. Goldby LJ, et al. A randomized controlled trial investigating the efficiency of musculoskeletal physiotherapy on chronic low back disorder. Spine. 2006;31(10):1083-93.
14. Koes BW, et al. A randomized clinical trial of manual therapy and physiotherapy for persistent back and neck complaints: subgroup analysis and relationship between outcome measures. J Manip Physiol Thera. 1993; 16:211-9.
15. Lewis JS, et al. A randomized clinical trial comparing two physiotherapy interventions for chronic low back pain. Spine. 2005; 30:711-21.

16. Mooney V. Manual therapy and exercise therapy in patients with chronic low back pain: a randomized, controlled trial with 1-year follow-up. Spine. 2004; 29(1):107-8.

17. Niemistö L, et al. A randomized trial of combined manipulation, stabilizing exercises, and physician consultation compared to physician consultation alone for chronic low back pain. Spine. 2003; 28:2185-91 DOI: 10.1097/01.BRS.0000085096.62603.61.

18. Rasmussen-Barr E, Nilsson-Wikmar L, Arvidsson I. Stabilizing training compared with manual treatment in sub-acute and chronic low-back pain. Manual Therapy. 2003; 8(4):233-241.

19. Standaert CJ, et al. Comparative effectiveness of exercise, acupuncture, and spinal manipulation for low back pain. Spine. 2011; 36(21 SUPPL):S120-S130.

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Immediate changes in temporomandibular joint opening and pain following vibration therapy: a feasibility pilot study

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Objective: *The purpose of this pilot study was to determine the scientific and process feasibility in an effort to direct future larger trials.*

Methods: *Scientific Feasibility: Twelve subjects were randomly allocated to an intervention and a control group. The intervention protocol consisted of intraoral vibration therapy on the muscles of mastication bilaterally for a period of 1 minute per muscle. Process Feasibility: Several feasibility outcomes were examined including recruitment and retention rates and consent.*

Results: *Scientific Feasibility: Large effect sizes were generated for both mouth opening and VAS in favour of the intervention group. Process Feasibility: a recruitment ratio of 2.3 respondents to 1 participant was determined, along with a retention to loss ratio of 13:1 and a consent to loss ratio of 12:0.*

Objectif : *L'objectif de ce projet pilote était de déterminer la faisabilité scientifique et la faisabilité du processus afin de planifier des essais cliniques de plus grande envergure.*

Méthodes : *Faisabilité scientifique : Douze sujets étaient répartis de manière aléatoire dans un groupe intervention et un groupe témoin. Le protocole d'intervention comprenait la thérapie par vibration intraorale appliquée bilatéralement durant une minute par muscle sur les muscles de mastications. Faisabilité du processus : Plusieurs mesures de faisabilité ont été estimées, incluant les taux de recrutement, de rétention et de consentement.*

Résultats : *Faisabilité scientifique : Des effets de grandes tailles ont été observés dans le groupe d'intervention pour l'ouverture de la bouche et l'échelle analogue de douleur (VAS). Faisabilité de processus : Le ratio de recrutement était de 2.3 répondants pour 1 participant, le ratio de rétention et de perte de 13:1 et de consentement et de perte de 12:0.*

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Institution where work was performed: The experimental data were collected at the Canadian Memorial Chiropractic College, Toronto, Canada.
Declaration: The lead author and principal investigator Dr. Brad Muir, is a member of the VMTX Vibromax Therapeutics team.

Conclusion: *Scientific Feasibility: The scientific results should be interpreted with caution due to the small sample sizes employed. The study seems to support the scientific feasibility of a future larger* ***single treatment*** *trial. Process Feasibility: Recruitment and retention rates and ratios seem to support future studies. Utilizing the feasibility results of the current study to direct a future larger* ***multiple treatment*** *trial consistent with other comparable TMD studies however is limited.*

(JCCA 2014; 58(4):467-480)

KEY WORDS: temporomandibular joint, vibration therapy, mouth opening, chiropractic

Conclusion : *Faisabilité scientifique : Les résultats doivent être interprétés avec prudence considérant le petit échantillon de sujets. L'étude semble appuyer la faisabilité de mener un essai clinique de plus grande envergure avec* ***une intervention unidimensionnelle****. Faisabilité du processus : Les taux et ratios de recrutement et de rétention observés semblent également appuyer les études futures. Cependant, l'emploie des résultats du présent projet de faisabilité dans le but d'élaborer un futur essai clinique avec* ***une intervention multidimensionnelle*** *similaire à d'autres études comparables sur les désordres temporo-mandibulaires est limité.*

(JCCA 2014; 58(4):467-480)

MOTS CLÉS : articulation temporo-mandibulaire, thérapie par vibration, ouverture de la bouche, chiropratique

Background

Temporomandibular disorders (TMD) are a class of disorders affecting the muscles of mastication and/or the temporomandibular joint (TMJ).[1,2] The prevalence of TMD is reported as 10-30%[3,4] in the general population but can be as high as 42.9% in university students[5]. Symptoms can present as muscle and joint tenderness, popping or clicking, decreased jaw movement, altered mechanics or occasionally ear symptoms.[3]

There are various ways to classify TMD. The National Institute of Dental and Craniofacial Research (NIDCR), a branch of the National Institutes of Health (NIH), classifies TMD into three main categories: myofascial pain, internal derangement and degenerative joint disease. Internal derangement of the joint includes a dislocated jaw, displaced disc or injured condyle, while degenerative joint disease incorporates arthritides of the TMJ.[6] Myofascial pain presents as discomfort or pain in the muscles controlling jaw movements as well as the neck and shoulder muscles.[7] Stohler (2000), attributes up to 50% of all TMDs to masticatory myalgias or masticatory muscle disorders.[7] However, a study of the incidence and prevalence of myofascial pain in the jaw and face of dental students in Sweden reported a 4% incidence and a 19% prevalence over the period of 1 year.[8] In a systematic review, Manfredini et al. found that when using the research diagnostic criteria/temporomandibular disorders (RCD/TMD) Axis 1 diagnostic criteria, myofascial pain constituted 6-12.9% of the diagnoses while disc displacement with reduction comprised 8.9-15.8%.[9] Inflammatory-degenerative disorders were found to be uncommon in the TMD population.[9]

TMD is reported more frequently and graded as more severe among the female population.[3] The ratio of female to male prevalence is generally found to be 2:1 while the ratio of those seeking care is 5:1.[3]

Manual treatment of TMD has been shown to be clinically effective[10,11] and includes soft tissue therapy (myofascial release techniques, myofascial trigger point pressure release), mobilization techniques, manipulation and therapeutic exercises that focus on the soft tissues in the masticatory region[10,11]. Soft tissue therapy can be applied both extraorally or intraorally.[10,11]

Aside from traditional manual therapy, many dentists recommend the use of an occlusal appliance like a splint. Occlusal splints are manufactured in various materials, sizes, shapes, and have been shown to be beneficial, although the therapeutic mechanism remains unclear.[12] Low-level laser therapy, and electrical modalities, have shown some promise in the treatment of TMD, but once again the overall evidence is lacking.[13,14,15] Acupuncture has been demonstrated as having limited evidence of benefit compared to sham acupuncture in alleviating pain and masseter muscle tenderness in TMD.[16] Pharmacological intervention with the use of NSAIDs is also commonplace in the treatment of TMD.[17] However, chronic NSAID reliance has been linked to gastrointestinal side effects ranging from dyspeptic symptoms to life-threatening bleeding, especially in the elderly.[18]

In order to effectively treat the soft tissues surrounding the temporomandibular joint, the anatomy must be properly understood. The TMJ is a synovial condyloid joint between the mandibular condyle and the articular eminence of the temporal bone.[19,20] It contains a dense fibrocartilagenous disc to increase the ease of movement and decrease the concentration of joint stresses.[19,20] Primary muscles that move the mandible include the temporalis, masseter, and the medial and lateral pterygoids.[19-21] The superior portion of the lateral pterygoid is inaccessible to palpation whereas palpation of the inferior lateral pterygoid remains a contentious issue.[22-24] Recent MRI evidence indicates the possibility of direct palpation whereas older inquiries involving cadaveric dissection and x-ray analysis suggest otherwise.[22-25]

Vibration therapy has demonstrated the potential to aid in the management of acute soft tissue injuries, disuse or immobilization-related muscular deconditioning and to enhance muscular performance.[26-31] A study by Rittweger et al in 2002, showed improvements in chronic lower back pain with whole-body vibration although the mechanism of the pain reduction was not clearly understood.[32] To our knowledge, despite the positive effects of vibration on other areas of the body, the localized application of vibration to the muscles of mastication specifically has not been investigated.

According to Thabane et al. (2010), there are several reasons for conducting a pilot study.[33] These reasons can be grouped into broad categories including: process, resources, management and scientific. The process assesses the feasibility of the steps taken in the pilot that will take place as part of the main study and includes aspects such as recruitment rates and retention. The resource aspect deals with assessing time and budgetary requirements that may hinder the main study. Management refers to the potential human and data optimization issues such as personnel and data management in multicentre trials. The scientific aspect deals with the assessment of treatment safety, determination of dose levels and response and the estimation of treatment effect and its variance.[33]

The purpose of this pilot study was to determine the scientific and process feasibility in an effort to direct future, larger trials. The feasibility of the scientific aspect included: the proof of concept of localized, intraoral, vibration therapy on the muscle of mastication for the treatment of reduced mouth opening with respect to range of motion and pain; the assessment of treatment safety; and the efficiency of the study methodology including process time and the limitation of bias during the study and; the effect size and variability to determine future sample size calculations. The feasibility of the process aspect included: recruitment to participant, retention to loss and consent to loss of consent rates and ratios during the trial.

Methods

Scientific Feasibility

Trial Design

The study design was that of a randomized, clinical trial pilot study consisting of two participant groups: a therapeutic intervention group and a control group. Both groups consisted of individuals who experienced decreased mouth opening due to pain/dysfunction of the temporomandibular joint and its associated muscles and had a myofascial component associated with the decreased opening. The intervention group was treated with a onetime single intervention of localized, intraoral, vibration therapy to three muscles bilaterally: the medial and lateral pterygoid, and the masseter. The control group was a non-treatment control.

The principal investigator delivered the localized vibration therapy and was not involved in the measurement of mouth opening or VAS. The same co-investigator performed the mouth opening measurement throughout the study using the Therabite® Range of Motion Scale and gathered the VAS. This co-investigator was not blinded to the group the participant was assigned.

Participants

The study was undertaken at a chiropractic institution in Toronto, Ontario.

Inclusion Criteria:
Volunteers were included if they were within the ages of 20-60, had an inability to open their mouth the standard three finger width[34], had a 10 mm or greater amount pain on the VAS with mouth opening and the elicitation of a 1 or greater on an 11 point scale (0 (no pain) to 10 (maximum pain)) of pain during the light to moderate palpation of 3 of 6 of the muscles of mastication to be treated including the medial and lateral pterygoid bilaterally and the masseter bilaterally.

Exclusion Criteria:
Volunteers were excluded if they: (1) had current/previous injury, fracture or surgery to their jaw; (2) were receiving concurrent treatments from another practitioner (eg. medical doctor, chiropractor, dentist or physiotherapist) for TMJ issues within the last three months; (3) had anatomical deformities of the jaw or were missing their front teeth; (4) were diagnosed as having a tumour, infection, or inflammatory disease affecting the jaw; (5) had a previous history of TMJ disc pathology, capsule pathology or joint locking; (6) had a history of TMD issues related to the cervical spine; (7) had any known previous adverse reactions to vibration (eg. aggravation of sinus problems) (8) were involved in workers compensation or motor vehicle accident claims; (9) were using medications or other supplements that may have affected muscular health; (10) suffered from any neurological disorder which may have affected jaw function or the muscles of mastication such as Bell's palsy or trigeminal neuralgia; (11) neck, upper back and low back pain at the time of presentation that would preclude the participant from lying on their back for the period of the intervention; (12) were currently taking bisphosphonates (can predispose the patient to osteonecrosis of the jaw); (13) any open wounds in or around the mouth; (14) any canker sores, cold sores or other pathologies in or around the mouth.

Interventions
There were two groups in the study – an intervention group and a control group.

Intervention group

1. Time 0: participant is supine, mouth opening to the point of pain or maximum opening (whichever comes first), measurement by the co-investigator with the Therabite® ROM Scale, participant completes VAS (VASbase1).
2. Intervention (described below)
   Time 1: participant is supine, mouth opening to the point of ROM measurement at Time 0 by the co-investigator using Therabite® ROM Scale, participant completes VAS(VASbase2). Mouth opening is then continued to the point of pain or maximum opening (if greater than point of last measurement) and is measured by the co-investigator using the Therabite® ROM Scale, participant completes another VAS(VASfinal).
3. Following the study, participants in the intervention group were asked to fill out a post-study questionnaire.

Control group

1. Time 0: participant is supine, mouth opening to the point of pain or maximum opening (whichever comes first), measurement by the co-investigator using the Therabite® ROM Scale, participant completes VAS(VASbase1).
2. 6-minute rest time (equal to intervention time) – supine, participant is asked to refrain from full opening and limited talking.
3. Time 1: participant is supine, mouth opening to the point of ROM measurement at Time 0 by the co-investigator using Therabite® ROM Scale, participant completes VAS(VASbase2). Mouth opening is then continued to the point of pain or maximum opening (if greater than point of last measurement) and is measured by the co-investigator using the Therabite® ROM Scale, participant completes another VAS(VASfinal).

Treatment Intervention
A standardized head position was maintained having the participant supine with their head supported by a thin pillow with neck lordosis support. This lordosis support consisted of a rolled up towel (rolled to a level of comfort for the participant). A standardized body position was maintained by having a second pillow under the partici-

pant's knees. These positions were maintained throughout the study.[35]

The intervention involved palpating the medial and lateral pterygoid, and the masseter intraorally with a non-latex gloved index finger with the participant in a supine position. The single ball vibration unit is applied to the 1st webspace of that hand and the index finger applies tolerable pressure to the muscle for a period of 1 minute. All three muscles were treated ipsilaterally and then the procedure was repeated on the contralateral side (see Figure 1 below).

Note: The application of the vibration was on the investigator's hand – applying the vibration through a latex or vinyl glove may cause irritation to the skin beneath the vibration unit.

The control group in this study did not initially receive the intervention, however following completion of the data collection they were offered the intervention as per their choice. After the study, participants were returned to their regular and customary care.

ROM Measurement Procedure

The measurement of maximum interincisal opening involves placing one end of the Therabite® Scale against the incisal edge of one central mandibular incisor with the other end against the incisal edge of the opposing maxillary central incisor in a manner consistent with the protocol of La Touche et al (2011).[35] (see Figure 2 below)

Scientific Outcome Measures

The three scientific outcome measurements investigated were:

1. The amount of mouth opening in millimeters (measured using the Therabite® Range of Motion Scale). The Therabite® Range of Motion Scale was used to measure maximum interincisal opening. The Therabite® Scale has been used in several studies to measure maximum interincisal opening and may be considered the industry standard for clinical use.[35-39] In a recent study done by La Touche et al (2011), the investigators found that the intra-rater reliability of using the Therabite® Scale was excellent with ICC values from 0.92 to 0.94.[35] Interestingly, they also found that there was a statistically significant difference in maximum interincisal opening when measured in different head posture positions when seated.[35] This suggests care must be taken to ensure a similar head posture position when taking pre and post treatment measures of maximum interincisal opening.

2. The amount of pain associated with mouth opening (using a VAS in millimeters). VAS and mouth opening were measured and recorded by the co-investigators. The visual analogue scale (VAS) was used to assess pain rat-

Figure 1:
Localized Intraoral Vibration Therapy

Figure 2:
Therabite ® Range of Motion Scale and its application

ings. It has been used in previous TMD studies as reliability and validity has previously been established.[40-42]

3. A post-study questionnaire was issued for all participants involved in the intervention group (See Appendix A for the questionnaire).

Sample Size

A minimum of 12 healthy volunteers was required for participation in the study. No formal sample size calculation was used. The sample size was determined as a "rule of thumb" measure of 12 participants due to the unknown effect sizes of a scientifically untested treatment intervention.[33] In looking at a similar pilot study done by Kalamir et al. in 2010, no sample size estimate was reported.[43] In their study, 30 participants were randomized into 3 groups – 10 per group.[43] The age demographic was 20 to 60 years and was chosen in an attempt to reduce the number of comorbidities that may influence a lack of mouth opening or its measurement (eg. lack of teeth).

Randomization

Participants were randomized using a computer generated random numbers table into respective intervention and control groups. The random numbers table was generated by a member of the Research Ethics Board (REB), who had no other direct involvement in the study. A co-investigator enrolled the participants and assigned them to the group based on the sealed envelopes received from the aforementioned member of REB.

Blinding

The principal investigator was not involved in the measurement of mouth opening and VAS during the experimental procedure. The principal investigator's main focus was to deliver the treatment protocol and therefore had no impact on the measuring or recording of the data. The chosen co-investigator alone executed the measurement tasks (ROM and VAS) and recorded the data. The co-investigator executing the measurement tasks, however, was not blinded to the groups which may have increased bias during the measurement tasks. The participants were not blinded to the intervention and no sham intervention was attempted.

Statistical Analysis

Three scientific outcomes were examined, including: 1) change in mouth opening range of motion (ROMfinal – ROMbase1); 2) a) change in pain for each group when measured for a second time at the baseline ROM measurement (VASbase1 – VASbase2) and b) change in pain for each group when measured at the new final ROM (VASbase1 – VASfinal); 3) post study questionnaire for those in the intervention group.

For the first two outcomes, all measurements recorded (ROM(final – base), VAS(base1 – base2), VAS(base1 – final) were analyzed to determine mean scores, standard deviation and effect size according to Cohen.[44] Cohen's d equation is the following:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s} \quad \text{where} \quad s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2}} \quad \text{(where}$$

$\bar{x}$ is the mean score, s is the standard deviation, n is the number of participants in that group). The third outcome was reported as descriptive statistics based on the questionnaire.

Ethical Considerations and Funding

The Research Ethics Board at the Canadian Memorial College granted approval for this study on February 7, 2012 with the approval number of 1201A02.

All participants were required to complete consent form prior to participation ensuring that he/she is well informed of all study details, including possible risk, benefits and procedures.

No funding was received for this study.

Process Feasibility

Process Outcomes

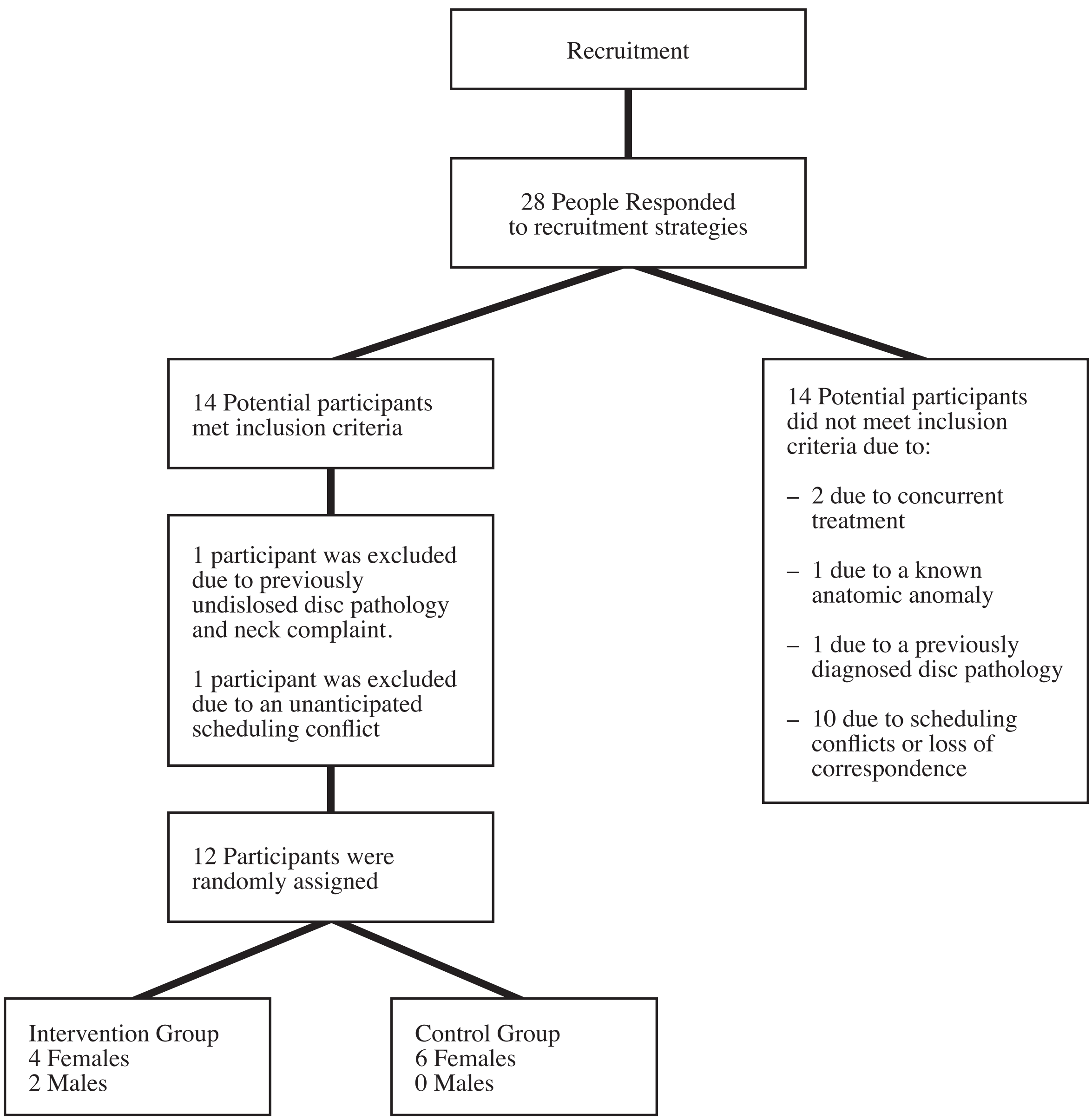
Recruitment and retention rates, and consent were collected and monitored during the study and are outlined using descriptive statistics including flow charts and tables. Ratios including recruitment to participant, retention to loss, and consent to loss of consent were also calculated.

Results

Patient Flow

A total of 28 people responded to the recruitment strategies. Fourteen potential participants met all of the inclusion criteria and indicated they were available during the study's testing period. Of the 14 participants that were excluded, two were excluded due to concurrent treatment, one due to a known anatomic anomaly, one due to previously diagnosed disc pathology, and ten participants were unavailable due to scheduling conflicts or loss of correspondence. A review of the inclusion criteria with each of the remaining 14 participants identified one participant with previously undisclosed disc pathology and cervical spine related complaint. This individual was then excluded from the study. One other participant was unable to attend testing due to an unanticipated scheduling conflict. In total, 12 participants were randomized using a computer generated random numbers table into respective intervention and control group. (See Figure 3 for the Study Flow Chart).

Figure 3
Study Flow Chart



Recruitment

Recruitment occurred over a period of 3 weeks. Participants were recruited through email, posters and class presentations directed at students, faculty and staff.

Baseline Data

The participants' baseline characteristics are presented in Table 1.

At baseline, there were no significant differences in participant age or ROM. The intervention group included two males whereas no males were randomized to the control group. There also appears to be a difference in the VASbase1 between the two groups.

Scientific Outcomes

Outcome 1 and 2.

The change scores for the outcome measures of mouth opening ROM and pain are tabulated in Table 2 and 3.

Note: The results of the changes in ROM and pain need to be viewed and interpreted with caution due to the small sample size associated with each of the groups as well as the differences in baseline characteristics (male/female ratio and VAS). Because of the small sample sizes the effect sizes may be considered unstable and may be due to chance.

In Table 3, the mean change in the mouth opening ROM for the control group was 0.17 mm while the intervention group was 6.5 mm although the standard deviations were somewhat large for both. Based on Cohen's effect size calculation, there was a large effect size of 2.12 which suggests the treatment intervention yielded positive effects in increasing mouth opening compared to the control group.

The same was true for the first measure of pain with the control group having a mean of 3.7 mm of change and the intervention group being 19.5 mm. Again, the two means had large standard deviations. This resulted in a smaller effect size than the ROM but was still considered a large effect size of 1.19. In examining the raw change scores (Table 2), participant 10 had a large decrease in pain at the baseline ROM which dramatically changed both the mean (12.2 mm when removed compared to 19.5) and the standard deviation (7.72 versus 19.17). This suggests a positive effect in decreasing the amount of pain in the intervention group when opening to the initial mouth opening ROM.

Table 1:
Baseline characteristics of the study participants

Characteristic	Control Group (n = 6)	Intervention Group (n = 6)
Age (y)[a]	25 (2.8)	24 (1.6)
Sex, male:female	0:6	2:4
VASbase1[b]	19.5 (2.7)	28.2 (22.3)
ROM[b]	37.7 (4.6)	38.5 (8.9)

[a] Means (standard deviations in parentheses).
[b] Means in millimeters.

Table 2:
Change scores by participant.

	Participant	ROM (Final – Base)	VASbase (Base1–Base2)	VASfinal (Base1-Final)
Control[M]	1	0	3	3
	2	0	–2	3
	3	–2	1	–1
	4	0	2	3
	5	–1	3	2
	6	4	15	5
Intervention[M]	7	5	2	–3
	8	2	12	–2
	9	5	9	3
	10	5	56	50
	11	8	15	9
	12	14	23	9

[M] score in millimeters

Table 3:
Baseline and change scores for the two groups

	Baseline ROM	ROM (Final – Baseline)	Baseline VAS	VASbase (VASbase1 –VASbase2)	VASfinal (VASbase1 – VASfinal)
Control[M] (n=6)	37.7 (4.6)	0.17 (2.04)	19.5 (2.7)	3.7 (5.85)	2.5 (1.97)
Intervention[M] (n=6)	38.5 (8.9)	6.5 (4.14)	28.2 (22.3)	19.5 (19.17)	11.0 (19.79)
Effect Size[a]		2.12		1.19	0.66

[M] Mean in millimeters (standard deviations in parentheses)
[a] Effect size calculated using Cohen's d Equation[44]

Cohen's d Equation is: $d = \frac{\bar{x}_1 - \bar{x}_2}{s}$ where $s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2}}$

Table 4:
Post-study questionnaire results, Intervention Group (n=6)

	Percentage of Favorable Responses
1. Rating of the experience:	67%
2. Rating of each subjects likelihood of pursing the study treatment in the future:	83%
3. Rating of the comfort of the procedure:	67%

Table 5:
Process feasibility outcomes: Recruitment, retention and consent

Recruitment		Retention		Consent	
Initial Response (IR)	28	Met Criteria	13	Initial Consent	12
Did not meet criteria	15	Lost before participation	1	Consent withdrawn during trial	0
Met Criteria (MC)	13	Retention: Loss Ratio	13:1	Consent: Loss Ratio	12:0
Recruitment Ratio (IR:MC)	2.3:1				

The pain rating at the final opening ROM was 2.5 mm in the control group while the intervention group had a change of 11.0 mm. The intervention group had a very large standard deviation compared to the control group (1.97 compared to 19.79). Again, examining the raw data, participant 10 in the intervention group had a large difference in pain scores at final opening ROM causing a dramatic change in mean (3.2 mm when removed versus 11.0) and standard deviation (5.76 versus 19.79). This resulted in a moderate effect size of 0.66 according to Cohen's d Equation. This suggested that there was a small difference between the groups with regard to pain at the end range mouth opening.

The dramatic change in means and standard deviations with one outlier removed from the calculation again reinforces the limitation of having small sample size numbers.

Outcome 3.

The analysis of the post-study questionnaire is presented in Table 4.

The results of the post-study questionnaire for the intervention group (Table 4) yield positive results with respect to the participants' subjective evaluation of the experience, likelihood to pursue a similar treatment in the future, and the comfort of the procedure. Sixty-seven percent of the participants rated their experience and the comfort of the procedure as favorable. Eighty-three percent of participants responded favorably as to their likelihood to pursue this treatment modality in the future.

Harms

There were no adverse events reported by any participants during or after the course of this study.

Process Feasibility Outcomes

The process outcomes are outlined in Table 5.

Discussion

The purpose of this pilot study was to determine the scientific and process feasibility in an effort to direct future, larger trials.

Scientific Feasibility

The results of the current study suggests that a single treatment of localized, intraoral vibration therapy directed at the muscles of mastication does have a beneficial effect with regard to an immediate increase in mouth opening and decrease in pain. Again, caution should be noted with regard to the interpretation of this data due to the small sample sizes in each arm of the study. This was consistent with our original hypothesis that vibration would have a positive effect on these two outcomes. With regard to the pain level at the finishing end range, it was somewhat consistent with our original hypothesis in that there was a moderate effect size demonstrated. We would have expected a small effect size if any at all because both groups were instructed to open to the point of pain or to maximum opening at which point that range and pain were measured. If the participants were being consistent in following the investigators instructions, the pain level should have remained consistent as well.

One caveat to this could possibly occur and may have been demonstrated by Participant number 10 in the intervention group (see Table 2). It could be speculated that during baseline ROM, the VAS for participant 10 was larger than the average. Following treatment, the second

VAS at the baseline ROM had decreased significantly. Participant 10's ROM increased by 5 mm and may have put them to maximal opening. If they did not reach the point of pain then the significantly lower VAS at final opening would be much different than that of baseline thus explaining the large difference. In future studies, if VAS is measured in the same manner, the participant should be asked and documented if they reached maximal opening or the point of pain in order to account for this possible scenario.

A study done by Kalamir et al, (2012), investigated whether intraoral myofascial therapy (IMT), education and self-care were better than no treatment.[11] Five outcome measures were used, including interincisal opening range, measured in millimeters using vernier callipers. Participants were randomized into 1 of 3 groups: IMT consisting of 2 treatment interventions per week for 5 weeks, IMT plus education and self-care exercises (IMTESC), and wait-list control.[11] The study found statistically significant differences in resting, opening and clenching pain, as well as opening scores and global reporting of change in both treatment groups as compared to the control group at six months and one year. The results suggest IMTESC and IMT are superior to no-treatment over the one-year study follow-up with IMTESC also being superior to IMT.[11] A follow-up study done by the same group in 2013 compared IMT and ESC directly over a 6 week period and found that although the change in pain scores were significant in favour of the IMT group, the results were not clinically significant ie. greater than a 2 point difference in a numerical pain rating scale.[45] In a study done by Ibanez-Garcia et al (2009), they measured pre and post treatment pain levels using VAS.[46] The externally applied treatments of neuromuscular technique and strain-counterstrain of the masseter muscle in those subjects with myofascial trigger points occurred one time per week for three weeks. The VAS measured local pain of the masseter using a mechanical pressure algometer set at 2.5kg/cm^2. The study found that there was a statistically significant change ($p<0.001$) in VAS in the neuromuscular group versus the strain-counterstrain and control groups. The change in VAS in the neuromuscular group was 13 mm suggesting a moderate effect size.[46] In the current study, pain was measured using the VAS. It has been suggested that the smallest detectable difference for "actual pain" using the VAS is 28 mm.[47] Our study showed a 19.5 mm change although our standard deviation was 19.17 suggesting that we may not have met clinical significance with regard to change in pain scores. Our study also had a low level of pain (at least 10 mm of pain or greater on a 100 mm scale) as a minimum for inclusion. This leaves little room for improvement on the pain scale and considering that 28 mm is considered the smallest detectable difference[47], this was a limitation. As a result, future studies should have a minimum of 30 mm or greater on the VAS for inclusion.

The follow-up study by Kalamir et al. (2000) did not find statistically or clinically significant changes in mouth opening either. This was defined as a 5 mm change in mouth opening.[45,47] Kropmans et al. (1999) suggested that a 5 mm change in mouth opening was clinically significant and generalizable for healthy subjects and to those patients with restricted mouth opening.[47] However, in 2000, the same group studied those with painful restrictions in their TM and found that a statistically and clinically significant change of 9 mm was necessary unless repeated measures was performed in which case 6 mm improvement would be necessary.[48] In our study, we found a difference of mouth opening of 6.5 mm which was greater than the 5 mm change[45,46] but less than the 9 mm change suggested by Kropmans[48]. When examining the change scores by participant (Table 2), only one participant in the intervention group did not achieve a 5 mm change while none of the control group reached 5 mm of change. The study by Ibanez-Garcia et al (2009) also measured changes in mouth opening and although they reached pre and post treatment statistical significance in both the neuromuscular technique and strain-counterstrain groups, neither group reached the 5mm threshold (4mm change in both groups).[46]

None of the above studies looked at acute changes in pain or mouth opening similar to the current study. All of the studies ranged in follow-up from 1 month to 1 year and involved 3 or more treatments.[11,45,46]

The post-study questionnaire given to the intervention group suggests the treatment technique is safe, comfortable and favored by patients although, again, the study had a small sample size in the intervention group. There were no adverse reactions reported by any of the participants during the course of this study.

The methodology employed during the study was adequate and efficient according to our post-study questionnaire but does require some changes. The principal investigator performing the intervention found the clinically meaningful treatment time to be roughly 15-30 seconds per muscle. This would shorten the intervention time furthering the efficiency of the study methodology. The use of mechanical pressure algometers similar to Ibanez-Garcia et al.[46] may also help to reduce the bias associated with subjective pain scores. However, the use of a pressure algometer may be limited to external musculature only, and to potential budgetary restrictions associated with future studies.

The present study was also limited due to its inability to verify the presence of unknown factors such as a bony anomaly, an arthritide or degenerative changes in the TMJ. Future studies may investigate the effect of vibration on patients with known joint and bone issues in those patients having had previous advanced imaging.

The main limitation of this study, as with most pilot studies[33,43], was the small sample size and the lack of statistical power. The interpretation of any results should thus be viewed with caution. Thabane et al. (2010) suggests that pilot studies are a "good opportunity to assess feasibility of large full-scale studies" and are a way to "enhance the likelihood of success of the main study and potentially help to avoid doomed main studies".[33] From this standpoint, even with our small sample size and potentially unstable effect sizes, the large effect sizes generated during the current study, would support a future, larger, single treatment trial utilizing localized intraoral vibration therapy as a treatment intervention, as well as help in the generation of future sample size estimates that would provide adequate statistical power.

Another limitation is the difference in the groups at baseline with regard to gender (no males in the control group). This is due to ineffective randomization which occurs when the sample size is too small. Another seeming difference of the baseline scores is the VAS score – 19.5 mm for the control group versus 28.2 mm for the intervention group. Although the difference seems large, it does not meet what Kropmans et al. suggests is the smallest detectable difference of 28 mm.[47] Therefore a difference of 8.7 mm may not be a clinically significant difference between the two groups.

One potentially critical limitation of the study methodology is its lack of blinding for the co-investigator in charge of measuring ROM and VAS. In an effort to correct this oversight and minimize its potential bias during future, similar studies, the co-investigator should be blinded to the participant group. This could be done by having the co-investigator leave the room and the vibration machine being turned on during the rest period for the control group so that the co-investigator wouldn't be able to guess the group based on the sound of the machine.

Another key limitation of the current study is its lack of follow up measures and thus its generalizability for patients seeking longer term results. Although the change in ROM for the intervention group appears to reach clinically significant levels[47], follow up measures would be needed to see how long these levels were sustained. The current methodology only applied a single treatment and only measured acute changes in ROM and pain. In order to accommodate those patients seeking longer term results and to be consistent with other comparable studies[11,45], the methodology should be expanded to include several treatments over a period of weeks with longer follow-up times. The current study only examined the feasibility of a single treatment model and, as such, its results cannot be reliably extrapolated to a larger, multiple treatment model and any attempts to do so should be done with caution.

Process Feasibility

From a recruitment standpoint, the current study yielded a 2.3:1 ratio for respondents to those meeting the criteria (Table 5). The current study also had a retention to loss rate of 13:1 and a perfect consent to loss of consent rate during the trial of 12:0. The recruitment process occurred over a 3 week period. The participant group had a gender ratio of 6 females to 1 male (Table 1) which is similar to patients seeking care for TMD related problems in other studies.[3] In a pilot study by Kalamir et al.[43], they advertised and recruited over a 6 month period yielding 66 respondents and ultimately 30 study participants. This would suggest that our recruitment strategies were adequate for a pilot study.

In the larger trial by Kalamir et al.[11] following their pilot study[43], they received 221 enquiries and were able to assess 134 potential participants with 93 ultimately being enrolled. This suggests a recruitment ratio of 1.7:1. The recruitment period for this trial was 1 year. Based on our recruitment ratio of 2.3:1 (over a 3 week period), in order to accommodate a future trial with 93 participants, it would take approximately 214 responses. This would take approximately 6 months to complete based on our recruitment strategy but it is suggested that 6 months to 1 year would be needed based on the existing literature.

A limitation of this calculation is that our recruitment, retention and consent rates are based on a single treatment intervention model compared to a multiple intervention and extended follow up study.[11] However, in the study done by Kalamir et al.[11], they only had one drop out during their 1 year follow up suggesting that multiple treatments and extended follow up times may not be a limiting factor for recruitment, retention and consent rates.

Conclusion

The scientific feasibility of this pilot study should be viewed and interpreted with caution due to the small sample sizes employed during the study and the unbalanced arms (male/female ratio and VAS). However, the large effect size for changes in ROM and VAS (at the baseline ROM) in favour of the intervention group is encouraging that there is a positive treatment effect associated with the use of localized, intraoral vibration on the muscles of mastication. Also, there were no adverse events reported suggesting the procedure is safe and the majority of the participants in the intervention group found the intervention comfortable and would pursue the use of the treatment in the future. However, there were many limitations with regard to the methodology utilized and these would need to be considered during future, larger trials. The study also seems to support the feasibility of a future, larger, single treatment trial from a process feasibility standpoint. Utilizing the feasibility results of the current study to direct a future, larger, *multiple treatment* trial consistent with other comparable TMD studies however is limited.

Potential conflicts of interest/commercialization of research

Dr. Brad Muir, the principal investigator of this research project, is a member of the VMTX Vibromax Therapeutics team that utilizes vibration therapy as the main component of its treatment technique. As a result, a potential conflict of interest arises as positive results could influence future sales of the VMTX equipment, manuals and courses.

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Appendix A – Post Study Questionnaire.

Post Study Questionnaire

Participant Name: ________________________________

Date: ____________________

Please circle the number that you feel most reflects your view.

1. Would you rate this experience as:

Unsatisfactory	1	2	3	4	5	Very Satisfactory

2. How would you rate your likelihood of pursuing the study treatment in the future?

Very Unlikely	1	2	3	4	5	Very Likely

3. Did you receive the study treatment? ☐ Yes ☐ No

If yes, how comfortable would you rate this treatment?

Very Uncomfortable	1	2	3	4	5	Very Comfortable

Foot and Ankle Sports Medicine
David Altchek, MD, Christopher DiGiovanni, MD, Joshua Dines, MD, Rock Positano, DPM, MSc, MPH
Lippincott Williams & Wilkins, Philadelphia, United States, 2013
Hard cover, 351 pages
$249.99 CAD
ISBN: 9780781797528

The foot and ankle are the foundation for athletic movement and performance. *Foot and Ankle Sports Medicine* is a new text that contains 32 chapters with contributions from over 40 medical doctors that specialize in the foot and ankle. The text does appear to lack contributions from other foot and ankle academic sources such as biomechanics, anatomy and radiology. Tendon disorders, trauma to the varying regions of the foot, surgical interventions and injury prevention are the main topics covered.

Within the text there are over 300 illustrations including numerous imaging studies, anatomical drawings and coloured anatomical specimen photographs. These images allow a field clinician quick reference, although relying on single images displaying a type of injury should not constitute a formal diagnosis. Surgical intervention, coloured photographs are also present in many of the chapters and although they make for excellent reference material it is unlikely the typical sports medicine physician would be conducting surgery.

Overall, *Foot and Ankle Sports Medicine* provides a recent and comprehensive orthopaedic-based approach to understanding the foot and ankle. The text relies on scientific literature rooted in surgical interventions that on-field sport clinicians and students without a surgical background may have a difficult time relating to. The current list price and lack of more detailed on-field assessments and treatment of the foot and ankle makes the text difficult to justify for all sports medicine clinicians and students alike.

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Tread Lightly: Form, footwear, and the quest for injury-free running
Peter Lawson and Bill Katovsky, PhD, RD, FACSM
Skyhorse Publishing, New York, NY 2012
258 pages, paperback, $16.95 US
ISBN: 978-1-61608-374-8

Tread Lightly arrives at a pivotal time, as runners everywhere have begun to experiment with minimalistic footwear, and question the relationship of footwear and the injury epidemic. Peter Larson is a professor of biology and leading blogger for running shoe innovation and selection. Bill Katovsky is the co-founder of Natural Running Center, and author of several books.

In Tread Lightly, Larson and Katovsky provide well-detailed and balanced interpretation of modifying running form and footwear while questioning the underlying belief that humans are indeed “born to run”.

The chapters are updated with current evidence regarding the running shoe, pronation, foot strike, stride, and nutritional considerations. Each chapter addresses the pros and cons of modifying the practices of recreational runners, and offers expert opinion from leading footwear scientists, biomechanists, coaches, therapists, and competitive runners. Particularly, the concluding chapter provides strategic advice with reference to literature citations, helping runners to make informed decisions. Readers require a foundational understanding of anatomy and biomechanics in order to fully grasp the proposed risks and benefits of altering running practices.

I would recommend this book to therapists, coaches, and recreational runners who desire a lifetime of pain-free miles for themselves and their athletes.

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ROYAL COLLEGE OF CHIROPRACTIC SPORTS SCIENCES (CANADA)
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RCCSS(C) Research Funding Awards

ANNOUNCEMENT:

The Royal College of Chiropractic Sports Sciences (Canada) is proud to announce the establishment of the annual Research Funding Awards. These awards are open to all members (Fellows, Residents and Members) of the RCCSS(C) and are meant to stimulate your interest in chiropractic sports science and are meant to encourage you to undertake research studies.

OVERVIEW:

VALUE	Total Amount of Funds available for rewards: $3500
APPLICATION DEADLINE	June 1st on a yearly basis
HOW TO APPLY	See below
FOR MORE INFORMATION	Please contact Bill Neilson at the RCCSS(C) Office

Decisions on awards will be made by Aug 1st yearly, and announced each year via the sport report and AGM.

AWARDS ALLOCATION:

Awards allocation options

- 3 awards @ $1000
- 1 award @ $500 **Best Paper** (for the published paper with the most 'significant' impact – may be one of the above or entirely separate)

REVIEW PROCESS:

Review Committee adjudicate applications and granting process.

- Regular panel of Research and Education committee members as reviewers, with the possibility of additional invited reviewers should the demand dictate this
- Assign 3 reviewers per application **(blinded to the author/applicant)**
- The Chair of the committee will referee the peer review process

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Applications to be peer reviewed by 3 reviewers per application

- Total summed score of a scoring rubric by reviewers will determine who win the awards
- Peer reviewers also have the option of providing blinded comments about the project to the applicants if they choose to do so during the peer review process
- Double blind peer review
  - Submission is removed of identifying information
  - Applicants are blinded to the reviewers
- Provide format for submission (no longer than 1500 words, not including abstract, references, budget or intent for knowledge dissemination sections)
  - Abstract
  - Intro
  - Methods
  - Any preliminary pilot work (if available)
  - Implications of your work to sports health care
  - Budget of funds applied for, if received
  - Intent for knowledge dissemination

STIPULATIONS OF THE FUNDING AWARDS:

- Submit an expanded abstract of the research proposal (no more than 1500 words)
- Submit a planned budget of funds, if received (could be for the project itself or for presentation/ publication purposes)
- Must acknowledge the RCCSS(C) in any presentations or in an acknowledgement section of a publication
- Must either present @ a RCCSS(C) conference as a 15 minute platform presentation OR create an e-presentation to be used by the RCCSS(C) website @ completion of the project. If the awarded applicant fails to meet this requirement, all funds must be paid back in full to the RCCSS(C).
- Funds are forwarded to the applicant only after a copy of the Research Ethics Board Approval by the applicant's academic institution has been received by the RCCSS(C) Research Committee office
- The project must be published or submitted for publication within 2 calendar years of the award being granted or the funds must be paid back in full to the RCCSS(C). (the R & E committee reserves the right to consider and extend this deadline under extenuating circumstances)
- All members of the Research and Education Committee are not eligible for any of these awards

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