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SafetyNET Community-based patient safety initiatives: development and application of a Patient Safety and Quality Improvement Survey

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Objectives: *To: 1) develop/adapt and validate an instrument to measure patient safety attitudes and opinions of community-based spinal manipulative therapy (SMT) providers; 2) implement the instrument; and 3) compare results among healthcare professions.*

Methods: *A review of the literature and content validation were used for the survey development. Community-based chiropractors and physiotherapists in 4 Canadian provinces were invited.*

Results: *The Agency for Healthcare Research and Quality's (AHRQ) Medical Office Survey on Patient Safety Culture was the preferred instrument. The survey was modified and validated, measuring 14 patient safety dimensions. 276 SMT providers volunteered to respond to the survey. Generally, SMT providers had similar or better patient safety dimension scores compared to the AHRQ 2016 medical offices database.*

Discussion: *We developed the first instrument measuring patient safety attitudes and opinions of community-based SMT providers. This instrument provides understanding of SMT providers' opinions and attitudes on patient safety and identifies potential areas for improvement.*

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KEY WORDS: chiropractic, patient safety, survey, spinal manipulation

Objectifs : *1) Élaborer/adapter et valider un instrument servant à évaluer les attitudes à l'égard de la sécurité du patient et les opinions des praticiens effectuant des manipulations vertébrales (MV); 2) adopter cet instrument; et 3) comparer les résultats obtenus entre les professionnels de la santé.*

Méthodologie : *Pour élaborer le sondage, on a revu la littérature, on a validé le contenu et on a invité des chiropraticiens et des physiothérapeutes de quatre provinces canadiennes à participer.*

Résultats : Le *Medical Office Survey on Patient Safety Culture de l'Agency for Healthcare Research and Quality's (AHRQ) était l'instrument préféré. Le sondage a été modifié et validé et a servi à mesurer 14 aspects de la sécurité du patient. 276 professionnels effectuant des MV ont accepté de répondre au sondage. En règle générale, les cotes obtenues chez les professionnels effectuant des MV pour ce qui des aspects de la sécurité étaient comparables ou meilleurs que celles des professionnels de la santé enregistrés dans la base de données de 2016 de l'AHRQ.*

Discussion : *On a élaboré le premier instrument servant à évaluer les attitudes à l'égard de la sécurité et les opinions des praticiens effectuant des MV dans une collectivité. Cet instrument permet de comprendre les opinions et les attitudes à l'égard de la sécurité du patient des professionnels effectuant des MV et de cerner les aspects qui pourraient être améliorés.*

(JCCA. 2018;62(3):130-142)

MOTS CLÉS : chiropratique, sécurité du patient, sondage, manipulation vertébrale

Introduction

Patient safety is a leading healthcare challenge.[1] In 1999, the U.S. Institute of Medicine's *To Err is Human: Building a Safer Health System*[2] report advised the development and sustainability of an open and constructive patient safety culture. In 2002, the Canadian government's *Building a Safer System: A National Integrated Strategy for Improving Patient Safety in Canadian Health Care*[3] supported and emphasized the need for leadership with this challenge. These reports laid out comprehensive strategies to reduce preventable medical errors, which did not focus on individuals making the error, but rather on how the systems, processes and conditions fail to prevent the error.[4]

One strategy to promote and understand a healthcare organization's existing patient safety culture is by assessing its current attitudes and opinions toward safety.[4] Although several surveys currently exist to assess attitudes and opinions, most are designed for large, acute care settings rather than community-based health care environments. As the majority of people receive care in community-based settings, further information about community-based health care providers' behaviors, attitudes, and opinions about patient safety is needed.[5]

Spinal manipulative therapy (SMT) is a therapeutic intervention commonly used by chiropractors and physiotherapists and perceived to carry added risks to patients with varying evidence regarding the incidence of associated adverse events (AEs).[6] It is estimated that 4.5 million Canadians and over 50% of Americans receive SMT per year.[7,8] Despite SMT's popularity, few formal patient safety and reporting mechanisms are available[5], increasing the need for specific SMT-related patient safety initiatives. As most SMT is provided in community-based offices/clinics[9], having a patient safety survey specifically for these settings is essential.

SafetyNET is an international and multidisciplinary research team, whose primary goal is to support strategies that promote a patient safety culture among SMT providers.[10] Although AEs following SMT intervention have been described to vary widely in severity and frequency, no robust causal inferences have been made.[6,11,12] Thus, systematic reviews investigating SMT-related AEs have called for more research.[13,14]

To date, only a few patient safety mechanisms, such as reporting and learning systems, exist to systematically monitor and reduce SMT-related harms.[15] With the call for more research and few patient safety measurement options, there is a need to measure and assess current patient safety attitudes and opinions. Therefore, our study aimed to: 1) develop or adapt an assessment tool to measure patient safety attitudes and opinions of community-based SMT providers, specifically chiropractors and physiotherapists; 2) validate this assessment tool; 3) implement this tool with community-based chiropractors and physiotherapists who apply SMT; and 4) compare the resultant scores against other healthcare professions.

Methods

Survey Development

We conducted a literature review with assistance of a health sciences librarian who is expert in scoping reviews to identify available patient safety surveys and their applicability to the SMT setting. Searches were conducted in Google, Google Scholar, and PubMed. Search terms included: 'patient safety survey', 'patient safety culture', and 'patient safety climate'; in conjunction with 'community-based', 'ambulatory', 'medical offices', and 'general practice'. Based on consultation with subject matter experts on our research team, surveys specific for SMT professions were not expected and, therefore, terms related to 'chiropractic', 'physiotherapy', 'manual therapy' or 'spinal manipulative therapy' were not included in the search. In addition to the electronic databases, content experts on the research team were also queried for suggested relevant surveys. All citation abstracts were screened and assessed by the SafetyNET team members to evaluate their relevance to the following criteria: 1) addressed the research question; 2) measurement properties established (i.e., with reported validity and reliability); 3) ease of use (i.e., lack of patient safety jargon, manageable number of sections, each section was not too long); and 4) estimated number of necessary modifications (although this was not a determinant factor).

Relevant surveys (Table 1) were independently assessed by eight SafetyNET multidisciplinary team members with expertise in SMT, epidemiology, patient safety and/or survey development. Feedback was summarized and presented to all 22 expert SafetyNET team members. The preferred survey was identified by consensus and modifications were made to meet our study needs using an iterative consensus-based process.

The final stage involved content validation adhering to the COnsensus-based Standards for the selection of health status Measurement INstruments (COSMIN) checklist.[16] A face-to-face qualitative focus group was conducted to evaluate the relevance and comprehensiveness of the modified survey with a convenience sample of volunteers attending a chiropractic educational conference in Edmonton, Alberta. Then, a feasibility assessment of the survey was conducted by circulating it amongst SMT providers to further evaluate the content and face validity, the functionality and time to complete the survey.

Survey Application

The final survey was created using a standardized Research Electronic Data Capture (REDCap) database. REDCap is a secure, web-based application designed to support data capture for research providing an intuitive

Table 1.
Surveys identified during the literature review that evaluate patient safety attitudes and opinions in ambulatory settings.

Author / Year	Manuscript Title	Purpose	Setting / Location	Population Studied (sample size)	Survey Items and Dimensions / Factors
de Wet *et al*., 2010 [22]	The development and psychometric evaluation of a safety climate measure for primary care	To measure perceptions of safety climate among primary care teams outside of North America.	Primary care teams in National Health Service, Scotland	563 primary care team members from 49 general practices	30 items, measuring 5 safety climate factors: 1) Leadership, 2) Teamwork, 3) Communication, 4) Workload, 5) Safety Systems.
Hoffman *et al*., 2011 [21]	The Frankfurt Patient Safety Climate Questionnaire for General Practices (FraSiK): analysis of psychometric properties	To measure patient safety climate in practices with only 1-2 doctors, who are owners with 2-4 other professional employees (small offices).	General practice in Germany	332 healthcare professionals working in 60 general practices	72 items, measuring 9 dimensions: 1) Teamwork climate, 2) Error management, 3) Safety of clinical processes, 4) Perception of causes of errors, 5) Job satisfaction, 6) Safety of office structure, 7) Receptiveness to healthcare assistants, 8) Patient safety of medical care. {Adapted from the SAQ-A}
Modak *et al*., 2007 [20]	Measuring safety culture in the ambulatory setting: the Safety Attitudes Questionnaire (SAQ)– Ambulatory Version (SAQ-A)	To measure safety attitudes of outpatient settings.	Academic, urban, outpatient practice in Texas, United States	251 outpatients providers (physicians, nurses, managers, medical assistants and support staff)	62 item survey, measuring 6 factors: 1) Teamwork climate, 2) Safety climate, 3) Perceptions of management, 4) Job satisfaction, 5) Working conditions, 6) Stress recognition.
Sorra *et al*., 2016 [18]	Medical Office Survey on Patient Safety Culture- User Guide	Modification of the *AHRQ Hospital Survey on Patient Safety Culture*. Emphasized safety and quality issues that are known to affect patient safety in medical offices.	Medical Offices in the United States	Pilot tested in 2007 with 200 offices, > 4,100 surveys. First released in 2009, with comparable databases released approximately every 2 years.	51 item survey, measuring 13 dimensions: 1) Teamwork, 2) Work pressure and pace, 3) Staff Training, 4) Office processes and standardization, 5) Communication openness, 6) Patient Care Tracking / Follow-up, 7) Communication about error, 8) Owner / Managing Partner / Leadership support for patient safety, 9) Organizational learning, 10) Overall perceptions of patient safety and quality, 11) List of patient safety and quality issues, 12) Information exchange with other settings, 13) Overall ratings on quality and patient safety.

interface for validated data entry, audit trails for data manipulation, and export procedures.[17] Invitation to participate in survey completion was distributed via email to Canadian community-based chiropractors and physiotherapists from four different Canadian provinces through their respective provincial associations.

Survey Data Analysis

Data on patient safety culture dimensions were analyzed in two ways using Stata13 Software (StataCorp. 2013) and Excel 2013. First, a positive percentage composite score was calculated for each dimension by averaging the percent positive responses on the questions within each dimension. For negatively worded questions, disagreeing was considered a positive response. Second, survey dimensions' scores were calculated based on the mean response to the five-point scale and its 95% confidence interval (CI). Pearson chi-square test was used to compare the scores from SMT providers with the AHRQ medical offices comparative database, with level of significance at p=0.05. Each dimension required that all questions be answered to be included. Frequencies of responses were calculated for factors inhibiting participation in a reporting and learning system, patient safety items and quality issues, information exchange with other settings, and overall clinic self-ratings.

Comparative Database

The Medical Office Survey on Patient Safety Culture is an expansion of AHRQ's Hospital Survey on Patient Safety Culture to the medical office setting. Its content has been extensively tested for validity and reliability, and it has been in use since 2004.[18] It was designed to measure the culture of patient safety in medical offices from the perspective of providers and staff. The Medical Office Survey on Patient Safety Culture 2016 User Comparative Database has been previously described.[19] Briefly, it consists of data from 1,528 medical offices located across the United States and 25,127 medical office respondents from varied specialties who completed the survey between 2013 and 2015. This comparative database report was developed as a tool for comparison of survey results, internal assessment, and to provide supplemental information to help offices/clinics identify their strengths and areas with potential for improvement.

Results

Survey Development

The literature review identified four commonly used surveys that assessed patient safety attitudes and opinions in community-based settings (Table 1).[18,20–22] The AHRQ Medical Office Survey on Patient Safety Culture was identified as the team's preferred instrument.[18]

Based on feedback from the SafetyNET team, the following modifications were made to the AHRQ medical office survey: 1) the word 'medical' was removed, and, replaced with 'clinical' or 'office'; 2) for 'Organizational Learning' and 'Overall Perceptions of Patient Safety and Quality' each question was asked regarding its clinical and administrative perspective; 3) in the 'Overall Rating' section, *socioeconomic status* was removed from 'Equitable' as the team felt it should not be grouped with the other qualities listed (i.e., gender, race, ethnicity, language) considering SMT is a non-insured service in Canada and access may be affected differently than these other qualities. *Socioeconomic status* was therefore developed into a separate question looking at 'To what degree do the following affect your care plan' with the addition of: 'Insurance coverage'; 'Patient accessibility to the office'; and 'Other (specify)'; and 4) a section on 'Reporting and Learning System Barriers', based on questions adapted from Benn *et al*. (2009)[23] was added. A brief description of the dimensions of the survey as well as the modifications made to the AHRQ medical office survey can be found in Table 2. The full modified survey is available from the authors upon request.

Chiropractors who participated in the focus group (n=24 of 63) stated that the survey was lengthy, but the information obtained would be valuable. They also felt that some questions would be better in different locations to promote response, and that some required additional clarification. Consequently, the following survey items were further modified: 1) the more sensitive section (i.e., List of Patient Safety and Quality Issues) was moved towards the end of the survey; 2) definitions were added to help clarify terminology differences amongst SMT professions (e.g., manual therapy, manipulation, adjustments); 3) modifications were made for each profession, reflecting the language/culture of each responding group (e.g., "office" versus "clinic"); and 4) the title of the survey was changed to 'Survey to Support Quality Improvement', to add clarity for the survey's purpose.

These actions resulted in two versions of the 'Survey to Support Quality Improvement', one for chiropractors and one for physiotherapists. Both surveys have 14 dimensions with seven derived directly from the AHRQ Medical Office Survey on Patient Safety Culture, six from the AHRQ Medical Office Survey with some modified questions, and one dimension unique for this survey added by the SafetyNET team (Table 2).

Survey Application and Comparison

Participant Response

A total of 417 SMT providers volunteered to respond to the survey: 356 chiropractors and 61 physiotherapists. Surveys from 120 chiropractors and 21 physiotherapists were excluded due to missing responses to questions (no complete section). We included 276 surveys, with complete data from 236 chiropractors (85.5%) and 40 physiotherapists (14.5%).

Table 2.
AHRQ's survey dimensions and description, reliability measures, and modifications made for the SafetyNET survey.

Dimensions	Dimension brief description[18]	# of items	AHRQ Cronbach's alpha	SafetyNet modifications
List of Patient Safety and Quality Issues	Issues that can happen in clinical offices that affect patient safety and quality of care.	8	0.86	Removed 'A pharmacy contracted our office to clarify or correct a prescription.'
Information Exchange with Other settings	How often the office had problems exchanging accurate, complete, and timely information with other entities.	4	0.90	Removed 'Pharmacies' and 'Hospitals'. Added 'Other healthcare offices' and 'Insurance / Third Party Payers?'
Teamwork	The extent to which the office has a culture of teamwork, mutual respect, and close working relationships among staff and providers.	4	0.83	No Changes
Work Pressure and Pace	The extent to which there are enough staff and providers to handle the patient load, and the office work pace is not hectic.	4	0.76	No Changes
Staff Training	The extent to which the office gives providers and staff effective on-the-job training, trains them on new processes, and does not assign tasks they have not been trained to perform.	3	0.80	No Changes
Office Processes and Standardization	The extent to which the office is organized, has an effective workflow, has standardized processes for completing tasks, and has good procedures for checking the accuracy of work performed.	4	0.77	No Changes
Communication Openness	The extent to which providers in the office are open to staff ideas about how to improve office processes, and staff are encouraged to express alternative viewpoints and do not find it difficult to voice disagreement.	4	0.81	No Changes
Patient Care Tracking / Follow-up	The extent to which the office reminds patients about appointments, documents how well patients follow treatment plans, follows up with patients who need monitoring, and follows up when reports from an outside provider are not received.	4	0.78	No Changes
Communication About Error	The extent to which providers and staff are: 1) willing to report mistakes they observe and do not feel like their mistakes are held against them, and 2) talk openly about office problems and how to prevent errors from happening.	4	0.75	No Changes
Owner / Managing Partner / Leadership Support for Patient Safety	The extent to which office leadership actively supports quality and patient safety, places a high priority on improving patient care processes, does not overlook mistakes, and makes decisions based on what is best for patients.	4	0.76	No Changes
Organizational Learning	The extent to which the office has a learning culture that facilitates making changes in office processes to improve the quality of patient care and evaluates changes for effectiveness.	6	0.82	Separated each question into administrative / clinical parts.
Overall Perceptions of Patient Safety and Quality	The extent to which the quality of patient care is more important than getting more work done, office processes are good at preventing mistakes, and mistakes do not happen more than they should.	8	0.79	Separated each question into administrative / clinical parts.
Overall Ratings on Quality and Patient Safety	Overall rating of care, systems and clinical processes the office has in place to prevent, catch, and correct problems that have the potential to affect patients.	9	0.87	Separated 'patient's socioeconomic status', 'insurance coverage', 'patient accessibility to the office', and 'other' into individual categories.
Factors inhibiting participation in a reporting and learning system	Not part of AHRQ. {Adapted from Benn *et al.*[24]}	9	NA	Not part of AHRQ. {Adapted from Benn *et al.*[24]}

AHRQ – Agency for Healthcare Research and Quality

Table 3.
Demographic and background characteristics of responding SMT providers. (n=276)

Provider Characteristics	SMT Providers
Gender, Female, n (%)	77 (27.9%)
Years in practice, Mean (range)	19.4 (1-53)
Hours worked in a typical week, Mean (range)	31.6 (4-55)
Average number (range) of personnel working in the clinic	
Other health care provider	3.1 (1-10)
Therapy Assistant	2.7 (1-10)
Other employee/ staff	2.4 (1-6)
Patient visits per week, n (%)	
< 50	45 (16%)
50-99	74 (26.8%)
100-149	44 (15.9%)
150-199	25 (9%)
Highest level of non-physiotherapy / non-chiropractic degree, n (%)	
Bachelor's degree	148 (53.6%)
Master's degree	13 (4.7%)
Academic Doctoral degree	8 (2.9%)
Other	14 (5 %)
Province of practice, n (%)	
Newfoundland and Labrador	31 (11.2%)
New Brunswick	15 (5.4%)
Ontario	190 (68.8%)
Alberta	40 (14.5%)

Table 4.
Providers opinions on factors that may inhibit participation in a reporting and learning system.

Factors inhibiting RLS participation	Not at all	Yes, a little	Yes, a lot
Patient Concerns			
Perceived inconvenience for the patients	22%	51%	27%
Potential to create negative perception in patients	26%	49%	25%
Office Concerns			
Time pressure	11%	42%	46%
Lack of clear definitions as to what constitutes a reportable incident	32%	55%	14%
Resource constraints	65%	28%	7%
Big Picture Concerns			
Regulatory implications	41%	42%	17%
Legal implications	36%	47%	17%
Fear of blame	57%	38%	5%
Believe reporting is unnecessary	65%	32%	3%
RLS – Reporting and Learning System			

Respondent and Patient Characteristics
Table 3 provides a summary of demographic characteristics of respondents. Respondents were predominantly male (72.1%), providing treatment for an average of 31.6 hours per week, and treating less than 100 patients per week.

Patient Safety Culture Dimensions
In Figure 1, composite scores are contrasted with the AHRQ 2016 comparative database. With the exception of Patient Care Tracking/Follow-up scores, all other scores were greater than the AHRQ database. Specifically, Work Pressure and Pace, Office Processes and Standardization, and Overall Perception of Patient Safety – Clinical scored statistically significantly higher than the AHRQ database.

Factors Inhibiting Participation in a Reporting and Learning System
Perceived barriers to participation in a patient safety reporting and learning system are summarized in Table 4. Time pressure was identified as the biggest limitation, with patient concerns (i.e., perceived inconvenience for the patients and potential to create negative perception in patients) being the next most frequently reported limita-

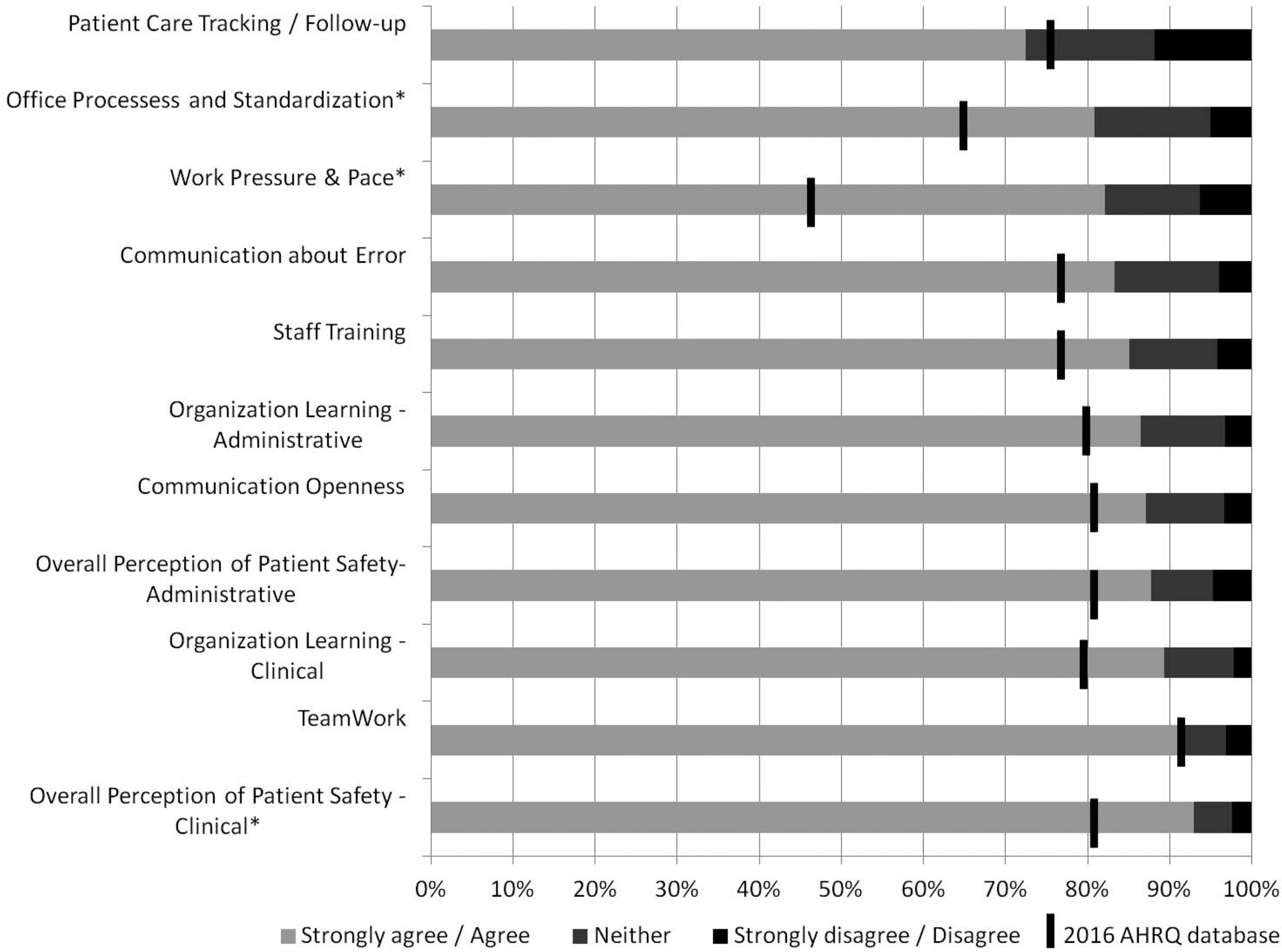

Figure 1.
The positive composite scores from the patient safety dimensions are presented for SMT providers who responded to the survey and the 2016 AHRQ comparative database. Asterisks indicate dimensions that the percentage of positive composite scores for "strongly agree/agree" responses from SMT providers were significantly different than the ones from the 2016 AHRQ medical offices comparative database.

tion. A modest level of concern was reported regarding potential regulatory and legal implications. Most (57%) reported the fear of blame was not a barrier to reporting potential AEs.

Patient Safety Items and Quality Issues/Information Exchange with Other Settings

In comparison to the AHRQ database, SMT providers who responded to the survey had higher scores in most other items (Table 5). The SMT providers scored statistically significantly lower than medical offices in items related to medication list being updated and abnormal lab or imaging test not being followed up within one business day. Scores related to the use of the wrong patient chart, a chart not being available, clinical information filed into the wrong chart, and equipment not working properly were similar to scores in the AHRQ medical office 2016 database (< 5% difference).

Table 5.
Composite-level average percent positive response by number of providers. A desirable outcome corresponds to a high percentage value, which represented less frequency of occurrence.

Dimension	Composite Mean %	AHRQ – 2016
Patient safety items and quality issue		
Access to care: A patient was unable to get an appointment within 48 hours for an acute/serious problem.	89%	90%
Patient identification: The wrong chart/record was used for a patient.	95%	97%
Charts/Records: A patient's chart/record was not available when needed	91%	90%
Charts/Records: Clinical information was filed, scanned, or entered into the wrong patient's chart/record	94%	89%
Equipment: Equipment was not working properly or was in need of repair or replacement	95%	92%
Medication: A patient's medication list was not updated during his or her visit.	56%*	80%
Diagnostics Test: Results from a lab or imaging test were not available when needed	82%*	70%
Diagnostics Test: Critical abnormal result from a lab or imaging test was not followed up within 1 business day	66%*	94%
Difficulty with Information Exchange with Other Setting		
Outside labs / imaging centers	91%	82%
Other physician clinics (AHRQ: Other medical offices / outside physicians)	89%*	77%
Other healthcare clinic	92%	NA
Insurance / Third Party Payers	70%	NA
Other (i.e. Worker's Compensation Board, employers of patients, schools)	76%	NA

AHRQ 2016 – 2016 Agency for Healthcare Research and Quality medical offices comparative database
* – Significantly different than 2016 AHRQ database scores

Respondents described the greatest difficulty in exchanging information with other healthcare clinics. While information exchange with outside labs/imaging centers was comparable, information exchange difficulty with other physician clinics was statistically significantly higher than the AHRQ medical office 2016.

Overall Clinic Self-Ratings

In Table 6, overall clinic self-ratings dimensions for respondents were found to be statistically significantly higher than the AHRQ medical office 2016 database; however, the overall clinic rating was comparable. Items that affect a patient's care plan were found to be equally distributed for items measured. Other items that were described as affecting the patient's specifically designed care plan were: patient's desire to follow care plan, patient's expectations, and patient's level of discomfort.

Discussion

Survey Development

As expected, our literature review did not retrieve a specific instrument developed for SMT providers, but it identified an existing validated survey used for other healthcare professions did meet our criteria. The selected survey tool, AHRQ's *Medical Office Survey on Patient Safety Culture* was adapted and minimally modified for SMT providers, allowing comparison of 14 patient safety dimensions with AHRQ medical office 2016 database.

A previous review of several patient safety surveys, including the AHRQ Medical Office Survey on Patient Safety, concluded that survey results should be interpreted with caution as there was no established link with improved patient outcomes.[24] However, another recent systematic review reported a trend demonstrating a positive relationship between patient safety culture and patient

Table 6.
Providers' perception of overall clinic self-rating.

Dimension	Poor	Fair	Good	Very Good	Excellent
Patient centered	0%	2%	12%	34%*	52%*
AHRQ 2016	0%	7%	27%	36%	30%
Timely	1%	3%	20%	41%*	35%*
AHRQ 2016	7%	13%	31%	35%	15%
Efficient	0%	1%	20%	43%*	36%*
AHRQ 2016	3%	9%	26%	45%	18%
Equitable					
Patient: gender, race, ethnicity, language, etc	0%	0%	5%	34%*	61%*
AHRQ 2016: gender, race, ethnicity, socioeconomic status, language etc.	1%	5%	15%	27%	52%
Overall clinic rating to prevent, catch, and correct problems that have the potential to affect patients	1%	5%	27%	46%	21%
AHRQ 2016	1%	7%	26%	49%	18%
*– Significantly different than 2016 AHRQ database for the same scores					
How do the following dimension affect patient's specifically designed care plan?	**Never**	**Rarely**	**Sometimes**	**Most of the time**	**Always**
Socioeconomic status	22%	22%	40%	10%	5%
Insurance coverage	32%	20%	33%	11%	4%
Patient's accessibility to clinic	26%	28%	34%	9%	3%
Other	9%	9%	55%	18%	9%
AHRQ – Agency for Healthcare Research and Quality AHRQ 2016 – 2016 AHRQ medical offices comparative database					

outcomes in hospital settings but this was not statistically significant.[25] In high-risk industries, an open constructive safety environment was found to lead to high employee safety compliance and better organizational performance.[26] The need to understand patient safety attitudes and opinions through the use of cross-sectional surveys may help researchers, patient safety personnel, and administrators identify areas of strengths and those in need of improvement with an aim to increasing positive patient outcomes and reducing medical error, despite the lack of current evidence for this result.

Survey Application

We present the first study to measure community-based SMT providers' patient safety attitudes and opinions. The patient safety dimension of 'work pressure & pace' scored greater than the AHRQ comparative data base, indicating that respondents often felt rushed and that they may have too many patients for the amount of time available. This was also observed in medical offices regardless of the job position[27], indicating the need for processes and systems to accommodate the busy work-load and to reduce potential staff burnout[27].

Similar to other healthcare professions, this survey found that 'time pressure and lack of clear reportable incident definitions' were the largest concern of SMT providers in participating in a reporting system.[23,28] Time pressure was an expected finding, as healthcare providers often have competing demands for their time and perceive themselves as "too busy" to report incidents[5,28,29], emphasizing the importance of 'ease of use' when developing an evaluation system. Although "busyness" is a socially acceptable excuse for non-participation in incident reporting systems, patient safety is one of the most prominent healthcare challenges and improving health care is a shared responsibility that must include health care providers, researchers and patients to be successful.[1]

'Lack of a clear definition for reportable incident' has been identified in previous studies among chiropractors and other professionals utilizing SMT.[5,28,30] More specifically, a qualitative study with SMT providers observed that not only was defining AEs following SMT challenging, but also that the perceived difficulty of tracking these events would exceed the benefits of having the reported information.[31] Similar to our survey findings, a systematic review focusing on clinical incident reporting suggested having a standardized definition of an AE, along with clearly described reporting methods, including mechanism, anonymity, accessibility, and ease of input.[32] To address these perceived challenges, the SafetyNET team adapted an AE definition based on the patient safety scientific literature and their content team experts to "*any unfavorable sign, symptom, or disease temporally associated with the treatment, whether or not caused by the treatment*"[33]. Regarding the incident reporting mechanism, the SafetyNET team has also developed and validated profession-specific instruments to track and evaluate potential AEs related to SMT in a systematic yet in a time-efficient manner.[34] Provider feedback from a larger study using these instruments (personal communication) suggest that both providers and patients find these instruments easy and quick to use .[34]

We found that providers perceived that 'potential patient concerns' were an important barrier to participation in a reporting system. Previous studies, however, suggest this concern is not shared by patients.[10,34] Patients who have participated in a SafetyNET's pilot reporting system stated that they were pleased their provider was participating in a study directly assessing patient safety.[34] Additionally, Huerta and colleagues (2016)[35] observed that not only can patients provide unique input on safety and care, but by reporting events related to safety, they are more engaged in their care.

Regarding direct patient safety items, our study found that respondents scored the item 'updating a patient's medication list' lower than medical offices.[19] Although prescribing medications is typically not within the scope of the SMT providers, seeking information about a patient's medication list provides healthcare professionals with important information regarding the patient's current health status.[36,37] Thus, not only do changes in a patient's medication list indicate a change in the patient's health condition[38], but some medications may pose specific risks for SMT treatment, such as increased risk of bleeding[39]. Therefore, adequate pharmacological training and continued professional development to recognize the importance of asking about patient medication use at every visit could potentially increase patient safety within health care providers' clinics/offices.

The development and application of the survey described in this study is an important step towards creating a paradigm-shift in SMT providers regarding patient safety research and initiatives. Understanding the opinions and attitudes of SMT providers towards patient safety and identifying potential areas for improvement can lead to specific strategies and interventions to promote a constructive patient safety culture and support the development of effective systems for continuous learning and quality improvement. Although patient safety strategies and initiatives are currently being developed to promote a safety culture and address specific areas, future investigations are needed to assess the feasibility of these strategies' and their impact on patient outcomes.

Limitations

Survey Development

Results from the pilot study conducted with the developed Survey to Support Quality Improvement suggest that a limitation of this instrument is its length. A lengthy survey is likely to lower the response rate, especially for items positioned at the end of the survey, and may lead to an increased chance for non-response bias.[40]

Survey Application

Given that the results presented in this study include responses from 276 SMT providers, the results from this study should be interpreted with caution as it only reflects the attitudes and opinions of SMT providers who responded to our survey.

Another limitation of our work is the comparator group. Although Canadian SMT providers' patient safety attitudes and opinions were investigated in the current study, an American database from medical offices (from AHRQ) was used for comparison as a Canadian patient safety database is not available. Therefore, potential cultural differences should also be considered as a potential limitation when interpreting our results.

Conclusions

This study identified, adapted, and conducted content validation for the SafetyNET's Survey to Support Quality Improvement to measure the patient safety culture of SMT providers, specifically chiropractors and physiotherapists. The survey measures the perceptions of their attitudes and opinions toward patient safety and quality improvement items and is the first study of its kind conducted in Canada. Generally, SMT providers had similar or better patient safety dimension scores compared to the AHRQ 2016 medical offices database. By understanding SMT providers' opinions and attitudes towards patient safety and identifying areas for improvement, organization-specific strategies can be developed to support a culture of patient safety and promote quality improvement.

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Does interprofessional interaction influence physical therapy students' attitudes toward chiropractic?

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Background: *Interprofessional education (IPE) facilitates collaborative health practice, improving clinical outcomes.*

Objective: *Explore physical therapy (PT) students' observations about chiropractic, including attitudes amongst distinctive PT programs.*

Methods: *We administered a 74-item electronic survey, including 12 attitudinal items comprising the chiropractic attitude questionnaire (CAQ), to PT students at two universities. PT students at University 2 interacted with faculty members who were chiropractors, while PT students at University 1 did not interrelate with faculty members who were chiropractors.*

Results: *Mean CAQ score for University 1 was 35.92 (SD ± 5.62), while the mean CAQ score for University 2 was 40.67 (SD ± 5.34) indicating a significant mean difference of 4.75 (SE ± 0.89) points (P ≤ 0.001).*

Discussion: *Our results suggest that interprofessional*

Contexte : *L'enseignement interprofessionnel (EIP) facilite les soins de santé en collaboration et améliore les résultats cliniques.*

Objectif : *Examiner les commentaires des étudiants en physiothérapie (PT) sur la chiropratique et les attitudes entre les étudiants des divers programmes en PT.*

Méthodologie : *On a mené un sondage en ligne de 74 questions, dont 12 faisaient partie du questionnaire sur les attitudes à l'égard de la chiropratique (QAC), auprès des étudiants en PT de deux universités. Les étudiants de l'université 2 échangeaient avec les professeurs qui étaient chiropraticiens, mais les étudiants de l'université* 1 ne le faisaient pas.

Résultats : *Le score moyen au QAC pour l'université était de 35,92 (ET ± 5,62), alors que celui obtenu pour l'université* 2 était de *40,67* (écart-type *± 5,34), soit une différence significative des moyennes de 4,75 (erreur-type ±* 0,89) *points (p ≤ 0,001).*

Discussion : *Nos résultats semblent indiquer que*

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interaction may improve attitudes amongst PT students.

Conclusions: *PT students exposed to chiropractors via interprofessional interaction demonstrated a more positive attitude toward the chiropractic profession.*

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KEY WORDS: physical therapy; chiropractic; interprofessional education; attitudes; students; questionnaire

les échanges interprofessionnels peuvent améliorer les attitudes chez les étudiants en PT.

Conclusions : *Les étudiants en PT ayant des échanges avec des chiropraticiens avaient une attitude plus positive envers la chiropratique.*

(JCCA. 2018;62(3):143-148)

MOTS CLÉS : physiothérapie, chiropratique, enseignement interprofessionnel, attitudes, étudiants, questionnaire

Introduction

As part of the ongoing national and international healthcare reform, recent efforts by health organizations and educational institutions have highlighted the role of interprofessional education (IPE) and interprofessional learning (IPL).[1-4] According to Buring *et al*. (2009), "interprofessional education involves educators and learners from 2 or more health professions and their foundational disciplines who jointly create and foster a collaborative learning environment".[5] Interprofessional learning may be defined as, "learning arising from interaction between members (or students) of two or more professions. This may be a product of interprofessional education or happen spontaneously in the workplace or in education settings."[4] Preconceived negative stereotypes and prejudices within health professions may act as barriers to interprofessional collaboration, thus creating a detrimental clinical outcome for patients and practitioners. Based upon previous literature, IPE and IPL facilitate collaborative health practice, ultimately leading to improved health services and outcomes.[6-8]

There has been a long-standing adversarial relationship between the chiropractic profession and other health care professions, including an attempt by the American Medical Association to limit medical physicians' collaboration with chiropractors.[9] More recently, literature has demonstrated a negative bias toward the chiropractic profession amongst medical and physical therapy (PT) students along with orthopedic surgeons.[10-12] For example, medical students who reported no interest in learning more about chiropractic care were significantly more attitude-negative toward the profession.[12] Yet, education and collaboration between different health disciplines may offer an avenue to reshape these biases.

However, an unanswered question persists about the relationship between chiropractors and physical therapists; does exposure to educational information about the chiropractic profession, including interaction with faculty members who are knowledgeable about chiropractic (i.e., licensed Doctors of Chiropractic or DC) influence PT students' attitudes about the profession? If successfully answered, this information may influence interprofessional collaboration between the physical therapy and chiropractic professions.

The objective of this study is to explore how PT students observe the chiropractic profession, including comparing students' attitudes amongst distinctive university-based PT programs. The long-term goal of this proposal is to facilitate IPE, thus creating collaborative relationships between chiropractors and physical therapists. Ultimately, a collaborative relationship between these professions may improve health services and patient outcomes. Its central hypothesis is that PT students who are exposed to educational resources related to chiropractic may demonstrate less negative bias toward the chiropractic profession.

Methods

Based upon previous literature[10,11], we designed a 74-item survey, including three open-ended questions, to explore PT students' attitudes concerning the chiropractic profession. Prior to using items from these aforementioned survey instruments, we obtained formal, written consent from the primary authors. Sixty-two survey questions queried respondents for information about demographics

Table 1.
Responses to Chiropractic Attitude Questionnaire Items (n = 165)

Item	Strongly Agree %	Agree %	Undecided %	Disagree %	Strongly Disagree %
The Chiropractic profession has a place in health care.**	17.4%	60.3%	18.0%	3.1%	1.2%
Information about chiropractic should be included within the early years of my physical therapy curriculum.***	13.7%	55.3%	18.6%	11.2%	1.2%
Chiropractic treatment is "evidence-based" i.e. use of evidence in research to guide practice.***	5.6%	31.3%	46.3%	13.8%	3.1%
Chiropractors make excessive use of radiographic imaging.	5.7%	19.5%	50.9%	22.0%	1.9%
Chiropractors provide a patient-centered approach.**	3.9%	57.1%	25.6%	11.5%	1.9%
Chiropractic manipulation of the neck is generally a safe therapy for patients.**	4.5%	36.9%	38.2%	17.2%	3.2%
Chiropractors can provide effective therapy for some non-musculoskeletal conditions (e.g. asthma, infantile colic).*	1.3%	13.8%	47.8%	30.2%	6.9%
Chiropractors can reduce patient overload for physical therapy patients with musculoskeletal complaints that are not surgical candidates.	3.1%	16.4%	47.3%	25.2%	8.2%
Chiropractors lack sufficient clinical training.***	1.9%	5.1%	34.2%	45.6%	13.2%
Chiropractors engage in overly aggressive marketing.***	11.3%	21.4%	40.0%	22.3%	4.4%
Chiropractic has no role in the routine care of physical therapy patients.**	1.9%	13.3%	34.8%	43.0%	7.0%
Chiropractic breeds dependency in patients seeking short-term symptomatic relief.	23.9%	43.4%	21.4%	10.7%	0.6%

All data reported as mean values. Differences between University 1 and University 2 are statistically significant ($p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).*

such as age and gender along with knowledge and perceptions regarding the chiropractic profession. Questions were scaled according to the 5-point Likert scale (strongly disagree, disagree, undecided, agree, and strongly agree).

We sought and gained approval for this study from a university Institutional Review Board. Before collecting any information, subjects read and agreed to an informed consent cover letter approved by the Institutional Review Board. Based upon a convenience sample, we surveyed PT students in two university programs. Both universities were private institutions of similar size (< 3000 full-time students), geographic location, and each university offered a 36-month Doctoral of Physical Therapy program. However, PT students surveyed at University 2 interacted via classroom activities with full-time faculty members who were licensed Doctors of Chiropractic, while PT students surveyed at University 1 did not participate in classroom activities with faculty members who were licensed Doctors of Chiropractic. At University 2, the full-time DC faculty (n = 2) facilitated informal, spontaneous interprofessional learning between PT students during the 3-year curriculum through direct classroom interaction, including instruction (i.e., lectures, laboratory skills, and small group discussions) and assessment (i.e., examinations, quizzes, and presentations) within basic science and clinical science courses. More specifically, DC faculty at University 2 facilitated courses within the PT curriculum that included orthopedic/musculoskeletal management, imaging/radiology, biomechanics/kinesiology, and clinical research. Informal, unstructured classroom discussions within these didactic courses incorporated interprofessional perspectives including topics such as scope of practice, clinical aptitude, and assessment/management principles. However, the curriculum at University 1 did not include interprofessional classroom interaction between DC faculty and PT students.

We recruited a convenience sample from students across a three-year PT program at two universities. We administered the 74-item electronic survey to 144 full-time PT students at University 1 and 80 full-time PT students at University 2. Students at both universities received an electronic link to the survey that we created using Qualtrics software (Provo, Utah). An initial request for voluntary participation was sent, followed by a second request approximately 10 days later. Also, in an attempt to improve survey response rates at both universities, we announced a request for participation during classroom activities.

Twelve of the survey items asked respondents about their attitudes toward the chiropractic profession. These 12 attitudinal items comprised the chiropractic attitude questionnaire (CAQ) for our data analysis. We scored each of the 12 items using a five-point Likert scale, ranging from one to five. The responses from each of the 12 items were summed to formulate a score ranging from 12 (most negative attitude toward chiropractic) to 60 (most positive attitude toward chiropractic). Previous literature supported the reliability and validity of the items comprising the CAQ.[11] However, we verified construct validity of our CAQ by examining the Spearman correlation coefficient between an item querying about the respondent's general attitude toward chiropractic and the CAQ. Based upon our analysis, the Spearman correlation coefficient was 0.75.

We constructed a frequency table (Table 1) for the 12 items comprising the CAQ, and explored the data for disparities in responses across items between University 1 and University 2 with the t test. Also, as part of our data analysis, we generated a regression model for predicting PT students' attitudes toward chiropractic. In our regression model, the dependent variable consisted of attitude toward chiropractic defined as the aggregate score of the CAQ. A priori, we hypothesized that PT students at University 2 might possess a more positive attitude toward chiropractic than PT students at University 1. Finally, we generated mean CAQ scores for each university (Figure 1).

Results

The two cohorts of PT students responded to 165 of 224 surveys producing a response rate of 74%. Response data to the 12 CAQ questions are outlined in Table 1. Upon review, there were nine items that differed between University 1 and University 2. PT students at University 2, in which students interacted in the classroom with a faculty member who was a licensed chiropractor, were more likely to agree that chiropractic has a place in health care along with favoring inclusion of information about chiropractic in their PT curricula. Also, PT students in University 2 were more likely to agree that chiropractic has an evidence-based and patient-centered approach to patient care. In addition, PT students at University 2 were more likely to agree that manipulation of the neck is generally safe and more likely to agree that chiropractors provide effective therapy for some non-musculoskeletal conditions. In contrast, PT students at University 2 were less likely to agree that chiropractors lack sufficient training, less likely to perceive that chiropractors engage in overly aggressive marketing, and less likely to report that chiropractic has no role in the routine care of PT patients.

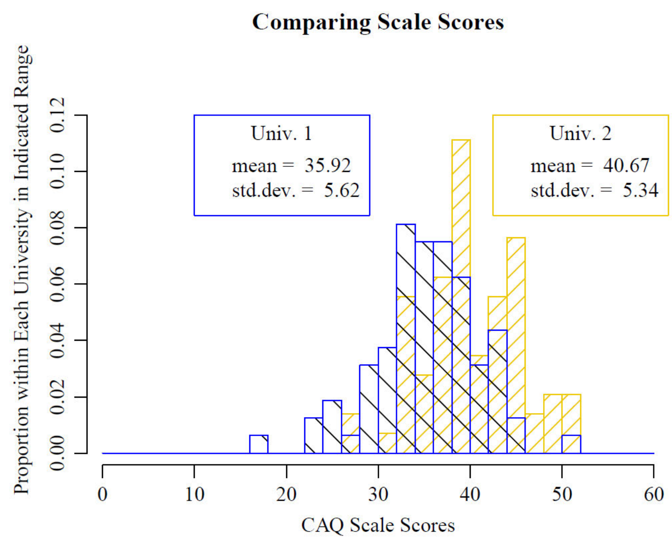

Figure 1.
Histogram plot comparing CAQ scores for University 1 and University 2. CAQ = chiropractic attitude questionnaire.

Based upon the results of our regression model, it appears that attendance at a specific university is significantly associated with PT students' attitudes toward chiropractic. For example, PT students at University 2 scored an average of 4.75 (standard error [SE] ± 0.89) points higher on the CAQ scale compared to University 1. The mean score amongst all respondents for the 12-item CAQ was 38.17 (standard deviation [SD] ± 5.97). However, the mean CAQ score for University 1 was 35.92 (SD ± 5.62), while the mean CAQ score for University 2 was 40.67 (SD ± 5.34), indicating a significant mean difference of 4.75 (SE ± 0.89) points ($P \leq 0.001$). For a graphic representation of CAQ scores, please review Figure 1. Our regression model accounted for 15% (adjusted $R^2 = 0.15$) of the variation in respondents' attitudes toward the chiropractic profession.

Discussion

Earlier literature has demonstrated a negative bias toward the chiropractic profession amongst PT students.[12] As already stated, the objective of this study was to explore how PT students observe the chiropractic profession, including comparing students' attitudes amongst distinctive university-based PT programs. Our survey results indicate that PT students at University 2, where students interacted in the classroom with faculty members who are chiropractors, appear more likely to demonstrate a positive attitude toward the chiropractic profession compared to PT students at University 1, where students did not experience classroom interactions with faculty members who were chiropractors.

However, the majority of students agreed that chiropractic breeds dependency in patients seeking short-term symptomatic relief. Also, the majority of respondents agreed that chiropractic has a role in healthcare, along with providing a patient-centered approach, and that PT educational curricula should include information about chiropractic. The majority of students appeared undecided about chiropractors' excessive use of imaging and ability to reduce patient overload for PT patients with musculoskeletal complaints. Lastly, the majority of PT students disagreed with the statement that chiropractors lack sufficient clinical training.

As mentioned earlier, other healthcare professions including physical therapy, medicine, nurse practitioners, and physician assistants demonstrated negative bias and/or limited understanding of the chiropractic profession.[9-13] Karim and Ross (2008) reflected this concern of the necessity for incorporation of IPE into chiropractic educational curricula, particularly after considering that medical schools already integrate IPE into their educational programs.[14,15] Riva *et al*. (2010) cited the potential benefit of interprofessional shadowing to facilitate team-building skills, including the interaction between pharmacists and chiropractors.[15] A case report examining the role of chiropractic within the collaborative framework of the Family Health Team (FHT), demonstrated how a multi-disciplinary approach to patient diagnosis and intervention, including a unique perspective provided through chiropractic consultation, may help optimize patient outcomes.[16] Riva *et al*. (2010) concluded that interprofessional collaboration, including co-location and personal interaction, fosters communication and trust between healthcare disciplines.[16] Scientific literature investigating the benefits of professional interaction, including the early pre-clinical stage through the later practitioner stage, amongst healthcare teams (i.e., medicine, nursing, pharmacy, nutritionists, and social work) demonstrates a positive impact on length of hospital stay, total charges, and prescription of medications, as well as a significant effect on attitudes toward interprofessional teamwork and education.[17,18] In summary, our findings that interprofessional interaction between PT students and DC faculty fosters a positive outcome corroborates preceding scientific literature.

Our results suggest that informal, spontaneous IPL following interprofessional interaction may improve attitudes amongst PT students. In the long-term, a more positive attitude amid physical therapists and chiropractors may improve interprofessional relations, perhaps leading to further collaboration between physical therapists and chiropractors. Ultimately, a collaborative relationship between these professions may improve health services and patient outcomes.

Limitations

This study may have been more impactful if we had baseline attitude surveys of both PT student cohorts (University 1 and University 2) prior to matriculation into their clinical degree programs. Our study only captured students' attitudes following matriculation into the PT program, so it is feasible that prior experiences and attitudes may have differed between the two cohorts. In addition, we administered our survey at a single time interval, but longer-term (one, two or three years) monitoring of attitudes and/or surveying the same cohorts following graduation (i.e., upon professional licensure) may provide additional insights into the influences of interprofessional interaction, including IPE and IPL. Finally, attitudes toward other professions may represent a complex interaction between many parameters, including personal and professional experience, education, knowledge, and pre-existing stereotypes, so it remains possible that other variables may account for the difference in the CAQ score between the two cohorts in this study.

Conclusion

Based upon the results of our survey, it appears that PT students who were exposed to chiropractors via interprofessional interaction at a teaching institution demonstrated a more positive attitude toward the chiropractic profession compared to PT students not exposed to chiropractic through interprofessional instruction.

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JCCA December 2018 Sports Chiropractic Special Issue: 10th Anniversary Edition

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(JCCA. 2018;62(3):149)

KEY WORDS: sports, chiropractic

MOTS CLÉS : sports, chiropratique

Ten years ago, we presented the Journal of the Canadian Chiropractic Association's first Sports Chiropractic issue[1] and it is hard to believe that it has already been a decade of showcasing of sports chiropractic research. The growth of research and scholarly activity in sports chiropractic in Canada has been fueled by dedicated researchers, faculty members, residents, and students at both of our educational institutions, as well as in field practitioner programs and private practice. I would like to thank all of the contributing authors and peer reviewers who have helped make the annual JCCA Sport issue so popular and well-received year after year.

Over the last decade we have published a great variety of articles ranging from interesting case reports to impactful systematic reviews, and this year is no exception. My hope is that you find them helpful, thought provoking, and applicable to your day-to-day practice when working with active and athletic populations.

I encourage you to get involved in research. If you have an interesting sports-related case, set of data or research ideas that you would like to further investigate and need any help, please do not hesitate to contact me or one of the JCCA Editorial Board members who are members of the Royal College of Chiropractic Sports Sciences (Canada).

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Developmental changes in the youth athlete: implications for movement, skills acquisition, performance and injuries.

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This narrative review summarizes the current literature on early sport specialization and changes that occur in the musculoskeletal system throughout growth and maturation. It discusses the impact of development on the motor and sensory systems and how this contributes to movement and coordination in the young athlete. With the increasing number of youth athletes in organized sport and the popularization of early sport specialization, the purpose of this paper is to educate those involved with the youth and adolescent athlete to important changes that are occurring at this time in development and the implications they have on movement, performance and injury. It is important for coaches, parents and athletes to understand and acknowledge the changes that are occurring, and to expect some difficulty in adaptation, which may be evident as either a plateau or deterioration in performance, or typical overuse injuries that are seen in the adolescent athlete.

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KEY WORDS: chiropractic, pediatric, athlete, growth, development

Cet article de synthèse résume la littérature actuelle sur la spécialisation sportive précoce et les changements qui se produisent dans le système musculo-squelettique durant la croissance et la maturation. Il traite des effets du développement sur les systèmes sensoriels et moteurs et comment ces systèmes participent au mouvement et à la coordination chez le jeune athlète. Le nombre de jeunes athlètes dans les sports organisés est à la hausse et la spécialisation sportive précoce est la mode. Cet article vise à sensibiliser les personnes travaillant auprès des jeunes et des adolescents athlètes aux importants changements se produisant au cours du développement et aux répercussions sur le mouvement, la performance et les blessures. Il est important que les entraîneurs, les parents et les athlètes comprennent et reconnaissent ces changements et s'attendent à certaines difficultés d'adaptation, qui peuvent être signe d'un plateau ou d'une détérioration de performance, ou alors des blessures de surmenage caractéristiques observées chez l'athlète adolescent.

(JCCA. 2018;62(3):150-160)

MOTS CLÉS : chiropratique, pédiatrie, athlète, croissance, développement

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Introduction

In 2008, there were 60 million participants between the ages of six and 18 years old in organized sport in the United States, compared to 52 million, eight years prior.[1] The number of youth participating in competitive sports is steadily rising with a concurrent drop in school-based physical education programs; only 29% of youth participate in daily classes.[1] This results in a large number of competitive athletes lacking exposure to different sports, and for children who do not participate in competitive sports, an overall lack of physical activity.[1] Discussions surrounding early sport specialization (ESS) run rampant in media and sport communities alike. ESS is defined as intensive year-round training in a single sport at the exclusion of other sports.[2] It has gained traction with the belief that ESS is essential for future sport success.[2] A recent cross-sectional study of club team athletes between 12 and 18 years old found that approximately 91% of athletes believed that specialization in one sport increased their chances of improving in that sport.[3] Sixty-six and 81% thought it would increase their chance of making college or high school teams, respectively, with only 45% believing it increased their risk of injury.[3] ESS can also arise from peer, coach or parental pressure, where up to 75% of athletes report being influenced by one of these factors.[2]

The ESS literature stratifies athletes by degree of specialization, based on three criteria: 1) training more than 8 months per year, 2) choosing a single main sport, 3) quitting all sports to focus on one sport.[2,4,5] The degree of specialization increases with a greater number of criteria applying to the athlete in question: low (1/3), moderate (2/3) or high (3/3).[2,4,5] The risk of injury also changes accordingly. Athletes with low specialization have low risk of injury but moderate risk of acute injury.[2,4,5] Moderately and highly specialized athletes have moderate and high risk of injury, respectively, and a low risk of acute injuries.[2,4,5] It is important to note that the criteria regarding the degree of specialization does not take into account athletes who have only ever played one sport. In this case, they cannot answer 'yes' for the third criteria but may still be considered a highly specialized athlete.[2,4,5] There is evidence to suggest that there is an increased prevalence of certain injuries associated with ESS, such as patellofemoral pain, Osgood-Schlatter disease and patellar tendinopathy.[4,6,7] Participating in over 16 hours per week of organized activity, regardless of the number of sports, is also associated with an increased risk of injury.[2,4]

Sport and recreation account for 8.6 million injuries in the emergency room every year.[8] Males between five to 24 years old account for over 50% of these injuries.[8] Basketball, football and soccer are in the top five activities resulting in injuries in people under the age of 18.[9] Injuries in these sports follow a similar pattern, where they peak around 14-16 years old, and decline significantly thereafter.[9] Injuries reported from a sports medicine clinic report that 67% of injuries were to the lower extremity (foot and ankle 22%, knee 13%, hip and groin 10%).[10] Serious overuse injuries were more commonly of the knee (34%) and serious acute injuries were more commonly of the foot and ankle (22%).[10] Unfortunately, details regarding sport activities of these athletes were limited.

ESS has been popularized by Malcolm Gladwell's book, Outliers, where he discusses the 10, 000-hour rule proposed by Ericsson in 1993.[5,11–13] Ericsson identifies the importance of deliberate practice, a highly structured practice environment explicitly used to improve performance, that is inherently not enjoyable.[5,11–13] He originally proposed this theory based on a small number of chess champions, elite musicians and mathematicians, however there is limited evidence that this applies to athletes.[5,11–13] The proposed risks of ESS include a greater risk of injury, not finding their favourite sport as a result of decreased sport sampling, limiting overall motor skill development and limiting sociological and psychological development due to isolation, staleness and burnout.[5,11] In addition, it has been identified that success at a young age does not predict long-term success in a sport, and in some cases may limit elite level achievement.[2,5] For example, in swimming, ESS resulted in less time on the national team and early retirement compared to those who did not specialize as early.[2,5] In a cross-sectional study comparing age of specialization in high school, collegiate and professional athletes of various sports, it was identified that high school athletes specialized on average two years earlier than collegiate and professional athletes.[14] In contrast, the benefits of early diversification include augmenting physical and cognitive skills, transfer of similar elements between sports (movement, perceptual and conceptual), and the positive effects of cross-training.[11]

Therefore, recommendations surrounding specialization in sport include sport sampling at a young age, participating in less hours of sport per week than their age while always remaining below 16 hours of total activity per week, and if ESS is chosen, to include an integrative neuromuscular program.[5,7] The recommended age of specialization varies based on sport. Early entry sports such as gymnastics, diving and figure skating typically require specialization in early adolescence.[5,7] Team sports, tennis and golf are recommended to specialize in middle adolescence, and endurance sports and track and field can specialize in late adolescence.[5,7]

When managing the adolescent athlete, training and competition requirements and scheduling are important concerns, however, the impact of physical and physiological changes cannot be ignored. With the increasing number of youth athletes in organized sport and the expectation of success and pressure from peers, parents and coaches, the purpose of this paper is to educate those involved with the youth and adolescent athlete to important changes that are occurring at this time in development and the implications they have on movement, performance and injury.

Growth, Maturation and Development

The use of the word development can be used in broad concepts of change in biology, behaviour and psychology.[15] Growth refers to the increase in size of the body or its parts, measured by stature, body mass or composition.[15] Maturation refers to the tempo and timing of progress towards a mature biologic state.[15] It can be measured by secondary sex characteristics, skeletal maturation and age at peak height growth.[15] The difficulty in measuring maturation stems from the varying rates of progress towards the same end point, limitations of measures representative of maturation and that chronological age is a poor marker of maturity status.[15]

Bone growth

As a child grows, they accrue more bone mineral mass and less cartilage due to physeal closure.[15,16] Accrual of bone mineral density (BMD) can be promoted by increased physical activity and reduced by excessive adiposity.[17–20] Average age of peak height velocity (PHV) is 12 years old in girls and 14 years old in boys.[21] The mean growth for children prior to the growth spurt is six cm/year and can increase to nine cm/year in girls and 10 cm/year in boys.[15,22,23] This rate of growth can last two to three years.[22] There is also differential growth between the legs and trunk, where leg growth precedes growth of the trunk in most youth.[22] Peak leg length growth occurs prior to or during PHV in 75.6% of girls and 77.6% of boys.[24] Peak trunk height growth occurs during or after PHV in 71.3% of girls and 83.5% of boys.[24] Therefore, leg length to trunk height ratio increases four years prior to PHV, reaches a maximum at PHV and subsequently decreases for three years thereafter.[24] This should be a consideration when using body stature or height to estimate strength differences, as many muscles cross both the legs and trunk, and global measures may not adequately represent the length of the legs during these times.[15,25] It may also be used as an estimate for maturation if athletes can be tracked over time.

Muscle growth

Peak growth velocity of body mass occurs approximately one year after PHV.[26] In girls, this tends to be fat mass, and in boys, muscle mass.[15,16] The delay in body mass development results in deferral of muscle length and mass relative to bone growth and size.[27–30] The increase in bone growth results in greater limb inertia, requiring more strength of the muscles to control the limb,[31,32] and a greater demand of muscles that are not fully developed.[33] When assessing a 14-year old's capacity to maintain knee extension in a seated position, it requires 4.7 times the torque than it does at six years old.[33] Muscle length is stimulated by the growth of the bone, where sarcomeres are added in series at the musculotendinous junction and optimal fiber length remains relatively constant.[16,27,34,35] In addition, changes in pennation angle occur contributing to increased muscle stiffness and subsequent increases in strength.[36–39] While the majority of strength improvement throughout adolescence is due to the increase in muscle size and mass, these changes can also affect the moment arm of the muscles around the axis of rotation of a joint.[40,41] Specifically, the Achilles and patellar tendon moment arms are smaller in prepubescent children.[42–44] Increases in moment arm with growth may manifest itself as an increase in strength, as it provides a more efficient mechanical advantage to the muscle.[41,43]

Tendon growth

Tendon length and cross-sectional area (CSA) increase by approximately 53% and 93%, respectively, throughout development.[39] Increases in collagen fibril diameter, density and intra-fibrillary cross-linking change the Young's modulus of the tendon, which can also be affected by increased loading of the tendon that occurs throughout maturation.[39] It is well known that musculoskeletal stiffness changes with high-intensity loading and unloading in adults.[45–49] Resistance training increases musculotendinous stiffness, whereas unloading decreases stiffness.[45–49] In prepubertal children, one study identifies similar results with a 35% increase in Achilles tendon stiffness after 10 weeks of resistance training, with no change in the control group.[50] The impact of tendon length and CSA changes throughout development have not yet been investigated.

Role of fascia

Fascia is defined as the soft tissue component of the connective tissue system that permeates the human body; it is part of the body's force transmission system that adapts its fiber arrangement and density according to local tensional demands.[51] The superficial fascia is formed by many different layers with the primary purpose of sliding one layer over the other.[52] These layers communicate through a microvacuolar system, a highly deformable web in several directions with vessels and nerves.[52] The deep fascia is the last layer before reaching structures such as muscles and bones.[52] It has a well-developed vascular and lymphatic system, various types of proprioceptive receptors, myofibroblasts and innervation from the autonomic sympathetic system.[52] This fascial system is crucial for the transmission of muscle force and correct motor coordination, for example, it can control the orientation of muscle fibers to better reflect force direction for a task.[52] Fascia develops in response to load which will be the primary factor in determining its changes throughout development, for example, the iliotibial band becomes strong and fibrous in response to bipedal locomotion, whereas it does not develop into as strong a structure in those who are wheelchair-bound.[52] In fetal and neonate feet, there is a continuous heavy layer of collagen wrapping from the Achilles tendon around the calcaneus to the plantar fascia.[53] Only a superficial layer remains and becomes part of the calcaneal periosteum by mid-20 years old, and no longer remains continuous through the periosteum in the elderly.[53] It appears that there are fascial changes that occur throughout development, however no further investigations have been conducted to describe them.

Sensory development

Some evidence suggests that humans are born with a precocial sensory system, meaning that all sensory systems are developed to varying degrees at birth.[54–56] It is also suggested that newborns are able to integrate different sensory modalities.[57,58] When challenged with a postural disturbance, children and adults show similar feedback processes; however, feedforward mechanisms are less developed in children.[59,60] Feedback control is the modification of movement in response to information from the sensory system that arises during the movement.[61] In contrast, feedforward movements are made without the use of sensory feedback during the action, therefore requires an internal map for accuracy of performing a movement.[61] Feedforward control and anticipatory contraction during movement depends on the ability to control inertial forces.[62–64] Therefore, the ability to control the growing skeleton will contribute to the development and limitation of feedforward mechanisms in this age group. By 11 to 13 years old, adolescents can choose between feedforward and feedback mechanisms; however, they still demonstrate a decreased ability to plan movement, particularly with greater task constraints.[60,65–70] Children also have more difficulty with conflicting cues, such as differences in vestibular and visual feedback.[59,60,65] In order to refine postural control, humans require the ability to reweight sensory information appropriately.[59,60,65,71] The ability of children to appropriately and quickly reweight sensory information during a task increases with age.[65,71]

Implications for Movement

When a task is performed appropriately, it reflects the interaction between the neuromuscular and sensory systems providing adequate movement planning, execution, and adaptation based on afferent feedback. With so many changes occurring throughout development, it is not difficult to imagine how they might affect movement and performance.

The development of muscle synergies begin in the legs and trunk becoming apparent around seven to nine months old, and continue until approximately 10 years old.[72,73] The patterns that arise are variable and display greater co-contraction to stabilize the joints.[72] The primary limiting factor for the emergence of appropriate muscle synergies in multi-joint action, including independent stance, is the development of anthropometric characteristics, such as mass and inertia, and the ability to generate sufficient force and joint stability to support the body against gravity.[63,64,74] In addition, difficulties in task optimization may result due to the lack of full utilization of passive structures in the development of multi-joint movement, as is needed in the stretch-shortening cycle (SSC).[75] The SSC is an eccentric stretching action prior to a subsequent concentric shortening of a muscle in the production of a movement.[39] The stretching action leads to a pre-load of a muscle, contributing to an enhanced performance of the concentric movement.[39] At 11 years old, adolescents act as a simple spring mass, taking advantage of the potential elastic energy stored in their muscles and tendons.[76,77] With age and practice, the efficiency of this system improves, for example, they learn to run more efficiently, finding their preferred stride frequency.[77–80]

A number of factors, including the continued development of contractile properties of the muscle, lower neuromuscular efficiency, musculotendinous stiffness and greater electromechanical delay (EMD) contribute to a lower voluntary muscle activation in children.[41,46,81–84] EMD represents the time between muscle activation and force production, and it continues to decrease up to 10 years old.[39,67] EMD can also be affected by muscle and tendon stiffness, neuromuscular development, and muscle relaxation time.[39,85,86] Children have a greater EMD, therefore it takes them longer for movement to occur after muscle activation begins. As these factors change throughout development, so does the ability of the child to fully activate muscles, take advantage of the SSC and produce more rapid and coordinated movements.

Joint and limb stiffness is controlled by muscle and tendon stiffness rather than passive structures crossing the joint.[87] Therefore, an increase in agonist and antagonist muscle contraction will lead to greater joint stability.[87] This suggests the importance of considering the contribution of agonist and antagonist muscles to movements, as joint movement output will be as a result of the balance between their contraction throughout a movement.[40] Failure to consider the antagonist, will underestimate the contribution of the agonist.[40,88] When assessing single joint force production and movement, co-activation varies based on the joint and the movements being performed.[40] In pubertal children, antagonist activation is comparable to those of adults when examining a single joint movement, but differences arise in more dynamic and complex tasks such as walking, where co-activation decreases with age.[41,89–92]

In the pediatric population, the emergence of multi-joint complex movements occurs as a result of the interaction of task requirements, environmental constraints and the developing nervous and musculoskeletal systems.[93] With regards to the learning of a new task, there are three principles that need to be considered: 1) controlling body mass, 2) opposing and taking advantage of gravity when appropriate, and 3) matching muscular and non-muscular forces efficiently (taking advantage of the SSC).[94] When infants learn a new task, they begin by freezing their mechanical degrees of freedom in order to achieve the task at hand.[95] As learning continues, they release them in order to use various ways of achieving the same task, allowing a more adaptable response to perturbations.[96] When assessing adaptations to walking after a perturbation, it is evident that temporal and spatial adaptations do not develop at the same speed.[97–99] In a study with a split treadmill, different speeds were provided for the left and right legs.[99] Children as young as three years old, were able to adapt to a change in treadmill speed by changing stride frequency (temporal adaptation), however, stride length (spatial adaptation) was only used after approximately 12 years of age.[99] Thus, if using adaptive strategies as part of the rehabilitative process, children under 12 years old should be given more time for training than adults.[99]

Implications for Skills Acquisition

All object projection skills (throwing, striking and kicking) integrate the generation and transfer of linear and rotational energy with an open kinetic chain.[100] They require the effective use of segmental inertial characteristics and exploitation of elastic tissue characteristics.[100] The generation of force in the open kinetic chain occurs due to proximal-to-distal sequencing of segments where the distal segments move relative to the proximal segment and add torque to the movement as the proximal segment begins to slow down.[101] This takes advantage of the segment mass and the elastic tissues across the joint to transfer and add torque to a movement.[101] The stretching of tissues across the joint promotes greater muscle activation and enhances the voluntary force contribution to the movement.[102,103] Optimizing the timing of this sequencing allows for greater recovery of stored elastic potential, thereby reducing joint torques and improving the outcome of the movement.[102,104]

The development of overarm throwing and striking are quite similar, differing only in the position of the arm to accomplish these tasks and whether the athlete uses equipment (ie. racquet).[100,105,106] As the advancement of this skill occurs, there is greater involvement of the trunk and lower limbs contributing force generation.[107–109] In addition, there is greater use of upper extremity lag to take advantage of the passive tissue stretch and greater recruitment of associated muscles.[105,106] Those who are less advanced or effective at these skills do not effectively exploit the advantage of the SSC.[107–109] It appears that there are one or more constraints that acts to systematically delay the development of striking compared to overarm throwing, Therefore, teaching both of these skills simultaneously may have a crossover effect.[105]

The development of kicking is different than throwing and striking as special considerations for the lower limb include the approach step, range of motion of the hip, trunk and arms and dynamic balance.[100] When learning of kicking begins, it is done from a static position where the kicking leg is swung back and moves forward to hit the ball, often limited by static balance.[100,110] As development of this skill progresses, it becomes more dynamic where the approach step is preceded by a run or jump, limited by dynamic balance abilities.[100,111] Range of motion requirements are similar to throwing and striking, where greater use of available range of motion leads to a greater speed of the object due to more efficient use of passive structures across joints.[110]

Given how learning occurs, even as infants, it is important to focus on the functional outcome of a task, rather than instructional cues on how to perform it.[112] Focusing on a functional outcome provides the learner with the opportunity to explore movement and the optimal method of performing a task for their own preferred efficiency.[101] In addition, changing environmental constraints can facilitate the learning of different movement outcomes while keeping the task consistent.[100] With regards to teaching object projection skills, focusing first on promoting the use of the kinetic chain is likely beneficial, and can be done by asking the athlete to focus on throwing or kicking with maximum velocity.[112,113] The use of this focus is more likely to produce a distal temporal lag, thus promoting the use of the SSC.[113] Once the athlete has reached intermediate levels of developmental sequencing, accuracy constraints can be added to further improve completion of the task.[113]

Implications for Performance

With regards to performance, it can easily be inferred how developmental changes contribute to differences within and between players. With maturation, changes in body size, muscle mass, and neuromuscular systems contribute to the potential for greater physical outcomes. When considering the stiffness of the muscle and tendon tissues placed in series, greater potential elastic energy will be primarily stored in the more compliant tissue.[87] Therefore, the changes in these structures will contribute to the performance of movements requiring the use of the SSC.[47,84] In addition, the changes in stiffness will have an impact on the sensory feedback, where lower tendon and muscle stiffness will result in less afferent feedback from receptors.[87,114] This has implications on movement, coordination and performance as a result of feedback control processes. The increase in muscle-tendon stiffness associated with development improves power production during multi-joint tasks, reaching adult levels by late adolescence (16 to 18 years old), this is further improved by changes in EMD and rate of force development.[76,86,115]

While there is the potential for improved performance, considerations should be made for athletes in their growth spurt, as the rapid growth of bone, and delay of muscle growth leads to a relative lengthening and an increase in resting tension of the muscles. In addition, the increased mass of their segments, and delay in muscle mass development limits the amount of force the muscles can produce to move the heavier segments. This also has implications for sensory feedback of the muscles and joints, affecting the neuromuscular control of simple and complex movements as demonstrated by impairment of coordination, or the classic "adolescent awkwardness", immediately during and up to one year following their rapid growth.[87,116–119] It is not unusual to expect a plateau or deterioration of performance while the athlete adapts to perceptual, spatial, physiological and biomechanical changes that are caused by growth.[40] In considering the difference in development between boys and girls, early maturing boys tend to have the athletic advantage as they experience greater shoulder width and muscle mass development, compared to girls who tend to gain hip width and fat mass.[15] Therefore, late maturing girls tend to have the athletic advantage, demonstrating more linear physiques and less fat mass.[15]

Implications for Injury

The changes occurring throughout development also place considerable risk for certain injuries. Lag of muscle hypertrophy and length are important training considerations during the growth spurt and one year thereafter.[120,121] Peak BMD occurs approximately one year after PHV, therefore bones have lower energy and force absorption compared to adults.[122,123] In addition, soft tissues changes may also lead to poor control of impact forces across joints, strength imbalances and uncoordinated biomechanics.[124] With the added stress of greater resting muscle tension after the growth spurt, it may not come as a surprise that growth-related injuries are common in athletes of this age, such as traction apophysitis'.[33,125] Although there is a lack of epidemiological data to support this, this is often supported anecdotally.

Any increase in training around this time could increase injury susceptibility.[126] Improvements in skill through developmental sequencing, can reduce the joint torques and improve object projection speed by improving mechanical efficiency.[102,104] However, implications of sport equipment and personal protective equipment must be considered, as inappropriate use may add additional overload to the athlete or lead to negative impact absorption or energy transfer.[124] For example, the use of tennis racquet, may increase the stress on the musculoskeletal system by increasing the moment arm of ball forces.[105,106]

Finally, considering maturation is an important aspect of injury prevention, as this varies between individual athletes. This has significant implications in contact sports where teams are formed by age-group. For example, a study of ice hockey players between 13 and 15 years old found that body mass and stature differences between the smallest and largest players were 53 kg and 53 cm, respectively.[127] When determining force impact differences between them, this resulted in a 357% difference.[128]

Conclusion

There are many changes occurring in the developing athlete. The growth spurt, or PHV, is an indication of the greatest period of growth, where growth rates can double those prior to that time. This results in a relative overload of the muscle and fascia, which is delayed in both length and CSA growth compared to bone, and a heavier segment but no concurrent improvement in strength to control it. It is currently unknown what changes occur in the fascial system during development and the impact this has on movement or motor control. The year following PHV is a year of system adaptation[129], which sees increases in muscle length and CSA, muscle and tendon stiffness, and BMD. This sequence of change has major implications for the coordination of movement which tends to deteriorate around the time of the growth spurt, or shortly after. In addition, with the advent of ESS and an increasing prevalence of year-round participation in competitive sports, it is important to consider this information to inform training, competition and performance decisions for these athletes. Coaches, parents and athletes must understand and acknowledge the changes that are occurring around this time, and expect some difficulty in adaptation, which may show itself as either a plateau or deterioration in performance, or typical overuse injuries that are seen in the adolescent athlete. The physical body of the athlete is already under considerable stress as a result of growth, and therefore may be susceptible to injuries. As a coach and parent, considerations may include reducing the training volume or intensity, spending more time on skills acquisition as well as ensuring sport equipment is reasonable for the state of the athlete particularly during the time of PHV.

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Roller massage: is the numeric pain rating scale a reliable measurement and can it direct individuals with no experience to a specific roller density?

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This investigation measured the reliability of the numeric pain rating scale (NPRS) for roller massage (RM) over two sessions and compared it to pressure pain threshold (PPT) during a third session. Twenty-five subjects participated. Session one, subjects rolled on 3 different rollers and filled out the NPRS for each roller then chose their preferred roller. Session two, subjects repeated the testing blind-folded to eliminate visual biases. Session three, subjects repeated testing but were measured with PPT. For the NPRS, there was poor to moderate reliability for the soft roller (ICC=0.60) and good reliability for the moderate (ICC=0.82) and hard density (ICC= 0.90) rollers. For preferred roller, there

Cette étude visait à mesurer la fiabilité de l'échelle numérique d'évaluation de la douleur (ÉNÉD) utilisée pendant deux séances d'automassage avec rouleau par rapport au seuil de perception de la douleur à la pression (SDP).Vingt-cinq sujets ont participé à l'étude. Durant la première séance, les sujets se sont massés à l'aide de trois rouleaux différents; pour chaque rouleau, ils ont utilisé l'ÉNÉD, puis ils ont indiqué leur rouleau préféré. Durant la deuxième séance, les sujets ont refait le test les yeux bandés pour éliminer les biais visuels. Durant la troisième séance, les sujets ont refait le test, mais cette fois-ci ils ont comparé leur douleur par rapport au SDP. En ce qui concerne l'ÉNÉD, la fiabilité variait de faible à moyenne pour le rouleau mou (CCI =0,60) et était bonne pour le rouleau de fermeté moyenne (CCI = 0,82) et le rouleau très ferme (CCI = 0,90). Pour ce qui est du rouleau préféré, aucune différence significative n'a été observée entre

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was no significant difference between sessions (t (24) =.00, p=1.00). For NPRS and PPT, there was a fair relationship for all rollers (Rho=0.34-0.49, p = 0.11-0.28). The NPRS appears to be a reliable measure and may help direct individuals to a specific roller. The NPRS and PPT should be used independently.

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KEY WORDS: massage, roller, muscle soreness, myofascial, perceived pain, recovery

les séances (t (24) =0,00, p =1,00). Pour l'ENÉD et le SDP, le rapport était juste pour tous les rouleaux (Rho = 0,34 -0,49, p = 0,11- 0,28). L'ENÉD semble être un instrument de mesure fiable pouvant aider les personnes à choisir un rouleau particulier. L'ENÉD et le SDP devraient être utilisés de façon séparée.

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mots clés : massage, rouleau, douleur musculaire, douleur myofasciale, douleur perçue, récupération

Introduction

Roller massage (RM) with a foam roller or other device is a common myofascial intervention. Rehabilitation professionals may utilize different types of rollers within their setting for specific patients. Many types of rollers are also available to consumers with different surface textures, shapes, and densities. There has been growing interest among researchers regarding the effects of RM on pain perception (e.g. numeric pain rating scale-NPRS) and pressure pain threshold (PPT) using algometry. Pain is a complex multidimensional process involving the central nervous system and other systems of the body.[1,2] Several studies have suggested that RM can modulate pain perception (e.g. delayed onset of muscle soreness) after exercise[3-9,12] and increase PPT in the ipsilateral[8,10-13] and contra-lateral limb[8,10-13]. Researchers have postulated that the mechanical pressure on the tissues from RM may modulate pain through stimulation of cutaneous receptors[14], mechanoreceptors[15], afferent central nociceptive pathways[11,14] and descending anti-nociceptive pathways (diffuse noxious inhibitory control)[14,16].

Several investigations have reported that the myofascial system may respond in a similar manner to low, moderate, and high RM pressure but higher pressure may have a greater effect.[14,15,17] Researchers have used preset NPRS scores to represent the spectrum of pressure or pain: light (5/10), moderate (7/10), and hard (9/10).[17] Grabow *et al*.[17] found that short bouts of RM (3 sets of 60 seconds) on the quadriceps at a low (3.9/10 ± 0.64 NPRS), moderate (6.2/10 ± 0.64 NPRS) and high pressure (8.2/10 ± 0.44 NPRS) produced similar post-intervention increases in range of motion (ROM) and did not impair muscle strength or jump performance in healthy subjects. Young *et al*.[15] showed that short bouts of RM (three sets of 30 seconds) at low, moderate and high pressures diminished spinal excitability measured by the Hoffman or H-reflex in the soleus muscle in healthy individuals. Using descriptor words to measure pressure, the higher roller pressure significantly decreased the H-reflex (58%) compared to moderate (43%) and low pressure (19%).[15] Cavenaugh *et al*.[11] also showed that short bouts of RM (three sets of 30 seconds) at a 7/10 NPRS pressure diminished evoked pain and prolonged muscle torque development in healthy males. Thus, higher RM pressure (NPRS ≥ 7/10) may have a greater effect on increasing PPT in subjects than moderate or light pressure.[14,15]

It is important to note that these studies used an examiner or mechanical device to apply the RM pressure based upon a predetermined NPRS score and subjects reported their pain level during treatment in order to maintain that level of applied pressure.[11,14,15,17] Researchers have also used pressure algometry to measure the post-treatment effects of RM on PPT in prior studies.[12,18,19] Clinicians must consider that these research measures may not be practical in all clinical settings. Furthermore, patients participating in a RM session may lay on a roller and apply pressure with their bodyweight making it difficult to apply a graded pressure that is based upon an NPRS score.

An alternative may be for patients to roll on different density type rollers and choose one that matches a desired NPRS score. In a clinic setting, the clinician may have different types of rollers available or may be limited to a specific type of roller for the patient to use. Clinician may also prescribe a certain roller based upon their clinical

Figure 1.
Types of rollers: soft (silver), moderate (orange), hard (black)

Figure 2.
JTECH algometer

experience since no clear guidelines exist.[20-22] For individuals, they may choose a specific roller based upon personal preferences such as: color, brand name, roller shape or style, texture, and cost.

The use of the NPRS to help direct patients to a specific density type roller may be more practical in the clinical setting. This may also have implications in the presence of injury or existing pain, a patient's perceived pain may be variable and influence their tolerance or preference for a certain density roller. Knowing this relationship may help clinicians to better match a roller to the patient or to utilize different rollers for certain conditions. The purpose of this investigation was to measure the reliability of the NPRS for different density type rollers over two sessions and compare it to PPT algometry. Through this research, we sought to answer the following questions: (1) Is the NPRS a reliable measure for different density type rollers? (2) Does measured pain perception after RM influence an individual's preference for a specific roller? (3) Does the NPRS and PPT offer interchangeable measures of pain perception with respect to RM?

Methods

Subjects

Twenty-five recreationally active adults (M=14, F=11) (age= 24.5 ± 3.4 years, height= 167.5 ± 9.3cm; body mass=65.4 ± 10.4 kg; body mass index= 23.2 ± 2.2) were recruited via convenience sampling (e.g. flyers). Subjects included in the study reported participating in recreational fitness activities (e.g. walking) with no prior experience using RM. Exclusion criteria included the presence of any musculoskeletal, systemic, or metabolic disease that would affect lower extremity joint range of motion or tolerance to testing and the inability to avoid medications that may affect testing. This study was approved by the Institutional Review Board at California State University Dominguez Hills, Carson, CA, USA (#18-024).

Rollers and Instruments

The three rollers used in this study were manufactured by TriggerPoint™ (TriggerPoint, a division of Implus, LLC, 5321 Industrial Oaks Blvd., Austin, Texas 78735, USA) and all had the same multilevel GRID surface pattern and diameter (14 cm) which allowed for a direct comparison. The difference between the three rollers was the density. The soft density CORE roller (silver) was constructed of solid EVA foam, the moderate density GRID roller (orange) had a hard, hollow core that was wrapped in moderately firm EVA foam, and the hard density GRID X roller (black) had a hard, hollow core that was wrapped in very firm EVA foam (Figure 1).

The JTECH (Midvale, UT) Tracker Freedom® wireless algometer (Figure 2) was used with the accompanying Tracker 5® Windows® based software to measure PPT. The manufacturer reports an accuracy error of <±

0.5% (.05kg/cm^2) for this technology.[23] Algometry is a valid and reliable tool for measuring pressure pain thresholds.[14,24-26] This instrument has also been used in prior foam roll research.[12,18,19]

Outcome Measures

Two outcome measures were used for this investigation. First, the NPRS was used to measure a subject's perceived pain level. The NPRS is a widely used patient reported outcome scale.[27-29] The ordinal 11-point NPRS (0-no pain, 10-most intense pain) is the most commonly used version which has good test-retest reliability (r=.79-.96) in individuals with chronic pain and musculoskeletal pathology.[27,28,30-32] The NPRS has been used in prior foam roll research.[3,6,8,9,33,34]

Second, the pressure algometer was used to measure PPT and considered the gold standard for this investigation. The dominant (kicking leg) quadriceps group was tested with the subject in the relaxed standing position (two measurements).[5,35,36] The 1.0-cm^2 probe of the algometer was placed into the midline of the quadriceps muscle (rectus femoris) midway between the iliac crest and superior border of the patella. The graded force was applied at a constant rate of 50-60 kilopascals per second (kPa/sec) until the subject verbally reported the presence of pain.[5,35,36] This measure has been used in prior foam roll research.[12,18,19]

Pilot Study

Prior to data collection, a two-session pilot training was conducted to establish intrarater reliability for algometry. The primary investigator took all the measurements. The primary investigator is a licensed physical therapist with over 13 years of experience and board certified in orthopaedics. Ten independent subjects were recruited and tested for this portion of the study. The intrarater reliability was calculated using the Intraclass Correlation Coefficient (ICC model 3, k). There was good intrarater reliability for pressure algometry (ICC= 0.94; 95% CI 0.61-0.96).

Procedures

All eligible participants were given an IRB approved consent form to read and sign before testing. Participants then completed a questionnaire to provide demographic information. All participants were blinded from the results and other participants enrolled in the study. The three foam rollers used in the study were assigned a number and randomized for all testing sessions using a random number generator. Testing was conducted between the hours of 10:00 AM and 12:00 PM and subjects were instructed to refrain from any strenuous activity three hours prior to testing and from taking any medication or supplements that would interfere with testing. All subjects underwent three sessions of testing with a 48-hour period between sessions.

Prior to each testing session, the primary investigator explained and demonstrated the testing procedures to each subject and answered any questions. For session one (NPRS), the subjects assumed the plank position, put the roller under their dominant leg (e.g. kicking leg) quadriceps muscle, and rolled back and forth using their preferred technique. The subjects rolled on each roller for one minute and then immediately documented their perceived level of pain using the NPRS after rolling. Subjects rested for one minute between each roller. The investigator was present to help change rollers and time each trial and rest period but did not provide any feedback to the subject. Upon completion of testing, the subjects then chose their preferred numbered roller based upon the level of discomfort they felt with all three rollers. The subjects could see the rollers but were not allowed to feel or hold them. This procedure was meant to mimic a possible situation where individuals may try different rollers, measure their perceived pain level, and choose their preferred roller.

For session two (NPRS control), the subjects replicated the first session procedures, however, were blind-folded by wearing an eye mask during testing. Subjects assumed the plank position and were assisted by the investigator. The investigator helped change rollers, place them under the dominant leg, timed each trial, and rest period. Subjects did not see the rollers and only lifted the mask to document their NPRS scores. Upon completion of testing, the subjects chose the preferred roller based upon the level of discomfort they felt with all three rollers. The subjects could not see the rollers or feel or hold them after testing. Session two was considered the control. Blindfolding of subjects was meant to control for visual preferences of seeing the rollers which could influence the grading of a subject's pain perception and choice of preferred roller.

For session three (PPT), Subjects followed the testing procedures in session one (non-blindfolded) and were assisted by a second investigator. The NPRS was replaced

Table 1.
Subject demographics

	Age (years)	Height (cm)	Mass (kg)	BMI (kg/m²)
Subjects (N=25)	24.5 ± 3.4 years	167.5 ± 9.3	65.4 ± 10.4	23.2 ± 2.2
Data reported as mean ± SD; m, meters; BMI=body mass index; kg=kilograms				

with PPT using pressure algometry. The primary investigator took posttest PPT measures for each roller and was blinded to which roller was used. The subjects and second investigator were blinded to all measures. Upon completion of testing, the subjects then chose their preferred numbered roller based upon the level of discomfort they felt with all three rollers. The subjects could see the rollers but were not allowed to feel or hold them after testing.

Statistical analysis

Statistical analysis was performed using SPSS version 24.0 (IBM SPSS, Chicago, IL, USA). Subject descriptive data was calculated and reported as the mean and standard deviation (SD) for age, height, body mass, and body mass index (BMI). The Intraclass Correlation Coefficient (ICC model 3, k) was used to calculate reliability between sessions for the NPRS. The ICC is a widely used reliability index for test-rest reliability.[37] The ICC has been used in prior research to measure the reliability of the NPRS among individuals with myofascial pain and fibromyalgia.[2] The criteria for evaluating the reliability coefficient was as follows: <.75 = poor to moderate, ≥.75 = good reliability.[38] Differences between sessions was calculated using the t-test.[38]

Correlations between the NPRS and PPT were calculated using the Spearman Rho (Rho) correlation coefficient (95% limits of agreement). The Spearman Rho correlation, a non-parametric statistic, was used to measure the correlation between the ordinal NPRS and ratio pressure pain threshold measurements.[38] The Spearman Rho correlation has been used in prior research to measure the correlation between the NPRS and PPT among individuals with myofascial pain and fibromyalgia.[1,2] The criteria for the evaluating the correlation coefficient was as follows: .00-.25 = little or no relationship, .25-.49 = fair relationship, .50-.75 = moderate to good relationship, and values greater than .75 = excellent relationship.[38] Statistical significance was considered p<.05 for all measures.

Results

Twenty-five subjects completed the study. There were no adverse events or subject attrition during data collection. Patient demographic data is presented in Table 1. For NPRS reliability (session 1 and 2), there was poor to moderate reliability for the soft-roller (ICC= 0.60; 95% CI 0.18-0.87), good reliability for the moderate density roller (ICC= 0.82; 95% CI 0.46-0.94), and good reliability for the hard density roller (ICC= 0.90; 95% CI 0.69-0.96). There was no significant difference between sessions for the soft (t (24) =-1.66, p=0.12), moderate (t (24) =.48, p=0.64), and hard (t (24) =.30, p=.30) density rollers. The average NPRS score for both sessions that correspond to each density were as follows: soft density 3.9/10, moderate density 5.3/10, and hard density 6.3/10. For preferred roller (sessions one and two), there was no significant difference between sessions for roller preference (t (24) =0.00, p=1.00). Sixty percent of subjects 60% (15/25) chose the same roller (hard 7/15, medium 5/15, light 3/15) and 40% (10/25) chose a different roller.

When correlating NPRS and PPT scores (sessions one and three), there was a fair relationship for the soft (Rho =0.34, 95% CI= 0.11-0.79, p=0.28), moderate (Rho =0.49, 95% CI=0.12-0.85, p=0.11), and hard density (Rho=0.41, 95% CI=0.19-0.81, p=0.18) rollers (Table 2). There was also a significant difference between the NPRS and PPT for the soft (t (24) =-17.24, p <0.001), moderate (t(24) =-20.27, p <0.001), and hard (t(24) =-14.75, p <0.001) density rollers.

Discussion

Several studies have used measured pain perception to control pressure applied during RM and to measure the post-treatment effects. These studies have either used

Table 2.
Correlation between NPRS and PPT (session 1 and session 3)

Roller Density	Spearman Rho (Rho)	95% CI	P-Value
Hard Density	.41	.19-.81	.18
Moderate Density	.49	.12-.85	.11
Soft Density	.34	.51-.79	.28
NPRS= numeric pain rating scale; PPT= pressure pain threshold, p-value significant at p<.05			

examiner or devices to apply a predetermined pressure based upon a NPRS score.[11,14,15,17] These methods may be good for research but may not be practical in the clinical setting. This investigation examined a more practical approach to measuring RM pressure and roller preference by having subjects roll on different density rollers (soft, moderate, hard) and document their posttest discomfort with the NPRS. Currently, there is no consensus on the optimal way to help individuals choose a roller. Clinicians may recommend a roller based upon their personal preference and individuals may also choose a roller using similar rationale. This study attempted to answer three clinical questions that are discussed below.

Is the NPRS a reliable measure for different density type rollers?

Subjects underwent two sessions of testing: non-blind folded and blind-folded (control). The blind-folded session helped eliminate any visual biases that would influence the subjects grading of their pain perception with each density roller. The results showed poor to moderate reliability for the soft (ICC= 0.60), good reliability for the moderate density roller (ICC= 0.82), and good reliability for the hard density roller (ICC= 0.90). These findings suggest that the NPRS may be used as a repeated measure and to direct individuals to a specific roller.

The average NPRS score for both sessions that correspond to each density were as follows: soft density 3.9/10, moderate density 5.3/10, and hard density 6.3/10. The average NPRS score found in this investigation are similar to the scores found in the Grabow *et al*. study[17] and support the theory that subjects may respond more to higher pressure levels than lighter pressure due to higher levels of perceived discomfort[15]. Higher pressure or discomfort may produce a stronger stimulus which effects a variety of mechanoreceptors and nociceptors, changes in neuromuscular stretch tolerance, or activation of the ascending and/or descending pain modulation systems.[15,17] Thus, harder density rollers may produce higher pressure to the myofascia resulting in an elevated level of perceived discomfort. This theory still needs to be confirmed with further research.

Does measured pain perception during rolling influence an individual's preference for a specific roller?

This investigation explored how measured pain perception influences a subject's choice for a specific roller. The results revealed no significant difference between sessions for roller preference (p=1.00). Sixty percent of subjects (15/25) chose the same roller and 40% (10/25) chose a different roller. The variability in subject's choice of rollers may be attributed to the differences between session one and session two (blind-folded). During session two, subjects were blind-folded which prevented them from seeing the roller and required them to grade their discomfort based upon the pressure felt with each roller. This controlled for possible visual biases and may have provided a purer measure of a subject's pain perception. These results were not expected when considering the consistency in NPRS scores for sessions one and two. Subjects would choose a similar roller each session.

Does the NPRS and PPT offer interchangeable measures of pain perception with respect to RM?

The NPRS is a widely used subjective pain measure that has good test-retest reliability (r=.79-.96). [27,28,30-32] The NPRS has been used in RM research to measure the post-treatment effects of RM on pain perception[3,6,8,9,33,34] and to grade the pressure applied during RM testing by following a predetermined pain level[11,15,17,39]. Pressure algometry has also been used in RM research to measure PPT[5,12,14,19,36,40] and is considered the gold standard in pain research[1]. Due to the widespread use of both measures in research, this investigation sought to examine the interchangeability of the measures for clinical practice. The results only showed a fair relationship between the two measures for all three densities challenging the interchangeability of the measures. It is recommended that each measure be used independently to ensure measurement accuracy, however the choice of a preferred roller is multifactorial. It appears that the NPRS may be more practical in the clinical setting since it's easier to administer.

Limitations

There are specific limitations to the investigation that need to be discussed. First, this investigation tested healthy untrained subjects which limits the generalizability of the results to this population. Second, the three foam rollers used had the same multilevel GRID pattern surface and diameter which allowed for a direct comparison. Other foam rollers with different surface patterns, diameters, and densities may have produced different results. Third, the immediate posttest effects of each foam roll intervention were studied with the dominant quadriceps muscle only. Rolling on other muscle groups may have produced different results. Fourth, the subjects used their own preferred method of rolling. Other rolling techniques may have produced different results.

Clinical Relevance and Future Research

The translation of RM research to clinicians can be challenging since the methods used in the studies may not be practical in all settings. This investigation attempted to examine the reliability of the NPRS for different roller densities and if it can direct patients to a specific roller. The results suggest several findings that clinicians may be able to use in most clinical settings. First, the NPRS appears to be a repeatable measure of perceived pain and may help the clinician to direct patient to a specific roller. The NPRS is easy to administer and can allow patients to progress through different density rollers based upon a preset score. This may be clinically relevant in the presence of injury or pain, since pain is very subjective and a multidimensional process involving the central nervous system and other systems of the body.[1,2] Second, the NPRS and PPT with pressure algometry may not be interchangeable measures. The results from this investigation suggest that each measure should be independent to ensure measurement accuracy.

There are still many unknown questions regarding the neurophysiological effects of RM and the optimal program for individuals. Future research should study the short and long-term efficacy of RM on perceived pain in individuals with specific injuries or musculoskeletal conditions. The current research is variable and has focused on the short-term effects of RM in healthy individuals.[20]

Conclusion

Currently, there is no consensus on the optimal method of progressing patients through the various density type rollers. This may be an issue for patients who are experiencing pain and may need a method of safely progressing through the different density rollers. The NPRS may be a reliable measure to help guide patients through the different rollers and provide a way of documenting a patient's tolerance and progress with RM. The NPRS appears to have more utility than other measures, such as PPT, and should not be interchanged to ensure measurement accuracy.

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Effects of local vibration therapy on various performance parameters: a narrative literature review

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Introduction: *The therapeutic effects of local muscle vibration (LMV) remain controversial due to a lack of specific protocols. This review was conducted to better understand the effects of various LMV application protocols.*

Methods*: A comprehensive literature search was performed based on title and abstract and a set of predetermined inclusion criteria. Study quality was then evaluated via the PEDro scale.*

Results: *23 articles were returned initially, and 21 studies were evaluated. The average PEDro score was 5.97/10. Reported outcome measures included muscle activation, strength, power, and range of motion / flexibility. The frequency and amplitude of LMV ranged from 5 - 300 Hz and 0.12 -12 mm respectively, and duration from 6 seconds - 30 minutes.*

Introduction : *Les effets thérapeutiques des vibrations musculaires locales (VML) demeurent controversés en raison de l'absence de protocoles précis. Cette revue de synthèse visait à mieux comprendre les effets de divers protocoles d'utilisation des VML.*

Méthodologie *: On a effectué une recherche exhaustive de littérature* à l'aide des mots du titre et du résumé ainsi qu'un ensemble de critères d'inclusion *pré*déterminés. La qualité de l'étude a ensuite été évaluée à l'aide de l'échelle *PEDro*.

Résultats : *23 articles ont été envoyés au point de départ et 21 études ont été évaluées. La cote moyenne sur l'échelle PEDro était de 5,97 sur 10. Les r*ésultats *signalés étaient l'activation musculaire, la force, la puissance, l'amplitude du mouvement et la souplesse. La fréquence et l'amplitude des VML étaient de 5* à *300 Hz et de 0,12 à 12 mm respectivement, et la durée variait de 6 secondes à 30 minutes.*

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Conclusion: *Most studies found that LMV elicits beneficial changes in the mentioned outcome measures. However, the methodological procedures used are quite heterogeneous. Further research is needed to understand the optimal application of LMV.*

(JCCA. 2018;62(3):170-181)

KEY WORDS: chiropractic, vibration, local muscle vibration, performance

Conclusion : *La plupart des études ont montré que les VML étaient bénéfiques sur les résultats mentionnés. Cependant les méthodologies utilisées étaient très* hétérogènes. *Il faudrait mener d'autres études pour savoir dans quels cas les VML procurent des bienfaits optimaux.*

(JCCA. 2018;62(3):170-181)

MOTS CLÉS : chiropratique, vibration, vibration musculaire locale, performance

Introduction

The use of vibratory stimuli has demonstrated practical applications in the areas of therapeutic rehabilitation and exercise performance. Much of the current evidence in support of vibration therapy has examined the effects of indirect vibration on muscle function through the application of whole-body vibration (WBV). Some limitations concerning WBV are the difficulty of applying the vibration stimulation to targeted muscles for a wide range of exercises and the attenuation of the vibratory signal by the time it reaches the intended muscle during its transmission through soft tissue, which may hinder the sought after therapeutic effects.[1] Furthermore, both the agonist and antagonist muscles are stimulated by indirectly applied vibration, which may decrease the net force output around a joint as a consequence of reciprocal inhibition.[1] Recently, local muscle vibration (LMV) has been demonstrating therapeutic and functional influences on muscle that addresses these concerns, providing an economically viable and portable alternative to WBV.[2,4,9,14,16-17,19-22]

The neurophysiological mechanism through which vibratory stimulation operates has been attributed to the tonic vibratory reflex (TVR). This mechanism is stimulated by a sequence of rapid muscle stretching that occurs when applying vibration, triggering muscle spindles and thereby causing an involuntary production of strength.[2] Other mechanisms of improved muscle function following vibration include elevated muscle temperature, enhanced corticospinal excitability and intracortical processes.[2] However, it has been suggested that the neurophysiological mechanisms may differ between LMV and WBV since the latter stimulates multiple receptors throughout the body or extremity resulting in adaptations to the motor unit firing frequency and synchronization, muscle tuning, intramuscular coordination and central motor command, while the former exerts its effects on receptors proximal to the simulator.[2] Such observations have proposed the hypothesis that a muscle's electrical and mechanical response could vary with the frequency of vibration and the damping characteristics of the soft tissue to the vibratory stimulus.

A frequency of 30 to 50 Hz, the same frequency of the discharge rate of motor units during maximal effort, has been identified as appropriate for promoting therapeutic adaptations such as improved isometric muscle strength.[2,3,8] These improvements are observed when LMV is applied in the absence of simultaneous voluntary muscle contraction.[2,3,8] Although the precise mechanism of adaptation is not fully understood, increased EMG activity following LMV suggests greater motor unit activation and firing frequency.[2,3] Based on prior studies, some have attributed the increase in EMG to increased excitation of the alpha motor neurons through the muscle spindle system during vibration exposure, changes in corticospinal excitability, and intracortical processes.[2] There is also evidence to suggest that local vibration applied during resistance training is an effective means of increasing maximum isometric force compared to traditional training alone.[4-6] Aside from improvements in active muscle performance, it has been suggested that LMV can improve range of motion and reduce perceived stiffness relative to the traditional treatment of ice, compression, and elevation following soft tissue injuries.[7]

Although mechanical muscle vibration has received considerable attention as a potentially useful method of muscle stimulation for therapeutic and sports training purposes, the results remain controversial. Specific vibrational training protocols are lacking, resulting in uncertainties regarding the most effective vibration intensities, frequencies, and application protocols. This literature review was conducted in order to gain further insight into what is known about the effects of local vibration therapy on various performance parameters.

Methods

Search Strategy

A comprehensive literature search was performed of electronic databases PUBMED, CINAHL, Cochrane, and via the Discovery Service for the Canadian Memorial Chiropractic College (CMCC). A combination of key words such as: vibration, mechanical vibration, direct vibration, local vibration, vibration exercise, neuromuscular output, power, strength, strength training, muscle strength, explosive strength, vibratory stimulation, vibratory stimulus, muscle activation, range of motion, and maximum voluntary contraction were used to find relevant studies. The search was initially limited to articles published in English up until February 2018. All relevant articles were initially selected by title and abstract by two independent reviewers, and irrelevant articles were excluded.

Inclusion and Exclusion Criteria

For articles to be included, they must have investigated the effect of LMV on various performance parameters (i.e. muscle activation, strength, power, joint stability, range of motion / flexibility) in human subjects of any age or gender. LMV was defined as "the application of local mechanical vibration to a tendon or muscle"[9] either directly or indirectly via an automated mechanical device. Studies utilizing only whole-body vibration techniques for therapy were not included, and the studies must have been available in full-text. No limitations were imposed on the type of study included in this review.

Criteria for Evaluation Used and Method of Analysis

The quality of each selected study was evaluated by two independent reviewers (AE, DG) using the PEDro Scale (see Appendix 1). The PEDro Scale seeks to identify which studies were likely to be "internally valid (criteria 2-9) and could have sufficient statistical information to make their results interpretable (criteria 10-11)".[10] The PEDro scale awards points ranging from 0-10, with a higher score indicating a higher quality of study. Additionally, the SIGN grading system was used to evaluate the quality of any included systematic reviews. The SIGN checklist identifies aspects of a study's design that have been shown to have a significant effect on its risk of bias.[11]

Results

Identified Studies

The initial search based on title and abstract returned 23 articles. Limiters were then applied based on the agreed upon inclusion and exclusion criteria, after which two studies were removed[12,13] leaving 21 studies remaining. A full list of the included studies, their characteristics, key results / conclusions, and quality graded via the PEDro scale and SIGN criteria can be seen in Table 1.

Characteristics of Subjects

A total of 831 participants were found in the search with sample sizes varying from nine to 44 and mean ages of both men and women ranging from 20.4 ± 1.4 to 77.6 ± 10.4 years.[2,14] The majority of the studies included recreationally active participants, and 5 studies examined the effects of LMV in various groups of elite athletes.[5,15-18]

Vibration Protocols

There was great variation in the methods used to provide local vibration therapy. The frequency and amplitude of the vibration stimulus ranged from five to 300 Hz and 0.12 to 12 mm respectively.[16,19] The duration of applied vibration stimulus was recorded as low as six seconds up to 30 minutes.[9] In most studies, the control group received a sham protocol, or no intervention.

Outcome Measures / Performance Parameters Assessed

There were a number of performance parameters assessed among the included studies. The most common outcome measures assessed were muscle activation / stimulation, which was evaluated in 11 studies[1-2,6,15-17,20-24], muscle strength evaluated in 10 studies[2-4,8-9,14,16,21-22,25], muscle power evaluated in 10 studies[1-2,5,15-17,19,21,23-24], and joint flexibility / range of motion evaluated in four studies[4,7,18,20].

Table 1.
Characteristics of included studies

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Alghadir *et al*. (2017)[9] Systematic review	To investigate the effects of local vibration on muscle strength in healthy adults. 11 studies with a total of 346 participants were included.	The frequency and amplitude of the vibration signals were 8 to 300 Hz and 0.4 to 6 mm; and timing ranged from 6s to 30 minutes	Muscle strength (Peak isometric muscle strength)	Most of the studies reported significant improvements in muscle strength after the application of local vibration. There was considerable variation in the vibration training parameters and target muscle location	Average score of included studies was reported as 5.36/10 *SIGN Grade = high quality (++)
Benedetti *et al*. (2017)[20] Randomized, controlled, single-blinded study	To (a) investigate the clinical effectiveness of high-frequency LMV on quadriceps muscle in 30 patients with knee OA between the ages of 40-65, and (b) to determine the underlying mechanism of this potential effect	Vibration was applied at 150 Hz over the rectus femoris, vastus medialis, and vastus lateralis muscle bellies of the quadriceps by means of a cup-shaped transducer with a contact surface of 5 cm for 20 min	Clinical outcome was measured using the Western Ontario and McMaster Universities Osteoarthritis Index, Visual Analogue Scale, knee range of motion, Timed Up and Go test, and Stair climbing test; Changes in muscle activation and fatigue was studied with the use of surface EMG during a sustained isometric contraction	The vibration group showed a significant change in Western Ontario and McMaster Universities Osteoarthritis Index score, Visual Analogue Scale score, Timed Up and Go test, Stair Climbing Test, and knee flexion; Surface EMG analysis suggested an increased involvement of type II muscle fibers in the group treated with vibration	9/10 Blinding of therapists administering therapy was not specified
Bosco, Cardinale, Tsarpela (1999)[15] Randomized controlled trial	To evaluate the influence of vibration on the mechanical properties of arm Flexor in a group of 12 international level boxers	5 repetitions lasting 1-min each at 30 Hz and 6 mm amplitude applied during arm flexion in isometric conditions with 1 min rest between repetitions	Mechanical Power and EMG analysis of arm flexors	Statistically significant enhancement of the average power and neuromuscular stimulation in the arm treated with vibrations	5/10 Concealment of subject allocation, similarity of groups at baseline, and blinding of subjects, therapists, and assessors was not reported
Cochrane D. (Feb 2016)[16] Randomized controlled trial	To examine the acute effect of direct vibration has on bicep curl force-generating capacity. 11 healthy team and individual sport-trained males	Vibration was applied to the biceps brachii muscles at a frequency ranging between 0–170 Hz and amplitude of 0–0.12mm on a pulsed setting for a total of 10 minutes	Peak force, mean force, rate of force development, and electromyography (EMG) were assessed during the concentric phase before and immediately after direct vibration	Following direct vibration peak force increased compared to the control arm, but this change was not significant; There were no other significant changes in mean force, rate of force development, or EMG between vibration and control arms	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Cochrane D. (June 2016)[17] Randomized controlled trial	To examine the acute effect of direct vibration on biceps brachii muscular power in 10 healthy male master field-hockey players	Vibration was applied to the biceps brachii muscles at a frequency ranging between 0–170 Hz and amplitude of 0–0.12mm on a pulsed setting for a total of 10 minutes	Mechanical peak power, mean concentric power and normalized electromyography (EMG) was assessed during the concentric phase of the biceps curl	Following vibration both peak power and mean concentric power increased compared to control; There was no significant difference in normalized EMG between vibration and control	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Couto *et al*. (2013)[25] Randomized, controlled, crossover study	To verify the acute effects of the application of local vibration on upper limbs during resistance training on the number of maximum repetitions, metabolic and hormonal responses in 32 male volunteers	vibration was locally applied at 20-Hz and 12-mm amplitude via a latissimus pull-down cable machine	Maximum number of repetitions; Blood lactate, testosterone, cortisol, creatinine kinase, creatinine, urea	No significant differences were observed in number of maximum repetitions between the control and vibration groups; Vibratory resistance training induced greater increases in testosterone and lactate concentrations; No significant changes were found in creatine kinase, creatinine or urea concentration. These data indicate that local vibration increases the metabolic and anabolic response to the resistance training, without changing the training volume	5/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported;

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Custer *et al*. (2017)[19] Single-blind crossover study	To examine the effects of a local-vibration intervention after a bout of exercise on balance, power, and self-reported pain in 19 healthy, moderately active subjects	Subjects received four 2-minute vibration interventions at 2-mm peak amplitude and frequency between 5 - 35 Hz	Static balance, dynamic balance, power via vertical jump test, self-reported pain	The local vibration intervention did not affect balance, power, or self-reported pain; There were no differences between outcome measures between the active and sham vibration conditions	7/10 Concealment of subject allocation, and blinding of subjects and therapists was not reported
Goebel, Kleinoder, Yue, Gosh, Mester. (2015)[4] Randomized controlled trial	Biomechanical advantage of combining localized vibrations to hamstring muscles involved in a traditional resistance training routine was examined in 36 healthy male and female subjects with at least 2 years' experience in resistance training	Local vibration was applied directly to hamstring muscles during exercise with a constant amplitude of 4 mm and a variable frequency between 18 - 38 Hz	Maximum isometric force of the hamstrings and maximum range of motion and muscle tension at maximum knee angle	The vibrational training group showed statistically significant improvements in maximum isometric force after the first week of training compared to 3 weeks for the traditional training regimen; The vibrational training group retained gain in performance for a longer time after the testing regimen than traditional training; The range of motion was improved, and muscle tension increase was less for the vibrational training group compared to the traditional training group	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Iodice, Bellomo, Gialluca, Fano, Saggini (2010)[3] Randomized controlled trial	To evaluate the acute and long-term effects of local high-intensity vibration on muscle performance and blood hormone concentrations in 18 healthy young men	Vibration was delivered for 30 min at 300 Hz, 2mm amplitude over 3 sessions a week for a total of 4 weeks; Vibration was applied over the base of the vastus intermedius, rectus femoris, vastus lateralis, vastus medialis, gluteus maximus, biceps femoris, gastrocnemius, and tibialis anterior	Counter-movement jumping (CMJ), maximal isometric voluntary contraction (MVC) test, and hormonal levels were measured before the procedure, immediately thereafter, and 1 h later	The HLV protocol significantly increased the serum level of growth hormone (GH, P \ 0.05) and creatine phosphokinase (CPK, P \ 0.05), and decreased the level of cortisol; There was a significant improvement in MVC; Overall, there were significant improvements in muscle performance after several weeks of vibration treatment, and some hormonal responses and minor performance improvements were detectable after a single session	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Issurin and Tenenbaum (1999)[5] Randomized controlled clinical trial	To establish the acute and residual effects of vibratory stimulation in explosive strength exercises in 14 elite and 14 amateur athletes during bilateral biceps curl exercises	Vibration amplitude was transmitted indirectly via cables to the upper limb with an amplitude of 3 mm and frequency of 44 Hz	The acute and chronic /residual maximal and mean power of bilateral biceps curl exercises was measured	Exercise mode with vibratory stimulation resulted in a significant immediate effect for mean power and for maximal power	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Kurt (2015)[18] Randomized controlled trial	To compare the effects of whole body vs. local vibration on lower body flexibility levels, and to assess whether vibration treatments were superior to static or dynamic stretching methods for lower body flexibility in 24 healthy well trained male combat athletes	Whole body or local vibration at a frequency of 30 Hz and a 4mm amplitude. Vibration was applied for 1 minute	Subjects performed the stand-and-reach test at the 15th second and the 2nd, 4th, 6th, 8th, and 15th minute following the intervention	Local vibration application showed statistically significant increased flexibility compared to other protocols. Subjects with high flexibility seem to benefit more from local vibration compared with other methods	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Luo *et al*. (2008)[24] Randomized cross-over study	To determine whether vibration applied directly to a muscle-tendon could enhance neuromuscular output during and 1.5 and 10 min after a bout of ballistic knee extensions in 14 young male volunteers	Vibration at an amplitude of 1.2 mm and frequency of 65 Hz was applied with a portable vibrator strapped over the distal tendon of the quadriceps (time of vibration application not provided)	Knee joint angular velocity, moment, power, and rectus femoris and vastus lateralis electromyography were measured during the knee extension	Vibration did not induce significant changes in peak angular velocity, time to peak angular velocity, peak moment, time to peak moment, peak power, time to peak power, or average EMG of the rectus femoris and vastus lateralis; It was concluded that direct vibration, at the selected amplitude and frequency, does not enhance these neuromuscular variables in ballistic knee extensions during or immediately after training	7/10 Concealment of subject allocation, and blinding of therapists and assessors was not reported
Luo *et al*. (2009)[23] Randomized cross-over study	To examine the influence of resistance load on the acute and acute residual effects of vibration training on the bicep tendon in 11 male subjects during a maximal- effort dynamic resistance exercise	Vibration was applied at an amplitude of 1.2 mm and frequency of 65 Hz over the biceps brachii tendon (time of vibration application not provided)	Concentric elbow joint angular velocity, moment, power, and bicep root mean square electromyogrphy (EMGrms) were measured during training and in the pre- and post-training tests	During training (acute effect) and at 5 minutes after training (acute residual effect), vibration did not induce a significant change in EMGrms, mean and peak angular velocities, moment, power, time to peak power, and initial power at 100 milliseconds after the start of the concentric phase for either resistance loads	7/10 Concealment of subject allocation, and blinding therapists and assessors was not reported
Mischi *et al*. (2009)[6] Cross-over study	To evaluate the effects of activation and coactivation of biceps and triceps muscles during isometric exercises performed with and without superimposing vibration stimulation in 12 healthy volunteers.	A sinusoidal vibration was modulated at 28 Hz. The amplitude of the input sinusoidal waveform was set to 1.2V. An electromagnetic actuator produces a mechanical torque which is modulated in time by a sinusoidal function and then a mechanical transmission is used to transmit the generated force to the muscle	Root Mean Square of the recorded surface EMG signal	In general, a larger EMG_{RMS} activity of the biceps and triceps brachii muscles was observed when vibration was applied	4/10 Similarity of subjects at baseline, random allocation of subjects along with concealment of allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Moran, McNamara, Luo (2007)[1] Randomized cross-over study	To examine the acute effects of direct vibration on neuromuscular performance in maximal-effort dynamic exercises in 14 young healthy adult males. To examine the acute residual effect of direct vibration training, both with and without a resistance exercise. Finally, to examine whether acute and acute residual effects of vibration training, if any, were placebo effects	Vibration was produced by a portable muscle-tendon vibrator that was strapped onto the skin over the biceps tendon. Vibration amplitude and frequency were set at 1.2mm and 65 Hz	Angular velocity, moment, power, and biceps root mean squared value of EMG and mean power frequency of EMG were determined for the concentric phase of muscle activation	Direct vibration of 65 Hz and an amplitude of 1.2mm applied to the biceps brachii muscle tendon does not enhance neuromuscular performance in maximal-effort contractions during or immediately after training	7/10 Concealment of subject allocation, and blinding of therapists and assessors was not reported; Additionally, it is unclear if outcome measures were obtained from at least 85% of subjects initially allocated.
Pamukoff, Ryan, Blackburn (2014)[2] Single group, cross-over study	Compared the acute effects of 30 Hz vs. 60 Hz LMV exposure applied to the right quadriceps muscle in 20 healthy volunteers on strength, rate of torque development, and EMG amplitude. Secondarily, to determine the duration of the observed effects following LMV exposure	A custom-built LMV device was secured over the quadriceps tendon. Subjects were placed in an isometric squat and LMV was applied as 6x1min treatment at a frequency of 30 Hz (amplitude of 1.2mm) or 60 Hz (amplitude of 0.4mm)	Isometric knee extensor peak torque (PT), rate of torque development (RTD), and electromyography (EMG) of the quadriceps	Results suggest that 30 Hz LMV treatment acutely enhances EMG activity in the quadriceps muscles for at least 5 minutes, and may increase PT in healthy individuals. LMV had no effect on RTD	6/10 Similarity of subjects at baseline, along with concealment of random allocation was not stated; Additionally, blinding of therapists and assessors was not reported

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Peer, Barkley, Knapp (2009)[7] Controlled clinical trial	To determine whether segmental biomechanical muscle stimulation (BMS) muscle therapy increases range of motion and reduces perceived stiffness in physically 10 active individuals with acute and subacute ankle sprains or hamstring strains	Three BMS placements were used for 2 minutes each at 20 Hz for the ankle. Four BMS placements were used for 2 minutes each at 20 Hz. Amplitude was not provided although the authors mentioned that the Swisswing device used in the study was capable of 1-6mm amplitudes independent of frequency and load	Ankle dorsiflexion/plantar flexion/inversion/eversion, hamstring flexibility, and subjective ratings of stiffness were measured	Significant increase in ankle dorsiflexion and eversion, and hamstring flexibility, and significantly decreased perceived ankle and hamstring stiffness following segmental BMS at 20 Hz	5/10 Random allocation of subjects along with concealment of subject allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Pietrangelo *et al*. (2009)[8] Controlled clinical trial	To determine whether a training program of passive muscle stimulation through local mechanical vibrations at high frequency applied to the lower limbs induced an increase in muscle mass and strength in 9 elderly subjects showing signs of sarcopenia	Local vibratory stimulation was applied on the skin of the distal part of the quadriceps. The duration of each application was 15 min and the frequency was 300 Hz (amplitude not provided)	Knee extensor isometric strength, thigh circumference, as well as needle biopsies of the vastus lateralis, cellular features and gene expression profiles were analyzed	Treated muscles displayed enhanced maximal isometric strength and increased content of fast MyHC-2X myosin. Single muscle fiber analysis did not show any change in cross-sectional area or specific tension. Changes in gene expression after 12 weeks of local vibration training in pathways related to energy metabolism, sarcomeric protein balance and oxidative stress response	4/10 Similarity of subjects at baseline, random allocation of subjects along with concealment of allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Souron R, Besson T, *et al*. (2017)[21] Randomized controlled trial	To evaluate the effects of a 4-week local vibration training (LVT) program on the function of the knee extensors and corticospinal properties in 17 healthy young and old subjects	Vibration device set to 100 Hz and 1 mm amplitude and was strapped directly on the right rectus femoris muscle; Subjects received 3, 1-hour sessions over 4 weeks for a total of 12 sessions	Jump performance, maximal voluntary force (MVC) and electromyographic (EMG) activity on vastus lateralis and rectus femoris muscles were assessed; Single pulse Transcranial Magnetic Stimulation (TMS) allowed evaluation of cortical voluntary activation (VATMS), motor evoked potential (MEP) area and silent period (SP) duration	LVT seems as effective in young as in old subjects to improve maximal functional capacities through neural modulations and may be used as an efficient alternative training method to improve muscular performance in both healthy young and old subjects	5/10 Random allocation of subjects along with concealment of subject allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Souron R, Farabet A, *et al*. (2017)[22] Controlled clinical trial	To evaluate the effects of an 8-week local vibration training (LVT) program on functional and corticospinal properties of dorsiflexor muscles in 44 male and female subjects	The vibration group performed 24, 1-hour sessions (3 sessions/week) at 100-Hz and 1mm amplitude applied to the right tibialis anterior	Maximal voluntary contraction (MVC) torque; Transcranial magnetic stimulation (TMS) was used to evaluate cortical voluntary activation (VATMS); Motor evoked potential (MEP); Cortical silent period (CSP) and input-output curve parameters	Despite no changes in excitability or inhibition, local vibration seems to be a promising method to improve strength through an increase of maximal voluntary activation, i.e. neural adaptations	5/10 Randomization and concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Tankisheva *et al*. (2015)[14] Randomized controlled trial	To investigate the effect of 6 months' local vibration training on bone mineral density (BMD), muscle strength, muscle mass, and physical performance in 35 postmenopausal women (66–88 years)	6-months of local vibration treatment with frequency between 30 - 45 Hz and acceleration between 1.71 - 3.58g; The vibration was applied for 30 minutes on the midthigh and around the hip in supine-lying position once per day, 5 days / week	The primary outcome variables were the isometric and dynamic quadriceps muscle strength and the BMD of the hip; Muscle mass of the quadriceps and physical performance was also assessed via the Modified Physical Performance Test and Shuttle Walk Test	A net benefit of 13.84% in isometric muscle strength at 60-degree knee angle in favor of the vibration group compared with controls; No changes in BMD, muscle mass, or physical performance were found in both groups; Overall, 6 months of local vibration training improved some aspects of muscle strength but had no effect on BMD, muscle mass, and physical performance in post-menopausal women	8/10 Blinding of subjects and therapists who delivered therapy was not reported

Quality Assessment

The included studies had PEDro scores ranging from 4/10 to 9/10 with an average score of 5.97/10. The most commonly adhered to PEDro criteria were random allocation (criteria 2), similarity of groups at baseline (criteria 4), outcome measure assessments (criteria 8-9), and between group statistical comparisons with both point measures and measure of variability (criteria 10-11). The most commonly missed PEDro criteria among the studies were concealment of random allocation (criteria 3), and appropriate blinding of subjects, therapists, and assessors (criteria 5-7).

Discussion

This literature review was conducted in order to assess the existing evidence on the effect of local vibration on a variety of performance parameters. Overall, 21 studies with a total of 831 participants were evaluated. There were a number of outcome measures utilized in the literature, with the most common being muscle activation / stimulation reported in 11 studies [1-2,6,15-17,20-24], muscle strength reported in 10 studies [2-4,8-9,14,16,21-22,25], muscle power reported in 10 studies [1-2,5,15-17,19,21,23-24], and joint flexibility / range of motion being reported in four studies[4,7,18,20].

The included studies had PEDro scores ranging from 5/10 to 9/10 with an average score of 5.97/10. Overall, 12 studies were deemed to be of high methodological quality, and nine of fair quality. The average PEDro rating of 5.97/10 across all of the included studies falls within the upper limit of the 'fair' quality category.[10] The most commonly met PEDro criteria were random allocation (criteria 2), similarity of groups at baseline (criteria 4), outcome measure assessments (criteria 8-9), and between group statistical comparisons with both point measures and measure of variability (criteria 10-11). Given that criteria 2 to 9 are intended to assess the internal validity of a given study[10], only four out of these possible eight criteria were commonly met. The most commonly missed PEDro criteria were concealment of random allocation (criteria 3), and appropriate blinding of subjects, therapists, and assessors (criteria 5-7) - the remaining four criteria used to assess for internal validity.[10] Based on this observation, the limited internal validity of the current body of evidence investigating the effects of local vibration therapy in various performance parameters should be considered when interpreting study results. On the other hand, criteria 10 and 11 of the PEDro scale are intended to determine if there is sufficient statistical information to make a study's results interpretable.[10] These criteria were among those more commonly met throughout the papers evaluated in this literature synthesis. Lastly, it is worth noting that although criteria 1 is not included in the calculation the PEDro score, it was also fulfilled by a large majority of the studies evaluated here. This criterion speaks to the external validity or "generalizability" of the trial.[10]

The methods of local application varied significantly among the included studies. Methods ranged from indirect vibration transmission through a cable in some studies [5-6,15,25], to the application of specific hand-held vibration devices directly over the targeted muscle[1-4,7-8,14,16-19,20-24]. Further, some trials applied local vibration in combination with exercise, while others applied the intervention while subjects were at rest. When grouped, 11 out of the 15 studies (73%)[2-4,7-8,14,16-22] who utilized a direct LMV application technique showed positive results among their respective outcome measures, compared to four out of five studies (80%) [5,6,15] reporting positive results when an indirect LMV technique was used. Clearly, the limited number of trials employing indirect LMV methods makes it difficult to draw a true comparison of the two techniques. Based on the studies included in this review, it appears that both direct and indirect LMV techniques tend to generate positive results. However, there is currently not enough evidence to say which form of vibration application is more effective for eliciting a change in the various performance parameters investigated.

Another significant discrepancy that was found throughout the literature was related to the type of sham / control group used. There is no known, validated sham procedure for local vibration therapy. Some authors simply provided no treatment whereas others applied vibration to a different body location. One must consider that the various methods used among researchers may have an impact on the observed results or lack thereof.

Aside from differing methods of vibration application, the specific vibration parameters were also quite heterogeneous across trials. The frequency of local vibration ranged from five to 300 Hz, and the amplitude from 0.12 to 12 mm.[16,19] Similarly, the duration of the intervention period also spanned time frames of six seconds up to 30 minutes.[9] These discrepancies are perhaps some of the greatest limitations in the existing literature on local vibration therapy and changes in muscular performance parameters. For example, Lou *et al*.[23,24] and Moran, McNamara and Luo[1] demonstrated that utilization of vibration at 65 Hz and 1.2 mm was not effective. On the other hand, studies utilizing a higher frequency of 100 [21,22], 150 [16-17,20] and 300[3,8] Hz showed a positive result. However, those studies that applied LMV at a higher frequency also seemed to use a longer duration of LMV application, with lengths of 15[8], 30[3] and 60[21-22] minutes per session being reported. This is in contrast to the studies applying LMV at lower frequencies ranging from five to 50 Hz and shorter durations of one to two minutes[1-2,4-7,14,18-19,23-25], but who also typically reported positive results[2,4-7,14,18]. These observations may provide some understanding of the relationship between the frequency and duration of LMV application required to elicit beneficial results, as higher frequencies paired with longer treatment durations, and lower frequencies paired with shorter treatment durations both typically yielded positive clinical outcomes. Interestingly, one study by Tankisheva *et al*.[14] applied LMV at a lower frequency of 30 to 45 Hz, but for a longer duration of up to 30 minutes per session. They reported that this LMV protocol improved isometric quadriceps muscle strength when compared to the control group.[14] This challenges the previous observation and may suggest that the application of lower frequency LMV may be effective regardless of whether short or long treatment durations are used. Further research must be done to clarify this discrepancy and should seek to investigate the clinical efficacy of high frequency – short duration LMV treatments in order to better define any relationship that may exist between these two variables.

The inconsistencies among LMV protocols also breeds difficulty when trying to investigate the potential mechanisms through which LMV generates its muscular response. For instance, it has been proposed that "mechanical vibration (10± 200 Hz) applied to muscle belly or tendon" has been shown to elicit a tonic vibration reflex (TVR) contraction of the muscle.[2,15] As mentioned previously, this mechanism is thought to be stimulated by a sequence of rapid muscle stretching that occurs when applying vibration, consequently triggering muscle spindles and causing an involuntary production of strength.[2] However, some of the authors investigating this proposed mechanism also explain that "it is not known whether it [the TVR] can be elicited by low vibration treatment (30 Hz)".[15] Such observations have caused some to hypothesize that a muscle's electrical and mechanical responses could vary depending on the frequency of vibration and the differing damping characteristics of the soft tissues across subjects.[2]

Despite the inconsistencies among the aforementioned parameters of vibration application, statistically significant results were yielded by the majority of the studies across the performance outcome measures.[2-6,7-8,14,15-22] It is hypothesized that musculoskeletal structures respond to vibration because of the requirement of the tissue to adapt to or modulate muscle tonicity so as to accommodate the waves of vibration.[26] This adaptation to the frequency is regulated by afferent pathways which generate hormonal responses.[26] As a result of altering the hormonal response, it is theorized that neuromuscular performance could be improved in the subject.[26] Additionally, physiological analysis of vibration therapy has found that it is possible to stimulate more muscle receptors both in number and type.[27] The stimulation of these additional receptors could, at least in the short term, result in increased motor fiber recruitment.[27] When more receptors are primed via vibratory therapy, more muscle fibers are thought to be available for recruitment.[27] This can ultimately result in a higher peak contraction force and an overall increase in muscular performance.

Limitations

There are number of limitations to this review that should be considered. First, two independent reviewers gave analyses of the articles and came to a consensus over discrepancies in PEDro scores when they arose. However, reviewer agreement statistics are not provided. Second, the study authors and publication details were not withheld from the reviewers, which could introduce a factor of reviewer bias. Third, it is also possible that despite efforts to obtain all relevant articles on the subject up to February 2018, some studies may have escaped the search strategy. Lastly, because of time and logistic considerations, no attempts were made to contact the original authors of each study to gather more detailed data not included in the official report. Each study was judged based on the information contained in the published articles alone.

Conclusion

This literature review was conducted in order to determine what is known about the effects of local vibration therapy on various performance parameters. The average PEDro rating across all of the included studies (5.97/10) falls within the 'fair' category in terms of internal validity. The majority of the studies found that local vibration does seem to induce beneficial changes in outcome measures such as muscle activation / stimulation, muscle strength, muscle power, and joint flexibility / range of motion. With that said, the available literature is quite heterogeneous in terms of how local vibration therapy is applied (direct vs indirect), the type of control / sham procedure applied, and the frequency, amplitude, and duration settings used during vibration protocols. Future research should seek to better define the relationship between specific vibration parameters (frequency, amplitude, duration) and particular performance measures. Additionally, developing a more standardized procedure in terms of how vibration therapy is applied would allow the academic community to more confidently compare experimental results and draw more valuable conclusions.

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Appendix 1.
PEDro Scale Utilized for Study Evaluation

PEDro scale

1. eligibility criteria were specified no ❑ yes ❑ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) no ❑ yes ❑ where:
3. allocation was concealed no ❑ yes ❑ where:
4. the groups were similar at baseline regarding the most important prognostic indicators no ❑ yes ❑ where:
5. there was blinding of all subjects no ❑ yes ❑ where:
6. there was blinding of all therapists who administered the therapy no ❑ yes ❑ where:
7. there was blinding of all assessors who measured at least one key outcome no ❑ yes ❑ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups no ❑ yes ❑ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat" no ❑ yes ❑ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome no ❑ yes ❑ where:
11. the study provides both point measures and measures of variability for at least one key outcome no ❑ yes ❑ where:

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Last amended June 21st, 1999

https://www.pedro.org.au/english/downloads/pedro-scale/

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Conservative management of femoral anterior glide syndrome: a case series

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Background: *Femoral anterior glide syndrome is a movement impairment syndrome, which presents with anterior hip pain aggravated by hip flexion and extension. It is believed to occur because of altered muscle activation patterns contributing to altered gliding of the femoral head within the acetabulum and constant overloading and irritation of the joint structures.*

Study Design: *Case series*

Case Description: *Three elite athletes diagnosed with femoral anterior glide syndrome were treated conservatively with the main goal of improving posterior femoral glide. Rehabilitative exercises were completed to gain independent articular control of the hip and improve hip and low back dissociation.*

Outcomes: *Patients received complete symptom resolution allowing them to continue participating in their sport at full capacity. They were able to perform the*

Contexte : *Le syndrome du glissement antérieur de la tête fémorale est un conflit fémoro-acétabulaire se manifestant par une douleur antérieure de la hanche aggravée par la flexion et l'extension de la hanche. Ce conflit serait causé par des altérations de l'activation musculaire qui contribuent au glissement de la tête fémorale dans l'acétabulum et à une surcharge et une irritation des structures articulaires.*

Méthodologie de l'étude : *Série de cas*

Description des cas : *Trois athlètes d'élite présentant le syndrome du glissement antérieur de la tête fémorale ont suivi un traitement conservateur visant principalement à améliorer le glissement postérieur de la tête fémorale. Des exercices de rééducation ont été effectués pour améliorer le contrôle moteur au niveau de l'articulation de la hanche et améliorer le recrutement des fibres musculaires de la hanche par rapport à celles de la colonne lombaire.*

Résultats : *La disparition complète des symptômes a permis aux patients de recommencer à pratiquer leurs sports à pleine capacité suite à ces interventions. De plus , les tests du glissement antérieur de la tête*

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This study has been approved by the Institutional Review Board of the Canadian Memorial Chiropractic College.
The authors certify that they have no affiliations with or financial involvement in any organizations or entity with a direct financial interest in the subject matter or materials discussed in the article.
All athletes were informed that data concerning their case would be submitted for publication and have provided consent for the use of their medical information, which has been removed of personal data and any other identifiable information except age and profession.

femoral anterior glide tests without pain and aberrant movement patterns.

Discussion: *This case series provides data to support further investigation of treatment of femoral anterior glide syndrome.*

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KEY WORDS: chiropractic, femoral anterior glide syndrome, hip pain, athlete

fémorale ne déclenchaient aucune douleur et ne causaient aucun mouvement aberrant.

Discussion : *Cette série de cas fournit des données montrant qu'il faut mener d'autres études sur le traitement du syndrome du glissement antérieur de la tête fémorale.*

(JCCA. 2018;62(3):182-192)

MOTS CLÉS : chiropratique, syndrome du glissement antérieur de la tête fémoral, douleur à la hanche, athlète

Background

Groin pain has been reported in the scientific literature as an important athletic injury as early as 1980 by Renström and Peterson.[1] It is a common complaint in athletes from a variety of sports[2–5] despite the fact than an accurate clinical diagnosis of hip and groin pain remains a significant challenge in sports medicine[6]. Potential differential diagnoses for adults presenting with anterior hip pain include hip osteoarthritis, femoroacetabular impingement syndrome, acetabular labral tear, internal snapping hip, stress fracture of the femoral neck, pubic rami or acetabulum, osteonecrosis of the femoral head, hip joint laxity, inguinal disruption and/or a femoral, obturator or ilioinguinal neuropathy.[7] Athletic groin pain is commonly treated with surgical interventions in the athletic population.[8] However, alternative evaluation and treatment methods must also be considered. Sahrmann has proposed the evaluation of movement impairment syndromes such as femoral anterior glide syndrome.[9] Femoral anterior glide syndrome is reported to occur as a result of inadequate posterior glide (or excessive anterior glide) of the femoral head within the acetabulum.[9] As stated by Sahrmann, patients with femoral anterior glide syndrome will experience groin pain with hip flexion or standing and may experience generalized hip pain as the condition progresses.[9] It often occurs in younger athletes, especially those involved in sports that accentuate hip extension, such as gymnastics and running. Patients with femoral anterior glide syndrome will often present with characteristic movement patterns. During a supine active straight leg raise the greater trochanter is observed to move in an anterior or antero-medial direction and the patient will often complain of groin pain (Figure 1). This is proposed to occur as a result of inadequate posterior glide of the fem-

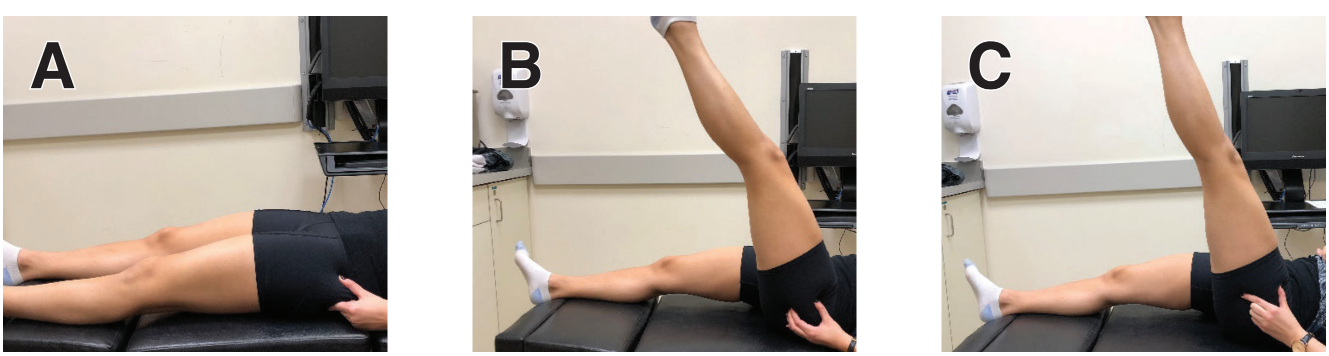

Figure 1.
Supine Active Straight Leg Raise. (A) Resting position and (B) elevated position of a supine active straight leg raise demonstrating minimal movement of the greater trochanter. (C) demonstrates an anteromedial movement of the greater trochanter with movement completion as seen in individuals with femoral anterior glide syndrome.

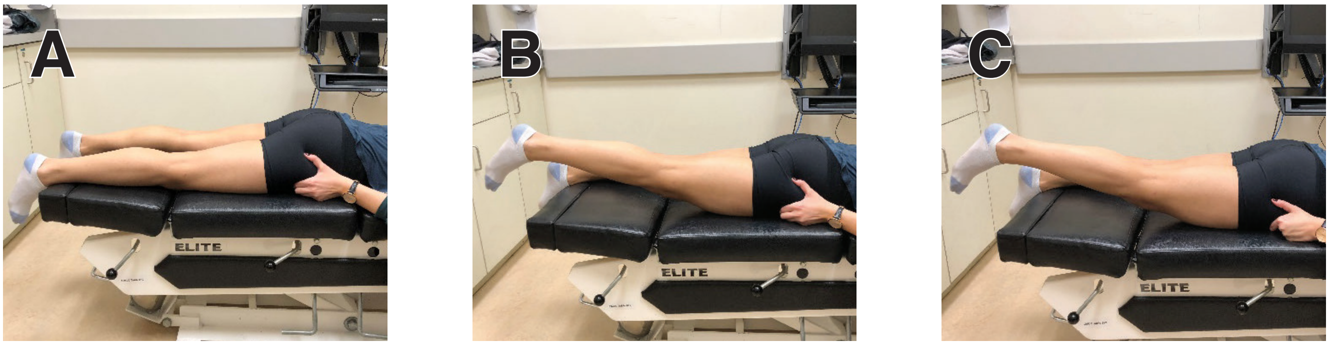

Figure 2.
Prone Hip Extension. (A) Resting position and (B) elevated position of prone hip extension demonstrating minimal movement of the greater trochanter. (C) demonstrates an anteromedial movement of the greater trochanter with movement completion as seen in individuals with femoral anterior glide syndrome.

oral head within the acetabulum. During an active prone hip extension, the greater trochanter is again observed to move in an anterior or antero-medial direction as opposed to staying in relatively the same position (Figure 2). The proposed mechanism behind this movement impairment syndrome is a motor control deficit which manifests as anterior hip pain from tissue overload of the anterior supporting structures. Although femoral anterior glide has not been directly measured in live human subjects during active hip flexion and extension, there is evidence to suggest this movement pattern may be a potential source of hip pain.[9–11]

The hip is a stable ball-and-socket joint having highly congruent joint surfaces: the convex femoral head and the concave articular surface of the acetabulum.[12] Although the articular surfaces of the hip are highly congruent, hip instability has been demonstrated in the athletic population.[13] The femoral head has considerably more articular surface area compared to the acetabulum. In the neutral, anatomical position, the anterior portion of the femoral head is not engaged in the acetabulum.[14] This allows for greater hip mobility but also increases the reliance on anterior soft tissues for stability during hip extension.[15] In addition to the labrum and anterior capsular ligaments, the iliopsoas is suspected to play a role in maintaining the anterior stability of the hip.[9,11–13,15,16] Amongst the purported mechanisms of pain with femoral anterior glide syndrome are irritation of the aforementioned anterior supporting structures, namely the psoas and anterior hip capsule.

According to osteokinematic and arthrokinematic movement principles, the hip must glide anteriorly and posteriorly to have complete hip extension and flexion, respectively (Table 1).[17] In a cadaveric study, Harding *et al*. demonstrated that anterior gliding of the femoral head within the acetabulum does exist when a posterior-to-anterior mobilization of the hip is applied.[12] The amount of glide was highly variable between subjects, ranging

Table 1.
Description of roll and glide of femoral head within the acetabulum during hip flexion and extension.

Hip Joint Movement	Roll of Femoral Head in the Acetabulum	Glide of Femoral Head in the Acetabulum
Hip Flexion	Anterior Roll	Posterior Glide
Hip Extension	Posterior Roll	Anterior Glide

between 0.25-2.90 mm. In 2013, Loubert *et al*. demonstrated the existence of posterior glide when a posterior mobilization force was applied to the thigh.[18] The average posterior glide amplitude in 20 healthy college students was 2.0 mm when measured by ultrasound. These findings demonstrate that although the hip is a highly congruent joint, both posterior and anterior glide of the femoral head occur within the acetabulum when a mobilization force is applied to that joint.[12,18]

Using a musculoskeletal model, increased anterior hip joint forces were demonstrated with decreased activity of the gluteus maximus during prone hip extension and with decreased iliopsoas activity during supine active hip flexion.[11,16] These studies suggest that altered muscle activation patterns can result in aberrant sagittal plane joint forces of the hip. Specifically, a motor pattern that relies more on the hamstrings and less on the gluteus maximus may be responsible. The bony attachments of the gluteus maximus are close to the axis of rotation of the hip, while the hamstrings are able to create hip extension despite originating from the ischium and inserting onto the tibia and fibula, thereby bypassing the femur entirely. It is thought that this long lever creates anterior gliding of the femoral head while it extends the hip.

Lewis and Sahrmann demonstrated that women perform consistent muscle activation patterns during prone hip extension, that begins with the medial hamstrings and is followed by the lateral hamstrings and gluteus maximus.[19] However, with verbal and tactile cueing to contract the gluteal muscles during prone hip extension, the women demonstrated nearly simultaneous contraction of the hamstrings and gluteus maximus, stronger activation of the gluteus maximus and a reduction in total knee flexion. These studies provide evidence to support the mechanism of femoral anterior glide syndrome. However, there is limited scientific evidence to support the treatment of patients with this condition.

The purpose of this case series is to demonstrate the effectiveness of conservative management of femoral anterior glide syndrome in three elite athletes. The symptom of anterior hip pain is believed to result from inadequate posterior glide of the femoral head within the acetabulum during hip flexion as well as improper muscle activation patterns during hip flexion and extension that result in increased anterior hip joint forces. Therefore, it is logical to expect decreased anterior hip pain with passive care focused on increasing posterior glide of the femoral head and rehabilitative exercises focused on correcting independent articular control of the hip and aberrant muscle recruitment patterns.

Case Description

Two professional football players in the Canadian Football League, ages 27 (Athlete A) and 31 (Athlete B), and a nationally ranked female boxer, age 24 (Athlete C), are included in this case series. All athletes were informed that data concerning their case would be submitted for publication and have provided consent for the use of their medical information, which has been removed of personal data and any other identifiable information except age and profession. All the athletes had anterior hip pain and had no specific mechanism of injury to cause their pain.

Athlete A noted pain in his anterior left hip following an on-field mid-season football practice. He denied experiencing a specific instant or mechanism of pain, but rather he noticed a vague discomfort in the region of the anterior left groin upon standing following a brief period of sitting in the locker room. This was his first instance of hip pain, and no associated signs or symptoms were noted. The pain was characterized as an ache and rated as 3/10 on a Numeric Pain Rating Scale (NPRS) and he scored a 71/80 on the Lower Extremity Functional Scale (LEFS). His pain was exacerbated by running, stretching the hip in extension, lunges and rear foot elevated lunges (both with the affected leg in the posterior position). No palliative factors were noted, including stretching, rolling, soft tissue therapy and hydrotherapy. Relevant past medical history included a self-reported grade II right ankle inversion sprain in his final year of high school, and a right medial meniscal tear, which resulted in an off-season partial meniscectomy, during his first year of college. Athlete A reported that he had not had any issues with either injury since. Coughing, sneezing and straining, including weight training, failed to reproduce his symptoms, as did movement through the lumbar spine. Past medical history, family history, and systems review were otherwise within normal limits and non-contributory to his current chief complaint.

Athlete B reported having experienced right anterior hip pain at the midway point of the past two seasons. There was no specific mechanism of injury during either season, and he reported that he "just began to notice it (groin pain) was there." Athlete B denied reproduction of his symptoms with Dejerine's triad. No abdominal pain, or gastrointestinal symptoms were noted with a sit-up. The pain was described as an "aching pull" across the front of the right hip, without radiation, primarily with sprinting, but he also felt it when the hip was fully flexed as in the bottom portion of a squat. Stretching, acupuncture, hot tub, sauna, heat packs and soft tissue were not helpful in preventing or alleviating his symptoms. He reported four to five previous ankle sprains between the left and right ankles, being unable to recall the exact distribution between the ankles. Athlete B rated his pain as 7/10 on the NPRS and scored 52/80 on the LEFS. Past medical history, family history, and systems review were otherwise within normal limits and non-contributory to his chief complaint.

Athlete C described her pain as a "stretching ache" that was localized over the right anterior hip in the region of the femoral head and anterior joint space. She denied having discomfort while boxing other than throwing right-handed uppercuts near the end of a sparring session. Once triggered, the pain was present until the end of her training whenever she would "flex the glute" or throw a right-handed uppercut. She noted that sprint training and distance running were also provocative, and once the pain began it persisted until the end of the workout. She scored a 66/80 on the LEFS and rated her intensity as "an average 4/10" on the NPRS. Other than avoiding the aforementioned activities, there were no palliative factors noted. Stretching prior to activity was not effective and stretching afterwards increased intensity and prolonged the duration of her symptoms. Past medical history, family history, and systems review were otherwise within normal limits and non-contributory to her chief complaint.

In summary, the duration of their pain was varying from three months to two years of intermittent pain. They described the pain as a pinching sensation during hip flexion and an aching, stretching sensation during hip extension. During hip flexion pain intensity was rated between 3-7/10 on the NPRS. Pain intensity during hip extension was rated between 3-4/10. None of the athletes reported snapping of their hip with movement. None of the athletes had previous hip pathology or trauma.

During the physical examination, all participants were observed to be in a relative posterior pelvic tilt with hyperextension of the hips and knees. They also had a decreased thoracic kyphosis and cervical lordosis. The anterior hip capsule was painful on palpation and tenderness was noted along the femoral nerve through the femoral triangle and proximal portion of the adductor canal of the affected hip. Tight and tender myofascial structures were noted, including the gluteus medius and minimus, tensor fascia lata, lumbar spine erectors and transversospinalis, adductor magnus, longus and brevis, pectineus, obturator externus, gracilis and the sacrotuberous ligament. All passive, active and resisted hip ranges of motion were 5/5 and pain-free, except for resisted hip flexion on the affected side, which was graded as 4/5 when tested in a seated position. A curvature of the lumbar spine towards the ipsilateral leg was noted for all athletes during seated resisted hip flexion of the affected side. This implies an inability to adequately stabilize the lumbar spine as per Dynamic Neuromuscular Stabilization (DNS) principles, which aim to establish a quality spinal stabilization for any dynamic movement of the extremities.[20,21] However, this curvature disappeared with core muscle irradiation, which was accomplished by having the athletes squeeze their palms together as forcefully as possible during hip flexion. Similarly, all three athletes demonstrated a tendency for apical breathing patterns and difficulty generating intra-abdominal pressure during the supine DNS breathing screen.[21] Hip adduction was not painful at 0° or 90° of hip flexion, nor was internal rotation at either position.

The femoral anterior glide tests proposed by Sahrmann, were completed on these athletes.[9] During an active straight leg raise they were noted to have anterior hip joint pain that increased as the angle of hip flexion increased. The greater trochanter was observed to move in an antero-medial direction during the active straight leg raise. Because of the positive findings from this test a passive straight leg raise was performed with simultaneous postero-inferior pressure application at the inguinal crease to maintain the axis of rotation of the hip. This decreased the severity of hip pain in all athletes. However, tightness of the hamstrings prevented the affected legs of all 3 athletes from achieving 90° of hip flexion. During prone hip extension, the athletes again experienced anterior hip pain but to a lesser intensity than hip flexion. A hamstring dominant prone hip extension pattern was displayed, and the greater trochanter was observed to move anteriorly during hip extension. In the quadruped

Figure 3.
Quadruped Rocking. (A) Starting and (B) finishing position of quadruped rocking demonstrating maintenance of the natural spinal curvature. (C) demonstrates the quadruped rocking position with loss of the lumbar lordosis as seen in individuals with femoral anterior glide syndrome.

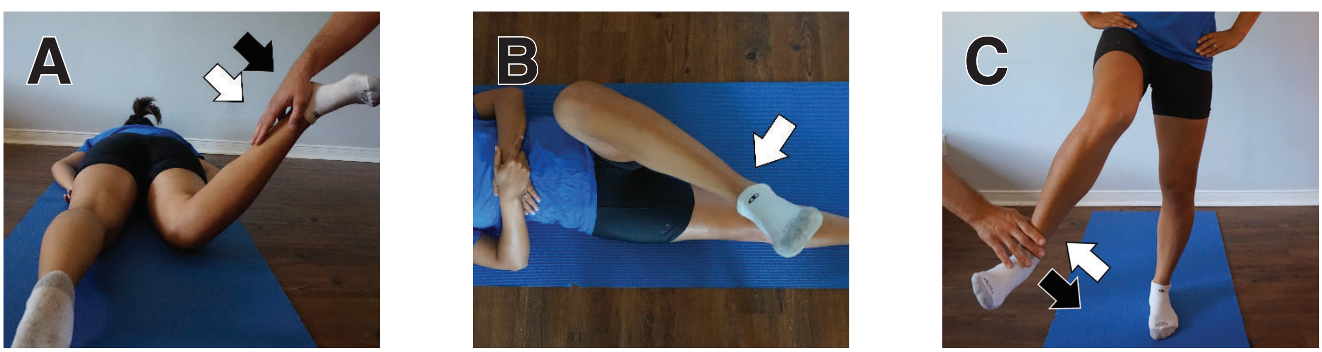

Figure 4.
*Hip Rotation Exercise Progression***.** *(A) Prone active-assisted hip internal rotation, (B) Supine active hip external rotation and (C) Standing resisted hip internal rotation. Black arrow indicates practitioner's applied force. White arrow indicates patient's force.*

Figure 5.
*Prone Hip Extension – Blocking Femoral Anterior Glide***.** *(A) Resting position and (B) elevated position of prone hip extension rehabilitation exercise with a pelvic block preventing the femoral head from moving anteriorly.*

Table 2.
Exercise Progression Principles

1. Improve independent articular control of the hip relative to the pelvis
   a. Prone internal and external hip rotation (0° of hip flexion)
      i. Active-assisted
      ii. Active
      iii. Resisted
   b. Supine internal and external hip rotation (90° of hip flexion)
      i. Active-assisted
      ii. Active
      iii. Resisted
   c. Standing internal and external hip rotation (90° of hip flexion)
      i. Active-assisted
      ii. Active
      iii. Resisted
2. Develop a gluteal-dominant hip extension pattern
   a. Prone hip extension
      i. Knee bent (90°) and pelvic block used
      ii. Knee straight and pelvic block used
      iii. Knee bent (90°)
      iv. Knee straight
3. Increase posterior glide of the femoral head within the acetabulum
   a. Quadruped rocking while maintaining a lumbar lordosis
4. Develop intra-abdominal pressure to maintain spinal control while moving the hip and shoulder
   a. 3-month supine developmental position
      i. Legs supported
      ii. Legs unsupported
      iii. Cross-crawling
      iv. Resisted cross-crawling
5. Integration of new movement pattern into strength and conditioning program
   a. Deadlift
      i. Hip hinging
      ii. Kettlebell deadlifts
      iii. Offset weight deadlifts (different weight in each hand)
   b. Squat
      i. Pull-down into a squat (i.e. holding weighted latissimus dorsi pull-down bar above head)
      ii. Overhead squat facing a wall
      iii. Reactive neuromuscular training using a band around the knees during a squat
      iv. Toe touch to overhead squat progression

position, the athletes were asked to rock their buttocks back toward their heels (Figure 3). All of them experienced anterior hip pain described as a pinching sensation and demonstrated compensatory pelvic rotation that was observed as the affected hip being higher.

All three athletes had plain film imaging, which failed to demonstrate any evidence of pathology. Both athlete A and B received diagnostic ultrasounds of their affected hips and no pathology was noted. Additionally, athlete A underwent magnetic resonance imaging without contrast which was read as negative for labral, bursal or tendon pathology.

Passive care for each athlete had the primary goal of decreasing pain and improving posterior glide of the femoral head within the acetabulum. They received soft tissue therapy of the posterior hip capsule, gluteus medius, gluteus minimus, tensor fascia lata, obturator externus, adductor magnus and rectus femoris as well as post-isometric relaxation stretching of the hamstrings on the affected side. They also received hip joint mobilizations, in which the patient was lying supine and a long-axis distraction was applied while bringing the hip up to 90° of flexion (practitioner's force is directed toward the ceiling) as well as a continuous passive motion mobilization in which the patient's leg was brought from neutral to 90° of flexion while oscillating between long-axis distraction and compression every two seconds. Frequency specific microcurrent used at the extremity setting (extremity joint 1-4 weeks) was applied to the anterior aspect of the affected hips.

Active care consisted of a variety of rehabilitative exercises with the primary focus of dissociating hip and low back movement and gaining independent articular control of the hip (Table 2). Specific exercises were completed to address each of the positive femoral anterior glide tests. Independent control of the hip relative to the pelvis was accomplished by slowly internally and externally rotating the hip without allowing motion of the pelvis, which began as active assisted and progressed to active and then resisted, in the prone position. Once competency was achieved this was repeated in the supine position with the hip flexed to 90° and finally with the patient standing (Figure 4). To develop a gluteal-dominant hip extension pattern the athletes completed prone hip extension with the knee flexed and extended. However, a pelvic block was placed under the proximal femur to prevent anterior

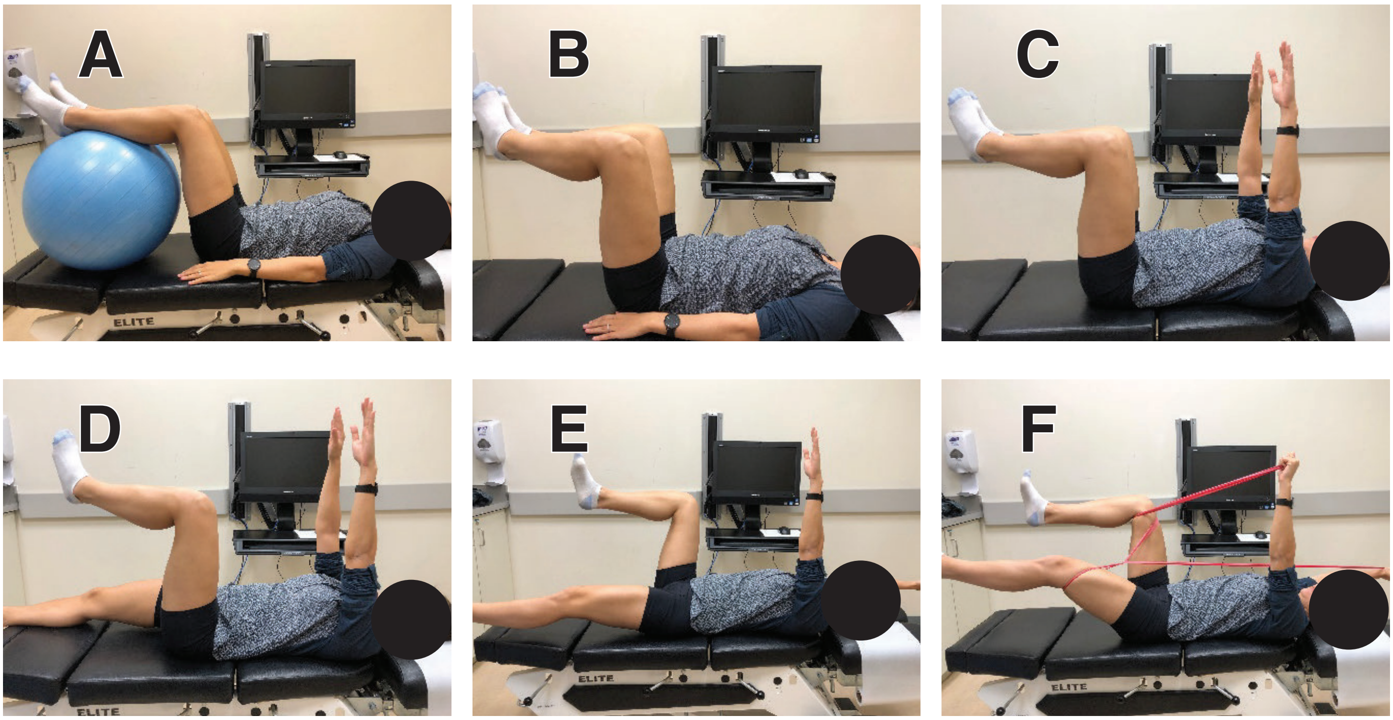

Figure 6.
Exercise Progression of 3-Month Supine Position. (A) legs supported, (B) legs raised, (C) arms and leg raised, (D) lowering one leg, (E) lowering opposite arm and leg and (F) resistance band lowering opposite arm and leg progressive rehabilitation exercises focusing on abdominal breathing and gaining independent articular control of the hip.

glide of the femoral head (Figure 5). Patients performed quadruped rocking while maintaining a lumbar lordosis and completed supine straight leg raises after passive therapy, which was aimed to increase posterior glide of the femoral head within the acetabulum. All athletes underwent training to be able to generate a proper corset with intra-abdominal pressure, which began in the three-month supine developmental position with their legs supported, transitioning to legs unsupported, then cross-crawl and finally resisted cross-crawl using tubing (Figure 6).

Deadlifts and squats were primary exercises in each of their training programs. Once, they demonstrated competency in femoral anterior glide tests (prone hip extension, supine active straight leg raise and quadruped rocking) they were coached on squat and deadlift mechanics. Deadlift progressions consisted of hip hinging, kettlebell deadlifts and offset weight deadlifts. Squat progressions included a pull-down into a squat, squatting facing a wall, reactive neuromuscular training using a band around the knees during a squat and finally reverse positioning of an overhead squat from a toe touch. Athlete A was treated twice per week for four weeks. Athletes B and C were treated twice per week for six weeks. All three athletes were given exercises at each treatment based on their level of competency with each movement progression, which were to be performed daily until the next appointment.

Outcomes

After the combination of passive care focused on addressing the inadequate posterior glide of the femoral head, and rehabilitative exercises designed to improve independent articular control of the hip, all the athletes were able to return to their sport without any hip pain for the remainder of the season. All athletes recorded 0/10 pain intensity on the NPRS and 80/80 on the LEFS. When retested with the femoral anterior glide tests they demonstrated adequate movement proficiency. During the supine active straight leg raise and prone hip extension the greater trochanter was observed to maintain a relatively constant position and they experienced no pain. During quadruped rocking, they could maintain a lumbar lordosis while rocking their buttocks toward their heels. Long-term follow-up has been completed with each athlete. Athletes A, B and C have been symptom-free for four years, three years and six months, respectively, and have been able to continue full participation in their athletic endeavours.

Discussion

This case series presents preliminary findings to support the conservative treatment of femoral anterior glide syndrome. All three participants had a complete resolution of hip pain symptoms and were able to continue with a full practice and training load and compete in their sport.

The scientific rationale for treatment of femoral anterior glide syndrome begins with research that demonstrates that there are accessory movements of the hip. In order for a joint to move there is a combination of angular displacement of the bones and their articular surfaces as well as a translational glide of one articular surface over the other in a linear or curvilinear direction.[18] This translational glide is often referred to as an accessory joint movement. Because of the high joint congruency of the articular surface of the femoral head and the acetabulum as well as the strong ligaments that surround the hip joint, it has been debated whether accessory movements of the hip exist. In 2003, Harding *et al*. demonstrated that there is anterior glide of the femoral head within the acetabulum when a postero-anterior hip joint mobilization is applied, and the magnitude of this glide is highly variable between subjects, when tested in a cadaveric model.[12] Loubert *et al*. added to this research by analyzing posterior glide of the femoral head within the acetabulum in live human subjects without any hip or low back musculoskeletal conditions.[18] They reported an average posterior glide of 2.0 mm. when a posterior force with a magnitude of 50% of the subject's bodyweight was applied posteriorly to the femur.

Considering that there is evidence of both anterior and posterior glide of the femoral head within the acetabulum, the next logical progression would be to analyze if improper muscle activation patterns (i.e. hamstring dominant prone hip extension) would result in aberrant sagittal plane joint forces (i.e. increased anterior joint forces of the hip). Lewis *et al*. used a pelvis and lower limb biomechanical model which could determine sagittal plane hip joint forces. These studies demonstrate that as the hip extension angle increases there are increased anterior joint forces on the hip.[11,16] Additionally, during a prone hip extension from 10° of flexion to 20° of extension, with decreased force contribution from the gluteal muscles there are increased anterior hip joint forces.[11] With a decrease of hamstring force contribution there was a decrease in anterior hip joint forces.[16] They also used the biomechanical model to estimate sagittal plane forces on the hip during supine hip flexion. With hip flexion, decreased force contribution from the iliopsoas resulted in increased anterior hip joint forces. As the model decreased the force contribution of the iliopsoas it increased the force contribution of the gluteus minimus, pectineus, rectus femoris, tensor fascia lata, sartorius and adductor longus.[16] The outcomes from this biomechanical model are consistent with the clinical observations proposed by Sahrmann.[9]

This evidence that altered muscle activation patterns can result in aberrant sagittal plane joint forces of the hip supports the mechanism of femoral anterior glide syndrome. However, for treatment to be effective those movement patterns would have to be modifiable. Lewis and Sahrmann, assessed the typical movement pattern of healthy women in prone hip extension and found that the subjects demonstrated a consistent muscle activation pattern of medial hamstrings followed by the lateral hamstrings and gluteus maximus.[19] They also demonstrated that with verbal and tactile cueing they were able to alter the timing of muscle activation and muscle force contribution, which resulted in a change in joint kinematics. This collection of research provides scientific evidence supporting the mechanism of femoral anterior glide syndrome and provides a rationale for conservative treatment.

This case series supports the successful outcomes of previous research in which a professional ballet dancer was treated for femoral anterior glide syndrome with conservative management. Khoo-Summers and Bloom reported on a 29-year-old professional ballet dancer with a suspected labral tear and femoral anterior glide syndrome based on the diagnostic criteria proposed by Sahrmann.[9,10] This patient had anterior hip pain and positive findings during the prone hip extension, supine straight leg raise and quadruped rocking tests. However, she also had positive orthopedic tests indicating the presence of a labral tear. Treatment focused on decreasing anterior hip joint stresses and improving the precision of hip motion through correction of alignment and movement impairments noted during functional activities and dance. After six treatments over a two-month period she had no pain with activities of daily living and the majority and dance movements. At a five-month follow-up she had complete resolution of her hip pain and had returned to her role as the principal dancer in a ballet company. These case reports highlight the importance of assessing and treating movement impairment syndromes, both in the absence and presence of pathology, such as an acetabular labral tear.

Future research should aim to objectively measure timing of muscle activation and force contribution in healthy subjects and those suspected to have femoral anterior glide syndrome. For movement impairment syndromes to gain traction in the scientific literature, future research will also need to identify objective measures and provide specific diagnostic criteria which can be used to identify healthy subjects and those with a movement impairment, such as femoral anterior glide syndrome.

Conclusion

The results of this case series suggest that conservative management of femoral anterior glide syndrome in elite athletes can result in resolution of anterior hip pain symptoms and may provide a basis for conducting a larger scale study.

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Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report.

Matt Wentzell, BKin, DC[1]

Objective: *To describe the successful rehabilitation of a distal biceps brachii tendon reattachment following an acute traumatic tendon rupture.*

Clinical Features: *A 30-year-old weightlifter presented five days post-op after a left distal biceps tendon repair. A three month one pound weight-restriction was recommended by the attending surgeon. Active and passive elbow and wrist range of motion were markedly reduced with profuse post-operative swelling and bruising noted upon initial inspection.*

Intervention and Outcome: *An accelerated treatment program was prescribed that included soft tissue therapy, scar mobilization, laser therapy, kinesiology tape and rehabilitative exercise. A novel training method known as blood flow restriction (BFR) training was utilized throughout the rehabilitative process to maximize recovery and retain muscle mass and strength. The weightlifter returned to near pre-injury activity level*

Objectif : *Décrire le succès de la rééducation du tendon distal du biceps brachial après une rupture traumatique aiguë.*

Caractéristiques cliniques : *Un haltérophile de 30 ans s'est présenté cinq jours après avoir subi une chirurgie de réparation du tendon distal du biceps brachial gauche. Le chirurgien ayant pratiqué l'intervention avait recommandé de limiter la levée de poids à l'épaule à une livre pendant trois mois. Au premier examen, on a noté une réduction considérable de l'amplitude de mouvement à la mobilisation active et passive du coude et du poignet, ainsi qu'un œdème postopératoire important et de multiples ecchymoses.*

Intervention et résultat : *On a prescrit un programme thérapeutique intensif comprenant le traitement des tissus mous, le massage des tissus cicatriciels, des traitements au laser, l'application de ruban de kinésiologie et des exercices de rééducation. Pendant toute la rééducation, on a eu recours à une nouvelle technique d'entraînement appelée « entraînement avec restriction du flux sanguin » pour favoriser au maximum la récupération, la prise de masse musculaire et le retour de la force musculaire. Au bout de 3,5 mois,*

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The involved patient provided consent for case publication.

after 3.5 months. Treatment, exercise and BFR protocols are provided.

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KEY WORDS: chiropractic, biceps brachii, post-operative, rehabilitation, blood flow restriction training

l'haltérophile a pu pratiquer son sport presque comme il le faisait avant sa blessure. Les protocoles du traitement, des exercices et de l'entraînement avec restriction du flux sanguin sont expliqués.

(JCCA. 2018;62(3):193-201)

MOTS CLÉS : chiropratique, biceps brachial, post-opératoire, rééducation, entraînement avec restriction du flux sanguin.

Introduction

The biceps brachii is an anterior arm muscle composed of two heads which bridge the shoulder girdle to the forearm. The distal biceps tendon from the two heads may converge or remain anatomically separate before they attach to the radial tuberosity.[1] Despite this variance in tendon anatomy, the biceps short head attaches more distal than that of the bicep long head on the radial tuberosity.[2] The orientation of the biceps short head primarily contributes to elbow flexion strength while the biceps long head primarily provides supination strength while the elbow is in a flexed position.[1,2]

Rupture of the distal biceps tendon is uncommon and is reported to account for only 3% of biceps tears.[3-5] Rupture of the distal biceps tendon is usually traumatic[1] and most commonly occurs in males[1,2,4,6], athletes[1-4] ,weightlifters[1,4,7], and laborers[1,4] between the ages of 40 and 60[2,4]. The tendon is usually injured when a strong and abrupt extension force is placed on the elbow and is resisted with the demand on the tendon exceeding its capacity to resist the motion.[1-3,6] Lifting a heavy object, catching a heavy falling object, or grabbing a fixed object while falling are a few ways in which the distal biceps tendon is commonly ruptured.[1]

Both operative and non-operative management of distal biceps ruptures are cited in the literature with operative care consistently demonstrating superior improvements in flexion and supination strength.[1-4,7] Single and two-incision techniques have been performed for anatomical re-attachment of the distal biceps tendon. Both procedures yield similar results in terms of patient safety and functional outcomes.[3,7] Non-operative care is typically reserved for patients reluctant to undergo surgery, accepting of functional and strength limitations, medically compromised, or who are presenting with a chronic rupture.[3]

A physiotherapy[2,8] or rehabilitation program[1,2,5,6] is recommended following a distal biceps rupture regardless of the type of intervention performed. Despite these recommendations, there is no consensus on what constitutes an optimal rehabilitation program.[1,6] Traditionally, post-operative rehabilitation consisted of up to six weeks of immobilization followed by gradual passive and active elbow and forearm ranges of motion with strength training commencing after two or three months.[8] Full activity or return to sport is typically assumed four to six months post-op.[2,6] More recently, early[2,5] and unrestricted[3] ranges of motion has been proposed in uncomplicated tendon repairs since the repair strength is greater than the force produced by an unweighted forearm[3]. Furthermore, strengthening of the upper back and shoulder girdle has also been recommended to help the patient return to full activity.[2]

Muscle atrophy and reduced muscle strength is a common side effect of prolonged unloading of muscle tissue through bed rest or immobilization.[9] Traditionally, resistance training has been used to mitigate this phenomenon with loads of >70% maximal voluntary contraction (MVC) recommended to optimize this process.[10] Blood flow restriction (BFR) or occlusion training has demonstrated similar changes in upper and lower limb muscle strength and hypertrophy using much lower loads when compared to traditional high-load resistance training.[11-13] BFR with low load resistance training provides a practical progression from immobilization to high load resistance training in injured populations who cannot withstand the early mechanical stress from higher loads.[11,13-15]

The purpose of this case report is to present the successful and accelerated multimodal rehabilitation program for a distal biceps tendon repair in a weightlifter following an acute traumatic tendon rupture. To the author's knowledge there are no case reports written on rehabilitation of a distal biceps tendon repair using BFR as an integral part of the rehabilitation process.

Case Presentation

A 35-year-old male weightlifter and strength and conditioning (S&C) coach presented five days post-op after the reattachment of his left distal biceps brachii tendon following a traumatic full rupture of the structure. The injury occurred while spotting a client during a push press exercise. While spotting the exercise, the client let go of the bar during its descent and the weightlifter reflexively grabbed it with his arm above 90 degrees of forward flexion and the elbow at full extension. The weightlifter experienced an immediate sharp and audible tearing sensation with mild to moderate swelling in the left cubital fossa. The complaint was diagnosed as a partial tear of the distal biceps tendon at a walk-in clinic the same day of the injury. Continued pain and substantial limitations in function led to a second diagnosis of a complete rupture of the distal biceps tendon being made by an orthopedic surgeon three days later. The weightlifter underwent surgical reattachment of the distal biceps brachii tendon the following day using a single incision technique. A second incision became necessary during the operation due to the degree of biceps retraction that was present during the procedure. A short course of Tylenol 3 was prescribed for the first three days post-op. The arm was immobilized in a soft cast and the weightlifter was advised to use a sling while at work. The surgeon recommended a lifting restriction of one pound on the left arm for three months.

During the initial consult, the weightlifter reported his pain was a 5/10 on the Numeric Pain Rating Scale (NPRS) and characterized it as a deep and profuse achiness with movement and at rest. The weightlifter reported a marked loss of left elbow, forearm and grip strength and mobility and occasional cramping in the forearm flexors and extensors since the operation.

A Disabilities of the Arm, Shoulder and Hand (DASH) and a Mayo Elbow Performance Index score was obtained during the initial examination. The DASH indicated a high degree of disability with a score of 87.5 in the primary module and a score of 100 for both the work (S&C coach) and sport (weightlifting) modules. The Mayo Elbow Performance Index indicated poor elbow performance with an initial score of 20.

Figure 1.
Post-operative anterior aspect of distal arm and proximal forearm.

No red flags were identified during the initial examination. The weightlifter reported weekly physical activity consisting of strength training and ice hockey in addition to the demands of his coaching position. He reported an alcohol consumption of one beer per day, caffeine consumption of one coffee or tea per day and no history of smoking. No allergies were reported. The only medication taken by the weightlifter at the time of the initial examination was 200mg of Advil as needed for pain relief. Advil consumption lasted one day following the initial appointment. No dietary supplements were taken throughout the course of the rehabilitation process. The weightlifter averaged seven hours of sleep throughout the rehabilitative process. No past or present conditions, illnesses or surgeries were reported. The weightlifter reported a history of minor hip and low back injuries, all of which have been managed with conservative care.

Clinical Findings

Visual inspection revealed profuse swelling throughout the extensor and flexor surfaces of the forearm, the dorsal aspect of the hand and all five digits. 18 staples over two incision sites were noted at the distal arm and proximal forearm with bruising noted around the incisions (Figure 1).

Passive elbow range of motion was limited to 40-100° of flexion-extension and active elbow range of motion was severely limited to 70-80° of elbow flexion-extension due to pain. Active wrist flexion, extension and supination were limited to 40°, pronation was limited to 30° and radial and ulnar devation were limited to 15° via visual estimation with patient reported achiness throughout the forearm with all movements. Flexion and extension ranges of motion for all digits were full with achiness reported throughout the forearm with both motions. Palpation revealed firm distention throughout the arm and forearm tissues. Resting tension was noted in both the biceps brachii and brachialis muscles.

Therapeutic Intervention

The weightlifter underwent a course of two treatments per week for 15 weeks. Exercise descriptions, treatment, and notable end of week patient progressions are provided in Table 1. The kinesiotaping application was applied in a weave pattern over the anterior aspect of the arm and forearm during the first five sessions, steering clear of the incision sites in an attempt to promote lymphatic drainage in the area. Compression and elevation of the arm was advised during this time. Laser therapy using a post-surgical setting of seven minutes at 6.5W for a total of 2730.0 J (LiteCure Lightforce™ Pro) was also applied along the incision sites and the attachment point of the biceps brachii tendon during the first 10 sessions.

Soft tissue therapy using Functional Range Release® techniques began three weeks following the initial appointment once the bruising and swelling in the arm and forearm and the scabbing over the incision sites were no longer present. Functional Range Release® is a hands-on method of assessing anatomic structures through palpating at tissue-appropriate depth and tension at rest and through movement to delineate between healthy and aberrant tissue motion. Manual tissue-specific inputs are then applied to the target tissues depending on the findings garnered by the assessment process. Soft tissue treatment initially began as scar mobilization and was then gradually applied to the other affected upper extremity tissues which most commonly presented in the anterior aspect of the arm and anterior and posterior aspect of the forearm.

Blood flow restriction (BFR) training started during the third week using the 30-15-15-15 protocol. The 30-15-15-15 protocol consists of one set of 30 repetitions followed by three sets of 15 repetitions, all with a 30 second break between sets. The weightlifter was required to complete the protocol without the cuff and with no reported fatigued or discomfort before the BFR training commenced. A WelchAllyn® blood pressure cuff was used with a pressure reading of 80mmHg with the arm at rest during each session. The protocol initially began with no external weight held by the affected arm in a wrist neutral position. Weight progressions and changes in wrist position are outlined in Table 1.

Exercises, many of which are grounded in Functional Range Conditioning® principles, were introduced immediately following the initial consultation. Exercises during the first few weeks of treatment were mostly open kinetic chain (OKC) movements to promote lymphatic drainage and early mobilization of the injured tissue. Controlled articular rotations (CARs) were prescribed to maintain and improve the ranges of motion for the wrist and shoulder articulations. Isometric loading of the biceps tendon using the opposite arm for resistance application commenced during week four. By week eight, external load was prescribed using a series of multi-joint exercises. Weekly exercise progressions with desired joint loading angles, % maximal voluntary contraction (MVC), and repetition and set counts are provided in Table 1.

A Disabilities of the Arm, Shoulder and Hand (DASH), Mayo Elbow Performance Index score and an NPRS score was obtained again 3.5 months after his initial presentation. The DASH indicated a score of 5 in the primary module and a score of 6.25 for the work (strength and conditioning coach) module and a score of 25 for the sport (weightlifting) module. It was the weightlifters belief that the degree of disability expressed in the sport module was largely influenced by the relative deconditioning that occurred following the injury. He was able to complete all of the multi-joint exercises that he could perform prior to the injury, however, the training load (sets/reps and weight) were not at pre-injury levels. The Mayo Elbow Performance Index indicated excellent elbow performance with a re-evaluation score of 95. The NPRS score was 0/10.

The weightlifter was discharged from care at 3.5 months post-op as he was leaving the country for several months.

Discussion

Rupture of the distal biceps brachii tendon is an uncom-

Table 1.
Exercise and treatment progression for distal biceps brachii tendon reattachment.

Timeline	Exercise Description	Treatment	End of Week Patient Progression
Week 1	Daily – OKC CARs of the scapulothoracic joint, glenohumeral, and radiocarpal joints with elbow in fixed, pain-free position. 10-12 rotations clockwise and counter-clockwise Daily – Alternating active finger flexion and extension to tolerance Daily – Passive and active-assisted elbow flexion and extension to tolerance, arm on table at shoulder height with furniture moving pad under forearm. 3x 5-6 repetitions	Lymphatic drainage Kinesiotape application Laser therapy, post-surgical setting – 7 minutes at 6.5W = 2730.0J (LiteCure Lightforce™ Pro)	No swelling in hand & digits. ↓ swelling & bruising around incision sites. AROM digit flexion & extension no longer painful, fist clenching – aching sensation. AROM elbow extension 60°, flexion 110° before ache. AROM forearm supination 60° & pronation 45°, mild ache at end ranges.
Week 2	Daily – Week 1 OKC exercises Daily – Passive & active-assisted elbow flexion and extension repetition count ↑ 3x 10-12 repetitions Daily – Passive & active-assisted elbow flexion & extension with the arm at side 3x 5-6 repetitions	Lymphatic drainage Kinesiotape application Laser therapy, post-surgical setting – 7 minutes at 6.5W = 2730.0J (LiteCure Lightforce™ Pro)	Pain-free elbow extension 75°.
Week 3	Daily – Week 1 OKC CARs Daily – Week 2 exercises Daily – Quadruped CKC scapulothoracic CARs, elbow extended to tolerance. 3x 5-6 repetitions per direction	Laser therapy, post-surgical setting – 7 minutes at 6.5W = 2730.0J (LiteCure Lightforce™ Pro) Scar mobilization techniques BFR training, 30-15-15-15 protocol. Bodyweight, wrist neutral	No swelling or bruising in arm or forearm. AROM elbow flexion 125° & extension 80°. AROM wrist pronation 60° & supination 75°, both non-painful & limited by 10°.
Week 4	Daily – Week 1 OKC CARs Daily – Week 2-3 exercises Daily – Isometric elbow flexion & extension, wrist neutral, <5% MVC at 60°, 90° and 120°, 30 seconds each	Laser therapy, post-surgical setting – 7 minutes at 6.5W = 2730.0J (LiteCure Lightforce™ Pro) Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. Bodyweight, wrist neutral	AROM wrist pronation 65° & supination 80° both non-painful. AROM elbow extension full & non-painful.
Week 5	Daily – Week 1 OKC CARs Daily – Week 2-4 exercises Daily – Isometric forearm pronation & supination, <5% MVC at pain-free end range, 30 seconds each	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 1lbs, wrist neutral	AROM elbow flexion 135°.

Legend: OKC = Open kinetic chain; CARs = Controlled articular rotations; AROM = Active range of motion; ROM = range of motion; BFR = Blood flow restriction; MVC = Maximal voluntary contraction; RPE = Rate of perceived exertion; ADLs = Activities of daily living; lbs = pounds.

Timeline	Exercise Description	Treatment	End of Week Patient Progression
Week 6 & 7	Daily – Week 1 OKC CARs Daily – Week 2-5 exercises Daily – Isometric hold sets doubled for elbow flexion & extension & forearm supination & pronation	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 1lbs, wrist supinated	AROM wrist pronation & supination full & non-painful.
Week 8 & 9	Daily – Week 1 OKC CARs Daily – Week 2-7 exercises Isometric hold intensity increased to 10% MVC 3x/week – Bench press 10kg bar, full ROM or to tolerance. 3x 8 repetitions	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 1.5lbs, forearm neutral to supination throughout movement	Patient reported improvement in strength via RPE with ADLs and work tasks.
Week 10 & 11	Daily – Week 1 OKC CARs Week 2-9 exercises Bench press increased to 15kg 3x/week – Bent over row 15kg bar. 3x 8 repetitions	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 4lbs, wrist supinated	Patient reported improvement in strength via RPE with ADLs and work tasks. Patient reported sensation that L arm now larger than the R due to earlier contact of the forearm against the arm with full AROM elbow flexion. 2cm increase in arm circumference on left.
Week 12	Daily – Week 1 OKC CARs Week 2-11 exercises 3x/week – Dumbbell shoulder press 12kg per arm. 3x 8 repetitions	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 4lbs, wrist supinated	Patient reported improvement in strength via RPE with ADLs and work tasks.
Week 13	Daily – Week 1 OKC CARs Week 2-12 exercises Bench press increased to 20kg Bent over row increased to 20kg 3x/week – Push press 15kg bar 3x 6 repetitions 3x/week – Single-arm kettlebell deadlift 16kg 3x 8 repetitions	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 4lbs, wrist supinated	Patient reported improvement in strength via RPE with ADLs and work tasks.
Week 13-14	Daily – Week 1 OKC CARs Week 2-13 exercises Push press increased to 20kg 3x/week – Barbell snatch 25kg 3x 4 repetitions	Scar mobilization techniques Soft tissue therapy of affected upper extremity tissues BFR training, 30-15-15-15 protocol. 4lbs, wrist supinated	Patient reported improvement in strength via RPE with ADLs and work tasks.

Legend: OKC = Open kinetic chain; CARs = Controlled articular rotations; AROM = Active range of motion; ROM = range of motion; BFR = Blood flow restriction; MVC = Maximal voluntary contraction; RPE = Rate of perceived exertion; ADLs = Activities of daily living; lbs = pounds.

mon clinical condition as it only accounts for 3% of biceps tendon ruptures.[3-5] The distal biceps tendon is a thin band-like structure which most commonly ruptures from its insertion on the radius rather than the mid-substance or musculotendinous junction of the tendon.[1] Tendon rupture can cause a gross deformity of the arm due to proximal retraction of the muscle belly. If the tendon remains attached to the lacertus fibrosis despite its rupture off the radial tuberosity, retraction of the biceps brachii may be less pronounced and may lead to a diagnosis of a partial biceps tear.[2,3] It is possible that the weightlifter's distal biceps tendon remained attached to the lacertus fibrosis given his initial diagnosis of a partial biceps tear. However, the surgeon required a second incision during his single incision procedure due to difficulty accessing the retracted biceps brachii. It is unclear if the initial diagnosis was incorrect or if retraction of the tissues progressed between his initial consultation and his surgical procedure.

It was imperative to have an accelerated recovery resulting in full and unrestricted activity of the affected limb given the demands of the weightlifter's job. Several therapeutic modalities were implemented in the management of this case. Kinesiotaping, laser therapy, scar mobilization and Functional Range Release® techniques were employed to promote the tissue healing response and improve the integrity of the affected area.

Both bone and soft tissue injuries undergo three phases of healing with the first stage commencing immediately after injury and the final stages continuing for several weeks to months post-injury.[16] Many factors influence the healing process including nutritional and physical activity status, alcohol and drug use and the presence of concurrent medical conditions.[17] The weightlifter reported using a short course of Tylenol 3 for the first three days post-op and Advil for the first eight days post-op to alleviate the throbbing pain he experienced in the cubital fossa and forearm post-surgery. Non-steroidal anti-inflammatory drugs (NSAIDs) such as Advil have an unfavorable effect on tissue healing by impairing the inflammatory response needed for adequate collagen synthesis during bone and soft tissue repair.[16] Although not classified as an NSAID, Tylenol is thought to provide analgesia by acting on several pathways including the cyclooxygenase enzymes that are integral to the inflammatory process.[18] The evidence is less clear on Tylenol having a detrimental effect on tissue healing but it should be considered given this possible mechanism of action. During the initial consult, the weightlifter was encouraged to limit drug intake and fortunately it was discontinued early in the rehabilitation process. The weightlifter also reported an alcohol intake of one beer per day. Alcohol intake has shown to have an unfavorable effect on bone healing[17] and protein synthesis.[19] It is not known if alcohol consumption remained consistent throughout the rehabilitation process.

The exercises prescribed during the first seven weeks of rehabilitation encouraged maximal range of motion of the upper extremity articulations provided that the movements elicited no more than mild discomfort around the surgical site. Emerging evidence supports early[2,5] and unrestricted[3] movement of the elbow following uncomplicated distal biceps tendon repairs. Aggressive post-operative rehabilitation of the injury is also advocated for an accelerated return to full activity[2] and is reportedly safe during uncomplicated tendon repairs given that the repair strength is greater than the force produced by an unweighted forearm[3].

Despite the recommendation for early and unrestricted post-operative range of motion, it is generally accepted that subjecting the distal biceps tendon to external load should be kept to a minimum in the early stages of rehabilitation so that the reattachment site has time to heal. External loads of greater than 1lbs was introduced by week 8 despite the surgeons recommendation for a 1lbs weight restriction until 12 weeks post-op. This decision was multifactorial and largely based on both the safety profile for introducing external load by the eight week mark[1,5,6,8] and the patient's determination to start strengthening the affected area earlier than the surgeons recommendation. No increase in adverse events have been reported with external load applications of one to two pounds being placed on the tendon by the six to eight week mark post-operatively.[1,5,6]

BFR training commenced three weeks post-op in an effort to mitigate the loss in biceps strength and mass as a result of the post-op weight restriction recommended to the weightlifter. BFR has been shown to diminish strength loss and muscle atrophy absent of muscular contraction[9,12] and when paired with external loads of 20-30% MVC, it has been shown to have a similar effect on muscle hypertrophy and strength that is comparable to resistance training with loads >70% MVC[11-13]. Numerous hypotheses have been proposed for the favorable effects of BFR training such as responses to altered metabolite concentrations[9,10,12], momentary ischemia[10], and hypoxia[10], fluid shifts via cellular swelling[13], increased motor unit recruitment[12], reactive hyperemia[12], increases in glycogen storage[10], and the propagation of satellite cells[12]. Regardless of the mechanism, the stimulus appears to rely on activating the mechanistic target of rapamycin (mTOR) cellular pathway which is involved in cellular proliferation.[12]

BFR training during the early post-operative rehabilitation of the biceps brachii may also have a favorable effect on the osteo-tendinous junction of the reattachment site. Increases in interosseous pressure is thought to occur through BFR training[13] and may influence fluid shifts through the capillary networks found in bony structures[20]. BFR training has shown to impact bone healing properties through metabolic markers that reduce osteoclast activity.[20] It is possible that this response is due to changes in the endothelial cells lining these vascular networks since they've been shown to contribute to both bone resorption and formation.[20]

The 30-15-15-15 is a common BFR protocol[12,13,15,20] and was employed for all BFR training used in this case. The protocol was performed initially with no external weight and was gradually increased up to four pounds. An external load equating to 10-30% MVC is often used with BFR training[11,12,20] however conservative loads much lower than 10-30% MVC were used given earlier recommendations for post-op external weight restrictions.

It is interesting to note that despite the lower MVC used for the BFR training and the marked reduction in use of the affected limb due to his weight restriction relative to pre-injury activity levels, the weightlifter reported the sensation of his injured, non-dominant arm being larger the his non-injured, dominant arm after five weeks of BFR training. Unprompted to consider changes in arm girth, he commented on how he felt as though his forearm would contact the bicep earlier on the left side if he were to flex at both elbow articulations. Measurement of arm circumference was then taken bilaterally by measuring midway between the acromion process and cubital fossa. A difference of two centimetre greater circumference was noted on the left non-dominant arm relative to the right, dominant arm. It is possible that the BFR training resulted in muscle hypertrophy using loads less than the 20-30% MVC that has been cited in the literature. However, this remains speculative since arm circumference was not measured during the weightlifter's initial presentation.

The author acknowledges this case was not without its limitations. Although the author recollects the weightlifter reporting a substantial improvement in pain and function during the appointment following the first BFR session, it is difficult to determine how beneficial the effects of the BFR training was for the weightlifter given the multimodal rehabilitative approach. It is likely that each element of the treatment and rehabilitation had varying degrees of importance depending on each stage of the healing process. Compliance with post-operative recommendations following distal biceps brachii reattachment is also known to be highly variable with some patients exceeding activity recommendations.[6] The weightlifter voiced his determination to begin rehabilitation earlier than the surgeons orders. It is possible the weightlifter could have performed more physical activity than was prescribed during his recovery.

Summary

Distal biceps brachii tendon rupture is an uncommon injury that accounts for only 3% of biceps brachii tears.[3-5] Although return to pre-injury activity levels is often reported following surgical intervention[2,5], there is no consensus with regards to the means in which the pre-injury activity levels should be achieved and timeframes vary from three to six months for return to sport[1,6]. This case demonstrates the successful and accelerated rehabilitation of a post-surgical biceps brachii tendon repair and makes use of a novel training modality which, to the authors knowledge, has not been documented in prior case reports. Clinicians may find BFR training to be a suitable modality to improve patient outcomes and compliment other aspects of their treatment when dealing with distal biceps tendon repair rehabilitation, or rehabilitation for other conditions when low levels of external load are advised.

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Symptomatic os trigonum in national level javelin thrower: a case report

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Introduction: *Os trigonum syndrome is a relatively uncommon condition, resulting from compression of a congenital bony anomaly (os trigonum) and adjacent soft tissues during repetitive hyper-plantarflexion. This condition is currently well-described in ballet, soccer, and running athletes, but few cases exist describing os trigonum syndrome in overhead athletes.*

Case Presentation: *A 22-year-old national level male javelin athlete presented with a recalcitrant history of posterior ankle pain following a hyper-plantarflexion mechanism. Imaging demonstrated a symptomatic os trigonum and inflammation of surrounding soft tissues. Re-aggravation following a conservative trial of care led to orthopaedic referral. Surgical excision of the os trigonum was performed with an open posterolateral approach. The athlete returned to competition three months later with no recurrence of symptoms.*

Summary: *This case discusses the clinical presentation, imaging, and management of a*

Introduction : *Le syndrome de l'os trigone est une pathologie relativement peu fréquente causée par la compression d'une anomalie osseuse congénitale (os trigone) et des tissus mous adjacents durant les mouvements répétitifs en hyperflexion plantaire. Cette pathologie touche souvent les danseuses de ballet, les joueurs de soccer et les coureurs. Peu de cas sont enregistrés chez les athlètes pratiquant des sports comportant des mouvements au-dessus de la tête.*

Présentation du cas : *Un lanceur de javelot de 22 ans se plaignait d'une douleur postérieure de la cheville déclenchée par des mouvements répétitifs en hyperflexion plantaire. Les examens par imagerie montraient un os trigone symptomatique et une inflammation des tissus périphériques. Une aggravation après une tentative de traitement conservateur a mené à une demande d'une consultation en orthopédie. L'excision chirurgicale de l'os trigone a été réalisée à ciel ouvert par voie d'abord ouverte postérolatérale. L'athlète e repris la compétition au bout de trois mois; ses symptômes ne sont pas réapparus.*

Résumé : *Cette étude de cas présente le tableau clinique, les examens par imagerie et la prise en charge*

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symptomatic os trigonum and related pathologies in a javelin thrower.

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KEY WORDS: chiropractic, os trigonum, posterior ankle impingement, plantarflexion, arthroscopic surgery, athletics, javelin

d'un os trigone symptomatique et des pathologies apparentées observés chez un lanceur de javelot.

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MOTS CLÉS : chiropratique, os trigone, conflit postérieur de la cheville, flexion plantaire, chirurgie par arthroscopie, athlétisme, javelot

Introduction

Os trigonum syndrome is a painful, relatively uncommon condition that results from compression of a congenital bony anomaly – an os trigonum, found at the posterolateral aspect of the talus – and nearby soft tissue in the posterior tibio-calcaneal interval.[1] Os trigonum syndrome fits into a broader diagnostic umbrella of posterior ankle impingement syndrome (PAIS), a term which encompasses any condition characterized by posterior ankle pain exacerbated with plantarflexion of the ankle.[2,3] While the presence of an os trigonum increases the risk of symptom development, a considerable disease list, which has been previously described elsewhere in great detail, contributes to PAIS.[3-6] Some examples include osteophyte formation, thickened joint capsule and surrounding ligaments, additional accessory ossicles, fracture or syndesmotic injury, and accessory soft tissue components. As such, the syndrome is synonymous with several terms, including posterior talar compression syndrome, os trigonum syndrome, posterior ankle block, nutcracker-type impingement, and posterior tibiotalar impingement syndrome.[5] More generally, the pathologic contributors can be categorized as either osseous or soft tissue, and, when affected, may all contribute to pain in hyper-plantarflexion.[6]

The presence of an os trigonum is a relatively common occurrence in the general population, with an estimated prevalence of nine to 25% in normal feet and ankles, often observed bilaterally.[7-9] Typically, it is asymptomatic in the non-sporting population.[3,7,10] First described in 1804 by Rosenmuller[11], an os trigonum was theorized to develop from a secondary ossification centre by Turner in 1882[12] which was confirmed by McDougall in 1955[13,14]. The secondary ossification centre can be visualized on a lateral ankle radiograph between ages seven to 11 in females, and 11 to 13 in males; fusion occurs within one year after initial appearance.[7,13-15] In the event of failed fusion, an os trigonum remains and is attached to the posterolateral talus via a fibrous or cartilaginous synchondrosis.[7,14] The os trigonum is believed to be vulnerable to trauma, specifically in repeated plantar flexion of the ankle.[14]

The presence of an os trigonum in itself is not considered sufficient to produce PAIS; commonly, it is considered an incidental finding. Rather, it is the combination of pain in plantar flexion and exposure to repetitive loading in positions of hyper-plantarflexion that is believed to contribute to development of PAIS, regardless of bony anatomy.[10] There is debate whether an acute incident may also be causative.[4,16]

The close proximity of the flexor hallucis longus (FHL) tendon, which passes in the fibrous-osseous tunnel posterior to the medial malleolus and follows the groove between the medial and lateral posterior talar tubercles,[1] predisposes this tissue to stenosing tenosynovitis in the presence of an os trigonum – a common concomitant condition.[5,17] Due to constant pressure exerted on the os trigonum by the FHL tendon[1,5,18], a chronic irritation of the FHL tendon inside its sheath can result in compression, synovitis, hypertrophy, nodules, and partial tearing[5,17].

PAIS has been well-described in ballet dancers, gymnasts, soccer players, and runners[2], but has not been well described in overhead athletes. The objective of this case report is to describe the presentation of a national level male javelin athlete with PAIS due to an os trigonum with concomitant FHL tenosynovitis. The case will also explore the prevalence, clinical presentation, and management strategies, as well as biomechanical considerations in the throwing athlete. The patient gave signed consent for release of his information to be included in this manuscript.

Case Presentation

History

A 22-year old male national level javelin thrower presented to a Sports Specialist chiropractor (Fellow of the Royal College of Chiropractic Sports Sciences, Canada) with an acute episode of chronic left posterior ankle pain. The pain began during a competition throw three months prior, where he reported over-extending his lead foot during the "block", also known as the delivery step (Figure 1). This phase is where the javelin athlete ends their run-up and cross-over steps (including the penultimate) by planting their lead foot and blocking the body from moving forward, thus creating a strong pivot point for the throwing side of the body to rotate around.[19] Offseason weight training and practice throws were not aggravating, but he continued to report intermittent pain and apprehension with competition level throws, where he describes extending his block foot further to gain an advantage.

At the time of assessment, pain intensity was rated as 3/10, but he noted that it could be 7/10 while throwing. The patient reported intermittent symptoms in the same region for approximately six years prior to presenting at the clinic. Symptoms typically came on in late spring when the outdoor throwing season begins in Canada, and symptoms dissipated in the fall when throwing season typically ends and he is able to rest for several weeks.

Figure 1.
The "block" phase at the end of the penultimate, immediately prior to throwing the javelin. The leading (left) foot is loaded in hyper-plantarflexion during this phase (arrowhead).

Previously, the patient had been diagnosed as an Achilles tendinopathy – a common misdiagnosis due to symptom location, as described in detail elsewhere[20] – which was treated conservatively by a therapist. Symptoms abated at that time, although this coincided with offseason rest, which may have contributed to symptom resolution.

Additional complaints included a chronic Grade 2 strain of the right external oblique near the pubic symphysis, suffered approximately six months prior to the time of initial assessment during a competition throw. This was treated conservatively by a therapist and was beginning to resolve at the time of assessment. The patient is right-handed and otherwise had no major prior injuries.

Physical Examination

Upon observation, there was no obvious signs of swelling, discolouration, or other visual abnormalities. Palpation revealed tenderness over the posterolateral ankle, slightly anterior to the Achilles tendon, as well as in the flexor compartment on the posteromedial ankle. Pain in both regions was increased with passive plantar flexion of the left ankle as well as with passive dorsiflexion of the great toe. Passive motion of the great toe caused a squeaking sound from the posteromedial ankle, which could be felt on palpation as a vibration over the flexor hallucis longus tendon at the medial ankle. Motion palpation revealed hypomobility in the cuboid and navicular bones, and restriction in subtalar eversion. There was a 20% decrease in active dorsiflexion of the left ankle in comparison to the right ankle as measured with the standing knee to wall test. Walking, jogging, lunging, squatting, weightlifting, and plyometric training did not exacerbate symptoms. Toe walking and standing inversion were mildly uncomfortable. Single leg squat revealed significant difficulty balancing on the left side. Muscle testing and neurological examination was within normal limits.

Diagnosis and Management

A lateral radiograph of the left ankle demonstrated an os trigonum (Figure 2A). Based on a combination of clinical symptoms, mechanism of injury, and radiographic findings, a working diagnosis was provided of PAIS (secondary to an os trigonum) with associated tenosynovitis of the flexor hallucis longus tendon. A 10-week trial of conservative care was implemented, including manipulation and mobilization of the foot and ankle, and Active Release

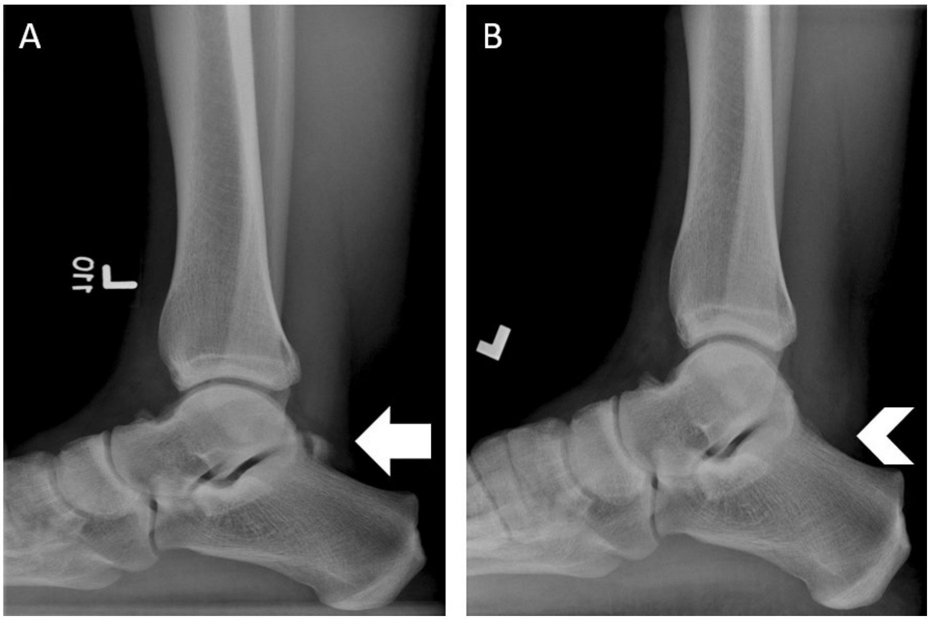

Figure 2.
Radiograph of athlete's left ankle pre and post surgery. (A) Lateral ankle radiograph demonstrating presence of os trigonum (arrow). (B) Post-surgical lateral ankle radiograph demonstrating the successful resection of the os trigonum (arrow head).

Techniques® to address soft tissue. The treating chiropractor and coach collaborated to integrate a rehabilitation program into the athlete's current training regimen, which was modified to avoid aggravating positions of excessive plantar flexion, thus minimizing disruption to his training schedule. Rehabilitation was geared towards improving mobility, intrinsic strength, and balance of the foot, as well as improving strength and coordination of the lower kinetic chain. At the end of the 10-week trial of care, the patient's condition stabilized, ankle dorsiflexion was symmetrical, and he was able to return to full training volume and competition-level throws with no pain. However, during a high-level competition eight weeks later, the patient re-aggravated the condition with the same mechanism.

At this point, the patient was referred to a sports medicine physician for co-management, who prescribed an MRI (Figure 3). The MRI identified marrow edema in both the os trigonum and adjacent talus extending into the body. There was fluid present at the synchondrosis and moderate fluid around the os trigonum extending into the posterior ankle recess. High signal was noted at the talar attachment of the posterior talofibular ligament (PTFL) and posterior tibiotalar ligament. There was also mild soft tissue edema and fluid present in the flexor hallucis lon-

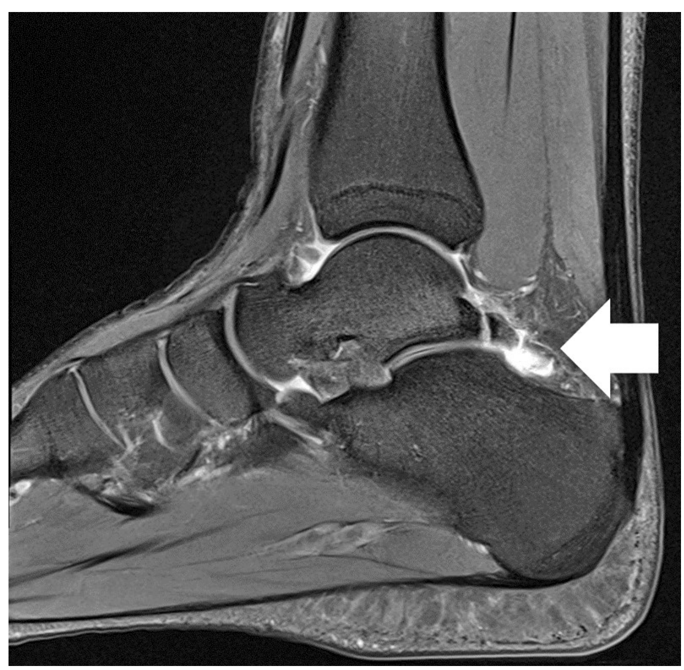

Figure 3.
MRI imaging of athlete's left ankle prior to surgery. Proton density fat suppression sagittal MRI slice demonstrating marrow edema in the os trigonum extending into the talar body and posterior synovial recess (arrow).

gus, tibialis posterior, and flexor digitorum longus tendon sheaths.

Due to the recurrent nature of symptoms and failure of conservative care, the patient was referred for orthopaedic consultation. Surgical excision of the os trigonum and subtalar synovectomy was recommended and successfully performed using an open posterolateral approach (Figure 2B). Following a standard post-surgical plan of management to control inflammation and restore range of motion, the athlete participated in a rehabilitation program designed to re-establish strength, stability, and coordination through the lower kinetic chain, trunk, and upper limbs. The rehabilitation program was influenced by concepts from dynamic neuromuscular stabilization (Figure 4) and emphasized the derivation of foot support in a tripod fashion (1st and 5th metatarsal heads and the calcaneus) to maximize arch support.[21] The program was global, with an emphasis on establishing control and strength through the foot and was designed to coordinate the integration of intra-abdominal pressure regulation with the dynamic and stabilizing functions of neighbouring joints and extremities to optimize movement competency and throwing efficiency. The athlete returned to full competition three months later with no pain and had no recurrent issues at one-year follow-up.

Figure 4.
Example of rehabilitation exercise based on dynamic neuromuscular stabilization principles, designed to maintain the arch structure of the foot in a centrated tripod support.[21]

Discussion

PAIS Management

The first clinical report of osseous impingement of the posterior ankle was in 1982.[22] The overall prevalence of PAIS remains unknown,[3] due to a paucity of published literature on the subject, and the wide number of conditions that may contribute to its development.[2,3] Albisetti reported a 6.5% prevalence of PAIS in 186 trained ballet dancers over a one year period[23], although this may be as high as 30% or greater in the same population[24], and as high as 60% in a wider spectrum of athletics[25]. Ribbans *et al*. presented unpublished data from 18 teams under the English Cricket Board in 2001-02, showing PAIS to be the second-leading cause of injury in the foot and ankle region in this population – more than lateral ankle sprains and Achilles disorders combined.[3] This was reported to most commonly affect the front foot of fast bowlers, although there is little available literature to support these observations in cricket athletes.

Typically, conservative measures are first considered for PAIS management, which are shown to be effective in the general population, although due to heterogeneity and a lack of understanding in causative mechanisms, treatment is seen to vary considerably.[2,3,23,26] Mouhsine *et al*. reported 16 of 19 athletes responded effectively to corticosteroid injection in a case series and were returned to sport with no further issues at a follow-up time of two years.[16] Surgical intervention was successfully performed on the three recalcitrant cases, and athletes returned to sports within seven to nine months from the date of initial injury. Similarly, Robinson *et al*. presented a case series of 10 soccer athletes with subacute PAIS, following an inversion mechanism of injury, in which two of these athletes were found to have an os trigonum, and one subsequently underwent surgery for removal of the bony anomaly.[27] Hedrick *et al*. report a 60% success rate with NSAIDs, steroid injections, cast immobilization and rehabilitation.[25] However, the short-term follow-up and lack of prospective studies limits the conclusions drawn surrounding conservative management of PAIS, particularly as recurrence of symptoms is quite common. Based on all available evidence, despite empirical recommendation for conservative treatment as a first option for treatment, there is little substance to provide evidence-based recommendations on the choice of non-surgical interventions, or prognostic factors to inform the patient on their condition.[3]

In the presence of a symptomatic os trigonum, it has been suggested that surgical intervention may be necessary for longstanding relief of symptoms[4], although recommendations for this approach are equally debatable. A comprehensive review of available literature by Ribbans *et al*. demonstrates a predominance of retrospective Level IV and V evidence and significant heterogeneity in reporting and outcome measures, limiting conclusions that can be made.[3] However, based on their review of 26 papers (384 open surgical procedures, 521 artho-endoscopic procedures), surgical interventions overall were seen to have a self-reported 67-100% effectiveness rate in returning the athlete to sport, with low complication rates of 4.8% (arthro-endoscopic), 3.9% (posteromedial), and 14.7% (posterolateral), respectively, many of which were temporary in nature.[3]

There is debate as to the most appropriate surgical approach, although there appears to be no clear advantage based on outcome.[1,3,4] Although a slightly faster return-to-play was noted with the arthro-endoscopic approach over the open approach[3], it is suggested that this approach may have greater risk for injury to cartilage due to the small space[1]. Overall, complication rates are very low with surgical intervention for PAIS, the most reported of which involve injury to the sural and tibial nerves, many of them transient and short-term.[1,3] Regardless of intervention, most athletes tend to return to their sport of choice, with many authors highlighting the importance of a dedicated therapist to facilitate the successful return to competition.[28] It should be noted that, due to the low quality of evidence, these findings should be interpreted with caution.

Lack of return to play guidelines for PAIS make it difficult to accurately determine prognosis for an individual athlete. Senecal *et al*. present a case report of a middle-aged recreational hockey player, suggesting the utility of a progressive return to play program adopted from that following ankle sprains.[26] Rogers also proposed a five step post-surgical rehabilitation protocol for horizontal jump athletes,[4] while Coetzee *et al*. presented a rehabilitation program designed specifically for ballet dancers, with the "Pointe Functional Tests" – comprised of the topple test, airplane test, and single-leg sauté test – as the final step before returning to relevé.[28] All programs follow logical, progressive steps towards recovery, with good self-reported results, although none have been explored further in prospective randomized control trials to assess efficacy.

Mechanism of Injury

Currently, there is discussion as to the development of PAIS. The first, and most commonly described, is through repetitive hyper-plantarflexion in loaded movements. A 2016 study from Russell *et al*. used high resolution MRI to assess 6 ballet dancers in a non-weightbearing en pointe position.[29] Every participant demonstrated convergence of the posterior edge of the distal tibia with the posterior talus and superior calcaneus; providing further visual confirmation of the "nutcracker" mechanism commonly described in previous literature.[2] Interestingly, in this position of extreme plantarflexion, the authors described incongruency of the talocrural joint in all athletes, noting one third of the articular surface of the tibial plafond resting on the posterior talus in this position, with anterior translation of the talus due to compression of the bone at the posterior aspect. The en-pointe and demi-pointe positions seen in ballet dancers have been proposed as a potential contributor to the high incidence of PAIS in this population, particularly as this highly repetitive forced plantar flexion is practiced during skeletal maturation.[6,14]

In a biomechanical study of soccer players, the degree of plantar flexion during ball strike exceeded that which was reproducible with passive clinical assessment, suggesting a consistent, repeatable compression of the posterior tibiotalar structures.[30] Rogers describes the mechanism of horizontal jumping athletes, who transition their running momentum into take-off foot in a rapid (40-70ms) compressive-based plantar flexion movement, during which time upwards of 10-15 times body weight is applied through the lead leg in maximal plantarflexion.[4] Furthermore, Rogers describes increased plantar flexion and braking load in the lead leg the further the lead leg is in front of the body's centre of mass.[4] This is thought to be mechanistically analogous to the forces experienced by a javelin thrower during the final delivery step and matches the mechanism of injury for the athlete in this case report, although there is no literature to support this supposition.

PAIS may also develop as the result of an acute injury. Mouhsine presented a case series of 19 athletes with PAIS, noting that 8 athletes presented with persistent pain following an ankle inversion sprain mechanism and a failed standard course of treatment for lateral ankle sprains.[16] Additional mechanisms of acute injury are postulated, including a single plantar flexion event and forced dorsiflexion leading to avulsion of the posterior talofibular ligament which can attach to the os trigonum.[31]

In general, whether acute or chronic, the available literature describes a consistent, logical mechanism of injury for impingement of osseous and soft tissue structures in the posterior ankle, particularly in the presence of an os trigonum or an elongated lateral tubercle.[32] However, anatomical, biomechanical, and capacity-based risk factors need to be determined to identify those at greatest risk of developing PAIS. In the absence of sound, evidence-based recommendations, intimate knowledge of a sport's physical demands becomes imperative for the treating clinician to understand. A team-based approach is of paramount importance, with coaches, therapists, and surgeons communicating freely to identify relevant potential risk factors that may affect prognosis, particularly positions of extreme plantar flexion associated with sport. This knowledge is important to consider in clinical management of patients with PAIS.

Global Biomechanical Considerations

Due to the chronicity of PAIS in many athletes, it is essential to monitor the athlete for compensatory movement strategies that may affect health status and performance. This case presents a national level javelin thrower with recalcitrant PAIS and a subacute external oblique strain, potentially representing an injury higher in the kinetic chain, that may be influenced by compensatory movement strategies. There is growing evidence that painful conditions in the lower limb can affect neurological patterning in the hip, pelvis, trunk, and the upper limb which holds potential to affect performance and increase injury risk in the overhead athlete. A review by Steinberg *et al.* into the impact of painful lower leg conditions on hip muscle performance demonstrated decreased strength and endurance, and delayed onset and offset of hip musculature in various movement patterns.[33] This co-dependent relationship between segments of the lower kinetic chain has been explored previously in other conditions including patellofemoral pain syndrome.[34-35]

Arguably of greater consequence in overhead athletes are the compensatory ramifications experienced higher in the kinetic chain. In this particular case, it could be suggested that altered activation patterns at the hip and pelvis may alter frontal plane mechanics and coordination of trunk rotation, leading to greater lateral trunk lean and loading in the abdominal wall – as demonstrated by an chronic external oblique strain in this athlete, as well as the throwing arm.[36] A study of 99 college-aged baseball pitchers by Solomito *et al.* demonstrated a 4.8% increase in varus moment of the elbow and 3.2% increase in glenohumeral internal rotation moment for every 10^{o} increase in trunk lean.[37] These findings were echoed by Oyama *et al.* in high school pitchers.[38] Furthermore, altered timing and magnitude of trunk rotation, a ramification of altered pelvic and hip control[36] has been demonstrated to significantly increase external rotation angles and proximal forces experienced at the glenohumeral joint[36,39]. These combined findings are important, as the load placed on the UCL during pitching is already close to matching the ultimate moment of failure observed in cadaveric UCL studies.[37,40] Additional load through the UCL and rotator cuff may have an added biomechanical cost in the throwing athlete, with only negligible performance gains.[36,37,39]

In a comprehensive review of throwing mechanics, Chu *et al.* highlights the necessary integrative nature of linked segments throughout the body in performing a thoroughly complex activity such as throwing which incorporates the entire kinetic chain.[41] The authors suggest that deficiencies in any of these areas may have a detrimental effect on performance and injury rates in the throwing population, thus endorsing the necessity of a thorough clinical and functional evaluation of the leg, hip, core, scapula, and shoulder for the overhead athlete. Ultimately, while there is no direct correlation established between injury of the lower quarter and upper extremity loads experienced in the throwing athlete, this information suggests the importance of assessing global biomechanical function of the throwing athlete, particularly in the presence of painful lower quarter conditions, to screen for aberrant movement patterns and the potential for increased loading throughout the kinetic chain.

Limitations

This is a case report, limiting the findings to a single case. It is not prudent to generalize the findings of this study to the general public, or to other patients. Further observation and larger prospective trials are required to assess individual contributors to PAIS, and to identify prognostic factors and the impact of conservative and surgical interventions on PAIS patients.

Summary

PAIS has a plethora of causes. While conservative treatment is encouraged as the primary intervention, surgical intervention may be required in the presence of osseous anomalies such as os trigonum for long-term relief of symptoms, particularly in elite athletes. This case describes a 22-year-old national level male javelin athlete with a 3-month history of posterior ankle pain following a hyper-plantarflexion mechanism during a competition-level javelin throw. Radiographs and MRI demonstrated the presence of an os trigonum with inflammation of surrounding soft tissues matching the clinical presentation. After a 10-week trial of conservative care was unsuccessful, surgical intervention was successfully performed using an open posterolateral approach. The athlete returned to javelin competition 3 months later with no recurrence of symptoms. The generalizability of the approach in this athlete is limited, as this represents a single case. Future research should focus on prospective studies to identify key prognostic indicators and standardize treatment methodologies, and a strong effort should be made to improve reporting in published studies. The reader is reminded of the potential for global biomechanical ramifications throughout the kinetic chain in response to painful lower limb conditions, and the importance of observation and full kinetic chain assessment in the overhead athlete before returning them to sport.

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