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JCCA December 2022 Sports Chiropractic Special Issue: 14th Edition

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Assistant Editor

(JCCA. 2022; 66(3):226)

KEY WORDS: sports, chiropractic, editorial

Éditorial
JCCA Décembre 2022 – Numéro spécial de la chiropratique sportive : 14e édition

MOTS CLÉS : sports, chiropratique, éditorial

I am honored to present to you this 14th Sports Chiropractic issue of the JCCA. This would not have been possible without the ongoing support and dedication of the Editorial Board, our esteemed peer reviewers, and the Canadian Chiropractic Association (CCA). I am grateful to all the authors for their efforts to further knowledge in Sports Chiropractic. I would like to thank you for taking time to read this great work and hope you will be empowered and enlightened by the content. I am thankful to have an annual issue dedicated to research in Sports Chiropractic, which is unique, and yet essential for Sports Chiropractic around the world. This year's issue includes important, interesting and thought-provoking articles. In this issue you will find a couple of original research papers from exploring the Canadian Sports Chiropractic research agenda to prevalence of shoulder problems in youth swimmers. There are also practical and rare case reports and a case series. I hope you find this issue informative and clinically applicable.

As always, I would like to encourage you to get involved in sports chiropractic research in any way that you can. If you have a dataset, an interesting case, or an innovative research idea and need help developing it, please do not hesitate to contact me, or any member of our Editorial Board or members of the RCCSS(C).

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Identifying and prioritizing research to inform a research agenda for Canadian chiropractors working in sport – the Canadian sports chiropractic perspective

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Objectives: *To identify and prioritize research to inform research agenda development for Canadian chiropractors working in sport*.

Methods: *Clinicians, researchers and leaders from the Canadian sports chiropractic field were invited to*

Définir et prioriser la recherche afin d'élaborer un programme de recherche pour les chiropraticiens Canadiens travaillant dans le domaine du sport – la perspective de la chiropratique sportive Canadienne

Objectifs : *Définir et prioriser la recherche afin d'élaborer un programme de recherche pour les chiropraticiens canadiens travaillant dans le domaine du sport*.

Méthodologie : *Des cliniciens, des chercheurs et des chefs de file du domaine de la chiropratique sportive*

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participate in 1) a survey to refine a list of research priorities, 2) a Delphi procedure to determine consensus on these priorities, and 3) a prioritization survey.

Results: *The top three research priorities were 1) effects of interventions on athletic outcomes, 2) research about sports healthcare teams, and 3) clinical research related to spinal manipulative and mobilization therapy. The three highest ranked conditions to research were 1) low back pain, 2) neck pain, and 3) concussion. Collaborations with sports physicians and universities/colleges were rated as important research collaborations to pursue.*

Conclusions: *These results represent the Canadian sports chiropractic perspective to research priority setting and will be used alongside stakeholder input to set the first research agenda for the Canadian sports chiropractic field.*

(JCCA. 2022;66(3):227-243)

KEY WORDS: sports, chiropractic, Delphi study, research priorities

canadienne ont été invités à participer à 1) un sondage pour préciser une liste de priorités de recherche, 2) une procédure Delphi pour déterminer le consensus sur ces priorités, et 3) un sondage d'établissement de priorités.

Résultats : *Les trois principales priorités de recherche sont 1) les effets des interventions sur les résultats sportifs, 2) la recherche sur les équipes de soins de santé dans le domaine du sport et 3) la recherche clinique liée à la thérapie de manipulation et de mobilisation de la colonne vertébrale. Les trois problèmes de santé les plus importants cités comme priorité de recherche sont 1) la lombalgie, 2) la cervicalgie et 3) les commotions cérébrales. Les collaborations avec les médecins du sport et les universités/collèges sont considérées comme des collaborations de recherche importantes à poursuivre.*

Conclusions : *Ces résultats représentent le point de vue de la chiropratique sportive canadienne sur l'établissement des priorités en matière de recherche et seront utilisés avec les commentaires des intervenants pour établir le premier programme de recherche du domaine de la chiropratique sportive canadienne.*

(JCCA. 2022;66(3):227-243)

MOTS CLÉS : sports, chiropratique, étude Delphi, priorités de recherche

Introduction

Research agendas identify knowledge gaps[1], prioritize future research[1,2], and ensures that the research being conducted is clinically relevant[2]. They can guide resource allocation, establish funding priorities, and inform the pursuit of strategic partnerships and collaborations.[1–3] With up to 55% of adults[4,5] and 74% of youth[6] participating in sports and physical activity in Canada, the importance of contributing to research about sport, physical activity, and their related injuries is an important endeavor for chiropractors as partners in the Canadian healthcare system.

To date, a research agenda for the sports chiropractic field has not been published, limiting the ability of the field to coordinate a research strategy to direct investment, align research efforts, cultivate research capacity, and foster sustainable research programs. A common method to provide data to inform a research agenda is to utilize the Delphi procedure, which is a systematic method used to integrate expert opinions to determine consensus. It involves recruiting a panel of experts to participate in an iterative survey process that uses repeated rounds of voting where experts vote on a list of statements (often referred to as 'seed statements') and rank their importance.[7–9] The results from each voting survey are fed back to the experts in progressive voting rounds to facilitate their subsequent voting with the purpose of determining consensus.[7–9] Previous researchers have applied the Delphi procedure to develop research agendas for various professions[10–13], including chiropractic[1,3].

In 2014, Rubinstein *et al*.[3] utilized the Delphi procedure to inform the first research agenda for the chiropractic profession in Europe. They reported consensus on 19 research priorities with cost-effectiveness/economic evaluations, identification of subgroups likely to respond to

treatment, and initiation and promotion of collaborative research efforts as the highest ranked research priorities. Similarly, in 2017 French *et a*l.[1] conducted a modified Delphi study to determine consensus on research priorities for the Canadian chiropractic profession and identified the integration of chiropractic care into multidisciplinary settings, cost-effectiveness of chiropractic care, and effect of chiropractic care on reducing medical services as the top three ranked priorities. While these research agendas facilitate research planning for the chiropractic profession, their Delphi panels had minimal sports chiropractic input, and may not address the specific research needs of these practitioners.

Chiropractors providing care to athletes must do so within the sports context, which is a performance-driven setting.[14–17] Athlete- and sport-specific factors, such as addressing time-loss from sport[14] and coordinating care within an integrated sports healthcare team[18], can affect how healthcare providers working in sport approach care delivery[14,19]. These contextual factors can influence the research requirements of healthcare providers operating in these settings. An interview study exploring the opinions of sports-focused chiropractors about research revealed that they concentrated their discussions about research on topics specific to the sports context, such as the effects of sports chiropractic interventions on athletic performance, injury prevention, and the care of athletes in clinical practice.[20] These sports-related research interests were not captured by previous Delphi studies conducted for the chiropractic profession,[1,3] reinforcing the need to develop a unique research agenda for the Canadian sports chiropractic field.

Developing a research agenda for a field of study requires input from multiple sources.[21] Research priorities must be identified, consensus on these priorities from research end-users must be reached, stakeholder input should be sought, and an evaluation of the field's research capacity must be conducted.[21] Our research group has planned and conducted multiple studies[20,22,23] to provide data on each of these areas to inform the setting of a research agenda and a subsequent implementation plan for the Canadian sports chiropractic field. An exploratory study to provide preliminary data on sports chiropractors' opinions about research was published[20], a qualitative study was completed to identify research priorities for consideration for research agenda development[22], athlete opinions about research direction for the chiropractic field was explored[23], research capacity evaluations are being conducted, and a stakeholder consultation study is being planned. This present study will build upon our previous work[20,22] and utilize the Delphi method to provide a key piece of information to inform research priority setting – the Canadian sports chiropractic perspective on the prioritization of research.

Methods

This project involved a 1) pre-Delphi survey to refine a list of research priorities identified from a qualitative study[22], 2) Delphi procedure to determine consensus on research priorities and 3) prioritization survey of the research priorities that achieved consensus from the Delphi procedure.

Identification of participants

Given the aim of the present study is to provide the Canadian sports chiropractic perspective for research prioritization, purposive sampling was used to identify representative experts from the Canadian sports chiropractic field.[24,25] Recognizing there are different domains of expertise within a field of study, our purposive sampling aimed to identify clinical, leadership, and research experts within the Canadian sports chiropractic field.[25] To assist with this sampling strategy, a study advisory committee was assembled by requesting the Board of Directors of the Royal College of Chiropractic Sports Sciences (Canada) [RCCSS(C)] to nominate four sports chiropractors who they deemed knowledgeable of the Canadian sports chiropractic landscape.

Clinical experts were identified by creating a list of all active fellows of the RCCSS(C) as of June 2020 (116 fellows). Leadership experts were identified by creating a list of all past and present members of the Board of Directors of the RCCSS(C), Board of Directors of the Foundation for the RCCSS(C), and Committee members of the RCCSS(C) (75 individuals). Research experts were identified by conducting literature searches to identify sports-focused research conducted by Canadian chiropractors that was published within the past 20 years. Literature searches of MEDLINE (EBSCO), PubMed, CINAHL, Index to Chiropractic Literature and SportDiscus databases were conducted in consultation with an academic librarian on January 22, 2020 (please contact the

primary author for detailed search strategies). The results of the literature searches were imported into EndNote, duplicates were removed, and citations were screened by the authorship team by using titles/abstracts and full text when clarification was required. For inclusion, articles must have met the criteria for sports-focused research as defined by the RCCSS(C)[26] (see Appendix 1 for the RCCSS(C) sports-focused research definition), been published in a peer reviewed journal, and at least 1 author must be a Canadian chiropractor or a non-chiropractor faculty member of a Canadian chiropractic educational institution as identified by internet author searches performed by the authorship team. This process yielded a list of 87 researchers.

To make sure key individuals from the Canadian sports chiropractic field were not missed, snowball sampling[27] was used by asking the study advisory committee to review the lists of clinical, leadership, and research experts gathered from our purposive sampling methods and use their knowledge of the Canadian sports chiropractic field to nominate any experts who they believe may have been missed. Snowball sampling added an additional six names to the clinical experts list.

The sampling strategy resulted in three lists of experts from the Canadian sports chiropractic field (clinical, leadership and research). To rank order these experts, each member of the study advisory committee was asked to independently rate the experts on each list based on their level of expertise within the respective expertise domain (clinical, leadership or research) using an 11-point Likert scale, ranging from 0 = the least experienced to 10 = the most experienced. The mean rating score for each expert on each list was calculated, and the lists were rank ordered based on the mean expert rating score. If any experts were identified on more than one list, they remained on the list of their highest ranking and were removed from lists where they had a lower ranking. This process resulted in three rank-ordered lists of Canadian sports chiropractic experts: clinical (n=65), leadership (n=42) and research (n=59).

Delphi panel member recruitment

Presently, there are no criterion standards for sample size determination for Delphi studies. Samples that are too small run the risk of a lack of stability of responses, and large samples can lead to large dropout rates with successive survey rounds.[28,29] Recommendations for sample sizes for Delphi studies have ranged from 15-30 participants[9,28], with the stability of responses demonstrated with as little as 20 participants for homogeneous samples[29]. Assuming a 40% response rate for the Delphi procedure, to ensure a reasonable Delphi panel size, the highest ranked 30 experts from each of the clinical, leadership and research rank-ordered lists (90 total experts) were invited to participate in the online Delphi procedure.

Pre-Delphi survey – identification of research priorities

Our previous qualitative study[22] that interviewed sports chiropractic researchers and leaders, identified 150 individual research priorities, categorized into three themes: area of research, research actions and research methodology. To further refine this list of research priorities for the Delphi procedure, it was first presented to the study advisory committee who reviewed the list for completeness and were asked to add any research priorities they thought may have been missed or remove priorities due to redundancies. Secondly, all 166 experts identified from our purposive sampling methods were invited to participate in an online pre-Delphi research priorities refinement survey where each participant was asked to rank the importance of each research priority using a nine-point Likert scale, anchored from "1" representing the "lowest importance" to "9" as the "greatest importance". All items ranked 3 or lower by 75% or more of the experts were deemed to reach consensus as an "unimportant" research priority, and "unimportant" items were removed from the list of research priorities that will progress into the Delphi procedure. Additionally, participants were asked at the end of this pre-Delphi survey to suggest any other research priorities that were not mentioned on the survey using an open text field. These text responses were qualitatively analyzed by the authorship team to determine if these suggestions were unique research priorities that should be added to the research priority list for the Delphi procedure.

Delphi procedure

Delphi panel members were invited by email to participate in the online Delphi procedure. Within the email, a brief letter explained the purpose of the Delphi procedure ('to understand what research priorities are important

to help direct future research efforts for Canadian sports chiropractors') and a link was provided to the online Delphi survey. The first round Delphi questionnaire collected non-identifying demographic data. All Delphi surveys presented participants with questions asking them to rate the importance of individual research priorities categorized into their respective research theme. In general, the questions were worded as follows: "How important is it that we conduct research on (*individual research priority*)?"

Similar to a previous chiropractic Delphi research prioritization study[3], participants were asked to rank the importance of each research priority using a nine-point Likert scale anchored by "1" representing the "lowest importance" to "9" as the "greatest importance"[3]. The use of the nine-point scale to rate the importance of an item was originally outlined by the RAND appropriateness method,[30] and has been recommended by the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) Working Group.[31] With an a priori consensus level of 75% for this Delphi procedure, each research priority could reach consensus on whether it is "important" (ranked from seven to nine), of "uncertain importance" (ranked from four to six) or "unimportant" (ranked from one to three) if 75% or more of the experts rate the item within one of these respective ranges. All research priorities that did not reach the 75% consensus threshold were determined to not reach consensus. At the completion of each voting round, items that reached consensus for being "important", of "uncertain importance" and "unimportant" were removed from the Delphi survey, and the remaining non-consensus items remained on the Delphi survey for subsequent voting.[3,28] Participants were provided with feedback in the form of summary results of the previous Delphi round prior to completing each subsequent Delphi round questionnaire. Retaining non-consensus items in successive Delphi round questionnaires and presenting them alongside the results from previous rounds can facilitate decision making by allowing participants to re-evaluate the remaining non-consensus items within the context of having knowledge of the group's prior ratings.[28] This process continued until either consensus was achieved on all research priorities or a maximum of three voting rounds were completed. Only the research priorities that reached consensus for being "important" were used to inform the final prioritization survey.

Prioritization survey

All 90 experts of the Delphi panel were invited by email to participate in an online prioritization survey. To create the final prioritization survey, the authorship team met to review the "important" research priorities that achieved consensus from the Delphi procedure. Similar research priorities were amalgamated to remove redundancy and were sorted into the categories: 1) area of research, 2) collaborations, and 3) specific conditions. The collaborations category was subcategorized into interprofessional, interorganizational, intraprofessional, sports community, and academic collaborations.

To prioritize these categories, participants were asked to rank each list of research priorities using a forced ranking procedure where participants were asked to rank each research priority from most to least important (with the most important ranking being ranked as #1, with each subsequent numerical ranking representing a sequential decline in importance). For these forced ranking questions, the weighted average ranking score for each research priority was calculated.

Pilot testing of the prioritization survey was conducted by eight members of the investigative team to trial the survey for ease of use. It revealed the category – *'area of research'* – was difficult to rank using a forced ranking procedure due to too many choices (28 priorities). A decision was made, a posteriori, to prioritize this category by asking participants, "Given the current research capabilities of the Canadian sports chiropractic field, select the 10 most important research priorities from this list that the Canadian sports chiropractic field should pursue." The percentage of participants who selected each research priority as a "10 most important research priority" was calculated, and the highest percentage determined the priority order of this list.

Survey administration

All email invitations to participate in all online surveys for this study were sent by the RCCSS(C). The data collection period for each online survey was for three weeks, with two reminder emails being sent each week. SurveyMonkey (Momentive, San Mateo, California, USA) was used for all online survey administration for this study.

Data analysis

All demographic data, research priority ratings, and re-

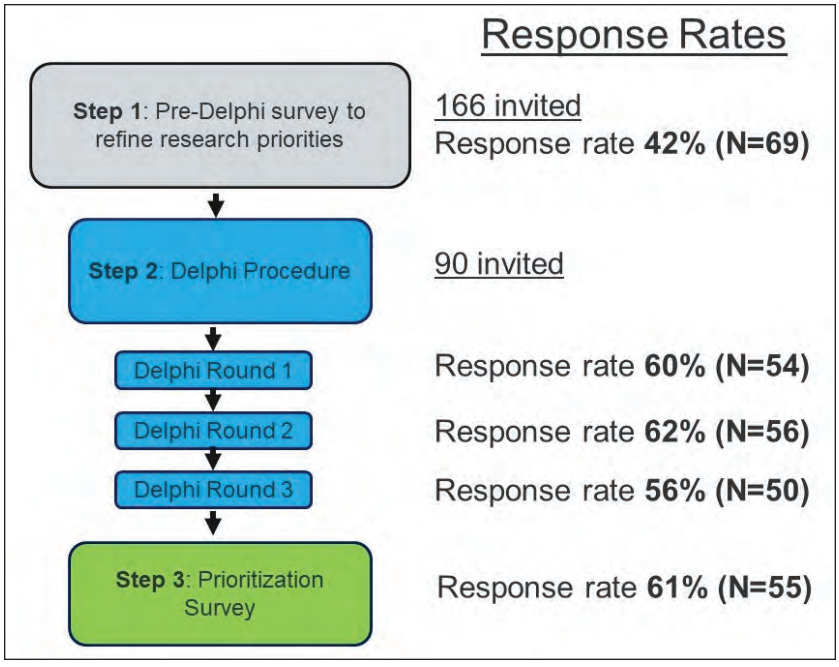

Figure 1.
Response rates for surveys

sponses to the area of research question of the prioritization survey were analyzed with descriptive statistics (frequencies, percentages and means) using Excel (Microsoft Corporation, USA). For all forced ranking questions of the prioritization survey, a weighted average ranking score was calculated by SurveyMonkey[32] where ranking weights are assigned and multiplied to the response count for each question item and are averaged across the total response counts for the question (Momentive., San Mateo, California, USA).

Ethics approval

This study received approval by the Canadian Memorial Chiropractic College (CMCC) Research Ethics Board (#1908B01, approval date 11/27/2019) prior to commencement. Each online survey from this project included a project information letter and informed consent form, and participants provided their informed consent to participate in each online survey by selecting the "accept" response at the end of the online informed consent form.

Results

Participation

The response rates for the online surveys for this study are listed in Figure 1. The pre-Delphi survey response rate was 42%. Three Delphi rounds were required, and the response rates for the three Delphi rounds and the prioritization survey were 60%, 62%, 56% and 61%, respectively.

Pre-Delphi survey – identification of research priorities

After reviewing the list of 150 research priorities identified from our previous qualitative study,[22] the study advisory committee added 11 unique research priorities and recommended the removal of seven due to redundancy. Additionally, the authorship team removed 17 research priorities related to research methods, as it was decided that research methods are determined by the specific research questions under investigation and did not constitute a specific research topic for this consensus study. As a result, 137 research priorities were included in the pre-Delphi survey to refine research priorities. The results of this survey revealed that no research priority achieved consensus for being "unimportant", so no research priorities were removed from the list. Nine research priorities were suggested by the pre-Delphi survey participants and upon consensus of the authorship team, two were deemed unique and were added to the list. A total of 139 research priorities were entered into the Delphi procedure.

Delphi procedure

The demographic characteristics of the Delphi panel collected from the round one Delphi survey is presented in Table 1. The mean age of the panel and years in clinical practice were 47.3 and 20.3 years, respectively. While participation was reported from seven provinces of Canada, the majority of participants were located in Ontario (74%), with 49 (91%) receiving their chiropractic training from the Canadian Memorial Chiropractic College. As for research training, 17 advanced research degrees (Masters and PhD) and 56 chiropractic fellowships were reported. Current and past involvement in research was reported by 21 (39%) and 26 (48%) participants, respectively. Only seven (13%) had never been involved in research. As for involvement in academia, 20 (37%) academic positions and 2 (4%) management positions at an educational institution were reported. Of the participants, 20 (37%) leadership positions in a chiropractic association/organization were reported.

In rounds one, two and three of the Delphi procedure 62, 22 and 4 research priorities (88 total) achieved consensus for being "important", respectively. No research priority achieved consensus for being "unimportant" or of "uncertain importance" in any of the Delphi rounds. Tables 2, 3, and 4 list the research priorities that reached consensus for being "important" in the first, second and third Delphi rounds, respectively. The top 6 research priorities that reached consensus for being "important" in the first round were priorities related to pursuing collaborations for research.

Table 1.

Delphi panel participant demographic characteristics (n=54), reported as n (%) unless otherwise stated[a]

Age (mean, SD)	47.3, 12.2
Years since graduating from chiropractic college (mean, SD)	20.5, 12.2
Years in clinical practice (mean, SD)	20.3, 11.9
Province of primary duties	
Ontario	40 (74%)
British Columbia	5 (9%)
Alberta	4 (7%)
Nova Scotia	2 (4%)
Manitoba	1 (2%)
Newfoundland and Labrador	1 (2%)
Quebec	1 (2%)
New Brunswick	0 (0%)
Prince Edward Island	0 (0%)
Saskatchewan	0 (0%)
Northwest Territories, Nunavut, Yukon	0 (0%)
Academic degree	
Bachelor's Degree	41 (76%)
Master's Degree	14 (26%)
PhD	3 (6%)
Doctor of Chiropractic	49 (91%)
Fellow of the College of Chiropractic Sciences	4 (7%)
Fellow of the College of Chiropractic Orthopedists	1 (2%)
Fellow of the Chiropractic College of Radiologists	0 (0%)
Fellow of the Canadian Chiropractic College of Physical and Occupational Rehabilitation	5 (9%)
Fellow of the Royal College of Chiropractic Sports Sciences	46 (85%)
Other	6 (11%)
Institution where chiropractic degree received	
Canadian Memorial Chiropractic College	49 (91%)
Université du Québec à Trois-Rivières	1 (2%)
Other: (New York Chiropractic College, Parker College of Chiropractic West, University of Western States)	4 (7%)
Holds an academic position	20 (37%)
Teaching Assistant	1 (2%)
Instructor	3 (6%)
Assistant Professor	7 (13%)
Associate Professor	2 (4%)
Full Professor	5 (9%)
Other: guest lecturer, adjunct professor	4 (7%)
Holds a management position at an educational institution	2 (4%)
Education Director	1 (2%)
Residency coordinator	1 (2%)
Holds a leadership position in a chiropractic association/organization	20 (37%)
Board member of a chiropractic association(s)/organization(s)	10 (19%)
Committee member of a chiropractic association(s)/ organization(s)	13 (28%)
Other: Journal editor-in-chief	1 (2%)
Involvement in research	
Currently involved in research	21 (39%)
Previously involved in research	26 (48%)
Never been involved in research	7 (13%)

[a] Due to rounding, may not add to 100%

Table 2.
Round 1 Delphi results – research priorities achieving consensus for being "Important".

Research priorities achieving consensus for being "Important"	Participants that ranked in the "Important" rating range
Interprofessional collaboration: sports physicians	100.0%
Interinstitutional collaboration: university/colleges	100.0%
Collaboration: funding agencies (eg. RCCSS(C), FICS, NIH, etc.)	98.1%
Interorganization collaboration: Canadian Academy of Sport & Exercise Medicine	96.3%
Sports collaborations: Sports organizations, federations & associations (eg. National Sports Organizations)	96.3%
Sports collaborations: specialized sports training & development centres (eg. Canadian Sports Institutes, Olympic training centres)	96.3%
Intervention & clinical efficacy research: exercise & rehabilitation	96.3%
Effects of intervention on specific outcomes: recovery	96.3%
Prognosis research: injury prevention	96.3%
Integration of sports chiropractic into health care teams	96.3%
Intraprofessional collaboration: chiropractic sports residents	94.4%
Interinstitutional collaboration: chiropractic educational institutions	94.4%
Effects of intervention on specific outcomes: performance	94.4%
Effects of intervention on specific outcomes: return to play/sport	94.4%
Create practice- and field-based research networks	94.4%
Intervention & clinical efficacy research: multi-modal interventions (assessing the efficacy of combining more than 1 intervention)	90.7%
Profiling an intervention: intervention timing & dosage	90.7%
Elite athletes	90.7%
Basic science & mechanism research related to rehabilitation	88.9%
Interprofessional collaboration: orthopaedic surgeons	88.9%
Intervention & clinical efficacy research: comparative effectiveness studies	88.9%
Develop guidelines and evidence-based care pathways	88.9%
Basic science & mechanism research, fields of study – biomechanics of injury	87.0%
Intraprofessional collaboration: Canadian Chiropractic Research Foundation Research Chairs (CCRF Research Chairs)	87.0%
Utilization of sports healthcare services	87.0%
Female athletes	87.0%
Basic science & mechanism research, fields of study – sports biomechanics	85.2%
Interprofessional collaboration: biomechanists	85.2%
Intervention & clinical efficacy research: functional treatment approach (eg. kinetic chain treatment)	85.2%
Prognosis research: risk factors	85.2%
Tendinopathy	85.2%
Interorganization collaboration: American College of Sports Medicine	83.3%
Diagnosis research: functional assessment/examination	83.3%
Intervention & clinical efficacy research: manipulative therapy – extremity	83.3%
Intervention & clinical efficacy research: mobilization therapy – extremity	83.3%
Masters level athletes	83.3%
Contributing to the broader sports medicine research effort	83.3%
Extremity research (in general)	83.3%
Soft tissue injuries & myofascial pain	83.3%
Interprofessional collaboration: multidisciplinary sports clinics in the community	81.5%
Interorganization collaboration: Sports Physiotherapy Canada	81.5%
Intraprofessional collaboration: chiropractic associations/ organizations (eg. Canadian Chiropractic Association, Ontario Chiropractic Association, etc.)	81.5%
Develop consensus and position statements	81.5%
Competency of sports chiropractors	81.5%
Utilization of sports chiropractic	81.5%
Intraprofessional collaboration: various sports chiropractic associations/organizations (eg. International Sports Chiropractic Federation (FICS), American Chiropractic Board of Sports Physicians (ACBSP), etc.)	79.6%
Intervention & clinical efficacy research: soft tissue therapies	79.6%
Profiling an intervention: intervention safety	79.6%
Interprofessional dynamics in sports healthcare	79.6%
Athletes with a disability	79.6%
Rotator cuff	79.6%
Basic science & mechanism research related to soft tissue therapy	77.8%
Interprofessional collaboration: physicians (as a group in general)	77.8%
Interprofessional collaboration: physiotherapists	77.8%
Diagnosis research: diagnostic studies evaluating sports chiropractors as diagnosticians	77.8%
Intervention & clinical efficacy research: manipulative therapy – spinal	77.8%
Research about sports healthcare teams	77.8%
Research on specific sports (e.g. soccer, baseball, basketball, etc.)	77.8%
Basic science & mechanism research related to spinal manipulative therapy	75.9%
Sports collaborations: non-profit organizations involved in sport (eg. AthletesCan, Own the Podium)	75.9%
Pediatric athletes	75.9%
Concussion	75.9%
Total	**62**

Table 3.
Round 2 Delphi results – research priorities achieving consensus for being "Important"

Research priorities achieving consensus for being "Important"	Participants that ranked in the "Important" rating range
Low back pain	89.3%
Sports chiropractors as diagnosticians	85.7%
Neck pain	83.9%
Interorganization collaboration: Canadian Physiotherapy Association	82.1%
Mobilization therapy – spinal	82.1%
Athletic field services (eg. Multi-sport games, team care & travel with athletes, pre-participation examinations, emergency care, field care)	82.1%
Basic science & mechanism research related to extremity manipulative therapy	80.4%
Injury incidence & prevalence	80.4%
Cost-effectiveness research	78.6%
Interorganization collaboration: Canadian Society of Exercise Physiologists	76.8%
Sports teams & clubs	76.8%
Neuropathies	76.8%
Thoracic spine pain	76.8%
Interprofessional collaboration: Exercise physiologists	75.0%
Diagnosis research (such as diagnostic accuracy studies, or specific tests or diagnostic approaches)	75.0%
Clinical prediction rules	75.0%
Injury surveillance	75.0%
Understanding the sports chiropractic patient	75.0%
Physical activity research (eg. exercise is medicine)	75.0%
Ankle sprains	75.0%
Labral injuries of the hip	75.0%
Patellofemoral pain syndrome	75.0%
Total	**22**

Table 4.
Round 3 Delphi results – research priorities achieving consensus for being "Important"

Research priorities achieving consensus for being "Important"	Participants that ranked in the "Important" rating range
Knowledge translation research in the sports setting	80.0%
Research supporting the strategic planning for the sports chiropractic field	78.0%
Hamstring strains	78.0%
Sprains & strains (in general)	84.0%
Total	**4**

Prioritization survey

Upon reviewing the 88 research priorities achieving consensus for being "important" in the Delphi procedure, three research priorities were not included in the prioritization survey as they were deemed to be related to research methodology and not research topics. After amalgamating similar research priorities to remove redundancies, the prioritization survey was comprised of 28 research priorities for area of research, 21 for collaborations, and 13 for specific conditions.

The prioritization results of the area of research category are listed in Table 5. The top three areas of research were "effects of interventions on athletic outcomes (e.g. athletic recovery, return to play/sport and athletic performance)", "research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams)" and "clinical research: spinal manipulative and mobilization therapy".

The prioritization results for collaborations are listed in Table 6. The highest ranked interprofessional and interorganizational collaborations to pursue were with "sports physicians" and the "Canadian Academy of Sport & Exercise Medicine", respectively. The highest ranked intraprofessional collaboration was with "sports chiropractic associations/organizations". "Sports organizations, federations & associations (e.g. national sports organizations)" was the highest ranked sports community collaboration, and "universities and colleges" was identified as the highest ranked academic collaboration. For the prioritization of specific conditions that reached consensus in the Delphi procedure (Table 7), the top five ranked specific conditions were "low back pain", "neck pain", "concussion", "soft tissue injuries & myofascial pain", and "thoracic spine pain".

Discussion

To our knowledge, this is the first study to investigate consensus on research priorities for the Canadian sports chiropractic field. The top five priority-ranked areas of research were 1) effects of interventions on athletic outcomes (e.g. athletic recovery, return to play/sport and athletic performance), 2) research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams), 3) clinical research: spinal manipulative and mo-

Table 5.
Prioritized list of areas of research (N=55)

Prioritized list of areas of research	Participants who selected the research priority as a "top 10"
Effects of interventions on athletic outcomes (e.g. athletic recovery, return to play/sport and athletic performance)	63.6%
Research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams)	54.6%
Clinical research: spinal manipulative and mobilization therapy	50.9%
Utilization of sports healthcare services (e.g. utilization of sports chiropractic)	50.9%
Research conducted on specific conditions (e.g. concussion, tendinopathy, hamstring strains, ankle sprain, neck pain, low back pain)	50.9%
Develop guidelines and evidence-based care pathways	49.1%
Clinical research: multi-modal interventions (assessing the efficacy of combining more than 1 intervention)	45.5%
Clinical research: extremity manipulative and mobilization therapy	45.5%
Injury prevention and risk factors	45.5%
Clinical research: exercise & rehabilitation	43.6%
Clinical research: functional treatment approach (eg. kinetic chain treatment)	41.8%
Clinical research: soft tissue therapies	40.0%
Diagnosis research: functional assessment	38.2%
Profiling an intervention: intervention timing, dosage and safety	38.2%
Special athletic populations (elite, female, masters, pediatric, athletes with disabilities)	38.2%
Competency of sports chiropractors	36.4%
Physical activity research (e.g. exercise is medicine)	32.7%
Injury surveillance, incidence and prevalence	27.3%
Clinical research: comparative effectiveness studies	27.3%
Athletic field services (e.g. multi-sport games, team care & travel with athletes, pre-participation examinations, emergency care, field care)	27.3%
Knowledge translation research in the sports setting	25.5%
Understanding the sports chiropractic patient	25.5%
Developing clinical prediction rules	21.8%
Cost-effectiveness research in sports healthcare	20.0%
Basic science research: biomechanics (e.g. biomechanics of Injury and sports biomechanics)	18.2%
Basic science research: manipulative therapy (SMT, EMT)	14.6%
Basic science research: soft tissue therapy	12.7%
Basic science research: rehabilitation	5.0%

Table 6.
Ranked list of collaborations that reached consensus for being "important" (N=55)

Collaboration	Ranking score
Interprofessional	
Sports physicians	5.71
Orthopaedic surgeons	3.58
Physiotherapists	3.38
Physicians (as a group in general)	3.29
Biomechanists	2.53
Exercise physiologists	2.51
Interorganizational	
Canadian Academy of Sport & Exercise Medicine	4.58
Sports Physiotherapy Canada	3.36
American College of Sports Medicine	2.69
Canadian Physiotherapy Association	2.20
Canadian Society of Exercise Physiologists	2.16
Intraprofessional	
Sports chiropractic associations/organizations	2.85
Chiropractic sports sciences residents	2.85
Canadian Chiropractic Research Foundation research chairs	2.45
Chiropractic associations/organizations (eg. Canadian Chiropractic Association, etc.)	1.84
Sports community	
Sports organizations, federations & associations (eg. national sports organizations, etc.)	3.24
Specialized sports training & development centres (eg. Canadian Sports Institutes, etc.)	3.04
Non-profit organizations involved in sport (eg. AthletesCan, Own the Podium)	1.93
Sports teams & clubs	1.80
Academic	
Universities & colleges	1.69
Chiropractic educational institutions	1.31

Table 7.
Ranked list of specific conditions that reached consensus for being "important" (N=55)

Specific condition	Ranking score
Low back pain	9.60
Neck pain	9.25
Concussion	9.07
Soft tissue injuries & myofascial pain	8.75
Thoracic spine pain	7.31
Tendinopathy	7.29
Research on specific sports (e.g. soccer, baseball, basketball, etc.)	6.84
Rotator cuff	6.35
Neuropathies	6.02
Hamstring strains	5.42
Patellofemoral pain syndrome	5.40
Labral injuries of the hip	5.38
Ankle sprains	4.33

bilization therapy, 4) utilization of sports healthcare services (e.g. utilization of sports chiropractic), and 5) research conducted on specific conditions. The highest ranked specific conditions were 1) low back pain, 2) neck pain, 3) concussion, 4) soft tissue injuries & myofascial pain, and 5) thoracic spine pain. Research collaborations were an important topic in this study, as 23 of the 88 research priorities achieving consensus for being "important" were related to pursuing research collaborations, with 100% of the Delphi panel rating collaborations with sports physicians and universities/colleges, as "important" research priorities.

When comparing our results to previous chiropractic Delphi studies[1,3] that prioritized research, we found our Delphi panel prioritized areas of research that were unique to the sports-context, such as the effects of interventions on athletic outcomes (e.g. athletic recovery, return to play/sport and athletic performance), research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams), and the utilization of sports healthcare services (e.g. utilization of sports chiropractic). These research priorities were not identified in previous chiropractic research priority Delphi studies.[1,3] Our results provide evidence that chiropractors working in sport have context-specific research requirements that necessitate a discipline-specific research agenda to direct research initiatives to improve care delivery and inform strategies for interprofessional collaboration.

While we identified research priorities unique to the sports chiropractic field, we did find overlapping research priorities with those from general chiropractic practice.[1,3] The Delphi study by Rubinstein *et al*.[3] identified "initiation and promotion of collaborative research efforts" as one of their top research priorities, which is consistent with our study where participants prioritized research collaborations, as evidenced by the 23 collaboration research priorities reaching consensus for being "important". Similarly, French *et al*.[1] identified "integration of chiropractic care into multi-disciplinary settings" as the highest prioritized research item. In the present study, the research priority "research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams)" can be viewed as a specific application of the research priority identified by French *et al*.,[1] but applied to the sport context. It is not surprising that chiropractors working in sport share common research priorities with general chiropractors, as some areas of research (such as spinal manipulation research) has applicability for the entire profession, including its sub-disciplines. It is important to recognize areas of overlapping priorities in general and sports-focused chiropractic research, as collaborative research efforts can improve investigative capacity within these priority areas.

To our knowledge, the only other sports healthcare profession that published their research prioritization efforts is the athletic training profession in the United States of America, by Eberman *et al*.[2] These authors used a combination of focus group sessions, content-expert review, and a web-based survey to produce a research agenda. They identified research priorities categorized into five major research categories: health care competency, vitality of the profession, health professions education, health care economics, and health information technology. Certain research priorities they identified, such as establishing evidence to support return-to-life/play/work decisions, preventing musculoskeletal injuries, and determining the effectiveness of interprofessional practice, are similar to ones identified in our Delphi study (effects of interventions on athletic outcomes, injury prevention and risk factors, and research about sports healthcare teams). These research areas may represent opportunities for interprofessional collaboration to advance research in sport.

Despite these similarities, differences in priority areas exist between Eberman *et al*.[2] and this present study. This is likely due to profession-specific factors and the overall purpose of each respective study. Eberman *et al*.[2] published a research agenda, while the intent of this present study is to report on one aspect of research agenda development – the Canadian sports chiropractic perspective. This Delphi study is only one input into developing a research agenda for Canadian sports chiropractors, as there are other considerations when establishing a research agenda for a field of study, such as obtaining input from the discipline's stakeholders and appraising its current research capacity and capability.

Research priority setting frameworks[21,33,34] recommend the active involvement of stakeholders in the research priority setting process when producing a research agenda. Involving a diverse range of stakeholders in the prior-

ity setting process can improve the relevance and legitimacy of research[21,35], help to ensure funding decisions and research meet critical evidence gaps to inform decision making[35], facilitate shared responsibility and accountability in implementing the research agenda[35], and aid in the diffusion of research findings into healthcare settings to achieve better health outcomes[36]. Stakeholders that can be engaged to set a research agenda for Canadian chiropractors working in sport can include athletes, their sports organizations, funding bodies, chiropractic associations, and academic institutions involved in the research effort.

This present study included input from intra-professional stakeholders in the Delphi panel by including clinical, leadership and research experts; however, it did not include stakeholders external to the profession. We chose not to include external stakeholders in this present study, as our aim was to understand the sports chiropractic perspective on research priorities. Additionally, the Delphi process is a consensus method that utilizes group interaction via questionnaires and not through direct face-to-face interactions.[28] It is possible certain external stakeholders with limited knowledge about research or the sports chiropractic field may find it difficult to participate in a consensus process without having the ability to interact in real-time. It may be more relevant to engage with stakeholders with consensus methods that utilize direct face-to-face participant interaction (e.g. face-to-face consensus meetings and the nominal group technique) to provide the opportunity for real-time discussions to clarify statements and provide meaningful feedback to the research prioritization process. As part of a qualitative study exploring athletes' expectations and experiences of care received by sports chiropractors, athletes' views on research direction for the sports chiropractic field was explored by asking them what areas of research the sports chiropractic profession should focus on. The athletes interviewed suggested research that focused on understanding the mechanisms behind how an injury occurs, how to prevent injuries, and how care can aid in enhancing their performance.[23] This data provides an initial understanding of the athlete's perspective on research direction for the sports chiropractic field and can be used in combination with this present study's findings to inform decisions to set an eventual research agenda.

Similar to athletes, the perspective of other stakeholders from the sports community, such as sports organizations, may provide valuable input when setting a research agenda. Finch *et al*.[37] identified differing research priorities amongst researchers from the International Olympic Committee research centres and international sporting federations. These authors recommend that sports prevention research should involve stakeholders from the sports community at the outset to ensure the incorporation of sport-specific contextual influences into the research, as this will increase the likelihood for more wide-scale adoption of the research by the sports community.[37,38] The inclusion of representatives from the sports community in setting a research agenda for Canadian sports chiropractors will not only inform the sports chiropractic discipline of its stakeholders' unique perspective, but it can facilitate more participatory research partnerships with the sports community in implementing the research agenda.

Lastly, while research priorities were identified and ranked in this present study, these research topics were not evaluated for their feasibility as to whether the Canadian sports chiropractic field has the resources to conduct such investigations. The authors of the European research prioritization Delphi study[3] provided commentary on the challenges of conducting research on targeted priorities if a field of study does not have the resources to achieve such research aspirations. This highlights the importance of conducting research capacity evaluations of a field of study when setting research agendas and plans for implementation. Feasibility assessment of the identified research priorities is beyond the scope of this present study, as this project is one of multiple studies being conducted to inform both a research agenda and research plan for the Canadian sports chiropractic field. Presently, both quantitative and qualitative investigations are being conducted to understand the research capacity and capabilities of the Canadian sports chiropractic field. The results of these investigations can help inform what research areas are feasible to prioritize when setting a research agenda. They can also direct the development of an accompanying implementation strategy by providing guidance for areas to pursue for investment, training, and partnership.

As a next step in setting a research agenda, our research group proposes conducting a multi-stakeholder study in partnership with Canadian sports chiropractic experts to co-produce a research agenda for Canadian chiropractors working in sport. Such an investigation can utilize the re-

sults from the present Delphi study, the qualitative data obtained from athletes' views on research direction,[23] the data obtained from the research capacity evaluations of the sports chiropractic field, in addition to further stakeholder suggestions for research priorities, as inputs to make decisions on setting a research agenda. Stakeholder engagement in this process can be optimized using consensus methods that involve face-to-face participant interaction, such as the nominal group technique, to provide opportunities to deliberate such important decisions. Recently, this approach was used to co-produce a multi-stakeholder research agenda for medicines optimisation.[39] The advantage of such a study is the co-production of a research agenda that is relevant to all stakeholders, leading to a greater likelihood that the implementation of the research agenda will have a societal impact to the communities chiropractors working in sport serve.

Strengths and limitations

There are strengths and limitations with this present study. As previously stated, this study only included sports chiropractic experts as part of the Delphi panel and did not include stakeholders external to the discipline. The intent of this study was to determine consensus on research priorities from sports chiropractic experts, and separate investigations will be conducted to obtain stakeholder input to inform the research agenda. One of the strengths of this present study was our multiple approaches to identify experts for the Delphi panel. This process involved obtaining clinician and leadership lists from the RCCSS(C), conducting literature searches to identify researchers, and seeking nominations and rankings of experts from a study advisory committee. Analyzing the demographics of our Delphi panel, we believe our sampling methods achieved our goal of recruiting adequate representation from the Canadian sports chiropractic field. The mean years of practice was 20.5 years, 37% held academic positions, and 37% held leadership positions in the profession. For research representation, 17 advanced research degrees (14 Masters, 3 PhD) and 56 chiropractic fellowships were reported. Only seven participants (13%) reported never being involved in research. One limitation is the small participation of those with PhD qualifications in the present study, which could impact our results as those with PhD training may be better positioned to judge the effort required to conduct research in certain priority areas. Preliminary unpublished data from our research capacity evaluations of the Canadian sports chiropractic field informs that there is a limited number of individuals in the field with PhD qualifications, which represents a key area where investment should be made.

While we are confident in our identification of experts to participate in the Delphi panel, we did not conduct maximum variation sampling to ensure equal representation of participants with certain demographic characteristics. Also, we did not collect participant sex or gender in the demographic section of our survey. This could possibly lead to either an over- or under-representation of participants with certain demographic characteristics, such as geographical location, years in practice, or type of expertise. Specifically, our Delphi panel was over-represented from the province of Ontario (74%) with the majority receiving their chiropractic training from CMCC (91%).

Another strength of this study was the comprehensive list of research priorities (n=139) that were entered into the Delphi procedure. These research priorities were identified from a separate qualitative study[22] and were further refined by the present study's advisory committee and pre-Delphi survey. While we are confident the research priorities list was robust, this led to a large amount of research priorities reaching consensus for being "important" (n=88) at the completion of the Delphi procedure. Previous Delphi research prioritization studies conducted for the chiropractic profession[1,3] took an opposite approach where lists of individual research priorities were collapsed into larger amalgamated research priorities prior to entering them into the Delphi procedure. In the present study, we entered all identified research priorities into the Delphi procedure, and then amalgamated similar research priorities that reached consensus after the Delphi procedure, before ranking them in the final prioritization survey. It is uncertain what the impact either approach would have on the overall results of the final prioritization of research priorities.

End users of Delphi studies should be aware the results obtained from this procedure are influenced by the methodological decisions applied. Presently, there is no consensus on an optimal strategy to use when providing participants with feedback between voting rounds, and it is unclear how this could influence the results of Delphi studies.[40] In our study, participants were provided with feedback in the form of summary results using descriptive

statistics.[9] One limitation is we did not ask participants to provide their written comments to justify their rankings. If we had captured this data, it may have enhanced the group interaction process and provided participants with more context to judge their decisions in subsequent voting rounds, potentially influencing the results.

Recently, investigations[41–43] have shown that different rating scales and consensus thresholds can impact the results of the Delphi process. Remus *et al*.[41] investigated the difference between the five- and nine-point Likert scales in a Delphi study to determine a core outcome set for pelvic girdle pain and found the five-point scale resulted in more items that reached consensus. In a similar study, Lange *et al*.[42] compared three-, five-, and nine-point Likert scales in a Delphi study to determine global treatment goals for total knee arthroplasty. The correlations between the rating scales ranged from 0.65 to 0.74 with more items reaching consensus with the nine-point scale. While the authors state none of the scales showed general superiority according to absolute and relative reliability measures, the nine-point scale reached the highest weighted kappa (0.78) for test-retest reliability. Additionally, De Meyer *et al*.[43] compared three- and nine-point Likert scales and different consensus threshold levels in a Delphi study to determine a core outcome set for incontinence-associated dermatitis. These authors reported the nine-point scale resulted in almost twice as many outcomes selected compared to the three-point scale. With respect to consensus thresholds, their results suggest a 60% consensus level might not be strict enough, but a 90% consensus level is likely too strict. They suggest thresholds of 70% or slightly higher as a reasonable compromise. As for recommendations for the use of rating scales, both Lange *et al*.[42] and De Meyer *et al*.[43] posit that the choice of the rating scale should reflect the context-based research question being evaluated, and it may be useful to get a first impression of a group opinion with a more wide-ranging rating scale (e.g. nine-point rating scale) to inform a subsequent consensus process, such as a face-to-face consensus meeting where a three-point scale might be preferred when determining a final consensus. Our present study is aligned with these recommendations as it utilized a nine-point rating scale for the Delphi procedure, which informed a subsequent prioritization survey to rank-order the items that reached consensus for being "important". The consensus level for the current study was set a priori at 75% which is in line with the recommendations by De Meyer *et al*.[43] Additionally, Delphi studies involving a prioritization survey of the consensus items produced by the Delphi procedure have used differing methods.[1,3] The Delphi studies conducted for the chiropractic profession by Rubinstein *et al*.[3] used a five-point scale and French et al[1] used a survey that employed conjoint analysis methods to obtain a final prioritized list of research priorities. In the present study, we asked participants to select the "10 most important" research priorities from a list of priorities and calculated the percentage of participants who selected each priority as a "10 most important" to determine the priority ranking for the area of research category. To prioritize the collaboration and specific conditions categories, we used a forced-ranking list and calculated a weighted average ranking score. It is possible that our results could have differed if we used an alternate rating scale, set a different consensus threshold, or used different methods for the prioritization survey. Our results should be interpreted within the context of our methodological decisions

Conclusion

This is the first study to involve diverse experts from the Canadian sports chiropractic field to investigate consensus on research priorities. The top three priority-ranked areas of research were "effects of interventions on athletic outcomes (e.g. athletic recovery, return to play/sport and athletic performance)", "research about sports healthcare teams (e.g. interprofessional dynamics in sports healthcare teams, integration of chiropractic in sports healthcare teams)" and "clinical research: spinal manipulative and mobilization therapy". Consensus on research collaborations were determined, with 100% of the Delphi panel identifying collaborations with sports physicians and universities/colleges as important research priorities. These results will be used to inform stakeholder consultations to establish a research agenda for Canadian chiropractors working in sport.

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Appendix 1.
RCCSS(C) sports-focused research definition

Sports-focused research is a field of research directly related or relevant to anyone involved in the sport, athletic, or exercise community. These topics may include but are not limited to the following: injuries, injury prevention, treatment, rehabilitation, biomechanics, performance, assessment metrics, nutrition, epidemiology, diagnostic imaging, emergency care, athletic event coverage, team travel, education, exercise physiology, and sport psychology.

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Prevalence of shoulder problems in youth swimmers in Ontario

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Background: *Shoulder problems are common in swimmers. Previous research has focused on elite swimmers. Our research questions were: 1) what is the prevalence of shoulder problems among Ontario age group swimmers and 2) how does prevalence relate to age, sex and years of experience?*

Methods: *A cross sectional survey was administered to youth swimmers from two Ontario clubs. Oslo Sports Trauma Research Centre Overuse Injury Questionnaire (OSTRC) was used to assess four-week prevalence of shoulder problems. Prevalence (%) with 95% confidence intervals (95% CI) was constructed and prevalence across age, sex and years of experience was investigated using cross-tabulations and chi-square tests.*

Results: *There were 83 surveys completed (response rate 50%). The 4-week prevalence of shoulder pain was*

Prévalence des problèmes à l'épaule chez les jeunes nageurs de l'Ontario

Contexte : *Les problèmes à l'épaule sont courants chez les nageurs. Les recherches antérieures ont porté sur les nageurs d'élite. Nos questions de recherche étaient les suivantes : 1) quelle est la prévalence des problèmes à l'épaule chez les nageurs des groupes d'âge de l'Ontario et 2) comment la prévalence est-elle liée à l'âge, au sexe et aux années d'expérience?*

Méthodologie : *Une enquête transversale a été menée auprès des jeunes nageurs de deux clubs de l'Ontario. Le questionnaire sur les blessures de surmenage de l'Oslo Sports Trauma Research Centre (OSTRC) a été utilisé pour évaluer la prévalence des problèmes à l'épaule sur quatre semaines. La prévalence (%) avec des intervalles de confiance à 95 % (IC 95 %) a été établie et la prévalence en fonction de l'âge, du sexe et des années d'expérience a été étudiée à l'aide de tableaux croisés et de tests du chi carré.*

Résultats : *L'enquête a obtenu un taux de réponse de 50 % (83 questionnaires remplis). La prévalence des*

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35% (95% CI 25%, 45%). Shoulder problems were not significantly related to age, sex or years of experience.

Conclusion: *These results can inform future studies on injury prevention and risk mitigation strategies in swimmers.*

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KEY WORDS: age group, shoulder injury, sports, swimming, youth athlete

douleurs à l'épaule sur 4 semaines était de 35 % (IC 95 % 25 %, 45 %). Les problèmes à l'épaule n'étaient pas considérablement liés à l'âge, au sexe ou aux années d'expérience.

Conclusion : *Ces résultats peuvent éclairer les futures études sur la prévention des blessures et les stratégies de réduction des risques chez les nageurs.*

(JCCA. 2022;66(3):244-252)

MOTS CLÉS : groupe d'âge, blessure à l'épaule, sports, natation, jeune athlète

Introduction

Swimming has continued to gain interest in Canada as a competitive sport in part due to the success of the Canadian 2016 Olympic swim team, with a total of 63,484 swimmers registered in Canada in 2019.[1] Age-group swimmers (under 18 years old) make up the majority of these athletes with a total of 33,599 swimmers registered in Canada in 2019.[1] Swimming Canada's Long Term Athlete Development (LTAD) plan has a goal to keep youth active in sport for life with an emphasis on development.[2,3] Appropriate athlete development aims to develop skills and performance while reducing the potential for injury to keep youth safe and able to continue participation. Most evidence on the prevalence of musculoskeletal concerns in swimmers has focussed on those at the elite level, with much less being known about the prevalence of musculoskeletal concerns in developing age-group swimmers.

The shoulder joint has been reported as the most common site of injury in competitive swimmers in different age groups, levels and data collection environments (i.e. practice or competition).[4-9] Studies conducted at championship meets found four-week shoulder injury prevalence of 13% at the 2015 Fédération Internationale de Natation (FINA) World Championships[4] while at the Brazilian National Championship meet, shoulder injury point prevalence was 9% and 12-month shoulder injury prevalence was 26%[4,5]. Studies conducted at competitions miss swimmers who are injured and unable to attend the meet due to their injuries. This highlights the importance of out of competition studies.[4] Two studies looked at injury incidence during the season among National Collegiate Athletic Association (NCAA) swimmers in the U.S. and found shoulder injuries comprised 35% to 46% of the total injuries in men and 31% to 33% of the total injuries in women.[6,7]

Most studies of shoulder pain and injuries have been conducted in the elite swimmer population. Recognizing that the majority of competitive swimmers are in the age-group category, understanding prevalence in age-group swimmers is necessary to better understand how to provide safe programs. Two studies have reported on shoulder problems in age-group swimmers. A study on Australian swimmers followed athletes for 12 months and found overall significant shoulder pain incidence was 38%.[10] A cross sectional study collected data during practice from Italian swimmers and determined the prevalence of shoulder pain over 12 months was 51%.[11] Understanding prevalence of shoulder problems in Canadian swimmers is the first step to inform education of coaches and programs, and ultimately to ensure safe sport.

In a recent systematic review, Hill and colleagues[12] identified, critically appraised and synthesized the literature on potential risk factors for shoulder injuries in swimmers. The factors studied included demographics (e.g., sex, age, competitive level, years of experience), shoulder joint anatomy and strength measures (e.g., range of motion, strength, muscle activity, flexibility), activity related factors (e.g., equipment use, training volume, stroke speciality, breathing side) and musculoskeletal anatomy (e.g., scapular kinematics, core stability, pectoral length).[12] Some of the training-related risk factors in the review are modifiable by the coach and can

potentially prevent shoulder pain or injuries if the need for prevention exists. However, based on their critical appraisal of the studies found, no risk factors had a high level of certainty. There was a moderate level of certainty for joint laxity, internal/external rotation, previous shoulder pain and competitive level posing a risk. All remaining factors they considered had a low level of certainty as risk factors for shoulder pain and injury in swimmers. That is, there is insufficient high-quality evidence to support or refute which of these potential factors (years of experience, training load, volume, intensity, gender, age, equipment, breathing side, scapular strength, core stability, pectoral length etc.) are indeed risk factors for shoulder injury.

A goal of Swimming Canada is to provide safe sport to athletes.[1] Safe sport is ensuring the physical and mental well-being of athletes, including preventing injury. The Long Term Athlete Development (LTAD) model has the goal to keep athletes active in sport for life, develop elite athletes and develop physical literacy.[13] LTAD provides a framework based on growth, maturation, trainability, and sports systems to emphasize the development of skills instead of winning, to prevent overtraining, burn out and lost potential.[2,14] Overuse injuries are a common reason for athletes to drop out of sport.[15] Therefore, to make sport safe, understanding prevalence and risk factors is necessary.

The primary objective of our study was to determine the four-week period prevalence of shoulder problems among Ontario age-group swimmers. The secondary objective was to determine if prevalence varies by age group, sex and years of swimming experience.

Methods

Study design

This was a cross sectional survey administered in December 2020 to age-group swimmers in Ontario. The study was reviewed and received approval by the Canadian Memorial Chiropractic College (CMCC) Research Ethics Board (REB) (REB #2004B02).

Participants and recruitment

Three Ontario swim clubs originally agreed to participate. Inclusion criteria were: 12 to 18 years old competitive swimmers, from one of the three clubs, who had been training for at least 10 to 12 weeks at time of survey administration. Demographics of this population included approximately equal numbers of boys and girls, middle to upper class socioeconomic status, mixed ethnicities, and following Swim Canada LTAD. The original plan for recruitment and administration was for the study primary investigator (PI) to attend regular swim practices for each swim group from the participating clubs, explain the study, answer any questions, recruit swimmers and administer the questionnaire at practice using paper and pencil administration. Due to COVID-19 restrictions, an amendment to the protocol was made to administer the survey online using SurveyMonkey (SurveyMonkey Inc., San Mateo, California, USA. www.surveymonkey.com). Swimmers were recruited during a training session which was being conducted remotely at the time of survey administration. Remote practices began 14 days prior to survey administration, but all recruited swimmers had been participating in in-water training for at least 10 to 12 weeks prior to survey administration. Parents provided consent and swimmers provided assent at the time of survey administration and the swimmers were prompted to continue to the online survey after assenting to participate. The link was emailed to swimmers post-Zoom practice for any swimmer interested in participating, but unable to get parental consent at the time of the Zoom session. A post practice reminder email was sent from the coaches two days after initial data collection, and a final reminder was sent seven days from the initial data collection. The SurveyMonkey link remained open for four weeks.

Sample size and response rate goal

Initially a total of 300 eligible swimmers were potential participants from the three participating clubs. Our goal was to recruit 70% of these eligible swimmers, which would provide 210 respondents. Shoulder problem prevalence estimation was 20%, based on the study conducted at the Word Championships.[4] The confidence interval width for an estimated 20% four-week period prevalence of shoulder problems with 210 respondents would have been +/- 5.4% .

Survey instrument

The primary outcome measure was shoulder problem prevalence in the past four weeks. A shoulder problem

was defined as pain or a diagnosed injury. The Oslo Sports Trauma Research Centre (OSTRC) questionnaire was used because the questions were simple, the questionnaire had been validated, and a previous study on injury prevalence in swimmers used the same questionnaire (Table 1).[4,16] Four questions from the OSTRC questionnaire assessed four aspects of shoulder problems covering pain, participation impact, performance impact, and training volume impact over the previous four weeks (questions 8 to 11 in Table 1). The period of four weeks was selected to keep consistent with the study that used the OSTRC questionnaire at the World Championships.[8]

Table 1.
Survey

Question		Answers
1	Parental consent	a. Yes (continues on to question 2). b. No (ends the survey)
2	Swimmer assent	a. Yes (continues on to question 3). b. No (ends the survey)
3	Age group	a. 12 and under b. 13-14 c. 15-16 d. 17 and over
4	Swim group	a. Swimmers typed in their swim group name
5	Sex	a. Female b. Male c. Prefer not to answer
6	Stroke specialization	a. Butterfly b. Backstroke c. Breaststroke d. Freestyle e. Individual medley f. No specialization
7	Years experience	a. Less than 3 b. 3-5 years c. 5-7 years d. 7-10 years e. More than 10 years
8	Have you had any difficulties participating in normal training and competition due to shoulder problems during the past 4 weeks?	a. full participation without shoulder problems b. full participation with some shoulder problems c. reduced participation due to shoulder problems d. could not participate due to shoulder problems
9	To what extent have you reduced your training volume due to shoulder problems in the past 4 weeks?	a. no reduction b. to a minor extent c. to a moderate extent d. to a major extent
10	To what extent have shoulder problems affected your performance during the past 4 weeks?	a. no effect b. to a minor extent c. to a moderate extent d. to a major extent
11	To what extent have you experienced shoulder pain related to your sport during the past 4 weeks?	a. no pain b. mild pain c. moderate pain d. major pain

Table 2.
Count and percentage by each question outcome.

Category		Count	% (95% CI)
Parental consent *based on parents who opened the survey and answered	Yes	*90/166	54% (47%, 62%)
	No	1/166	0.6% (–0.6%, 2%)
Swimmer assent *4 swimmers did respond to the assent	Yes	*86/86	100% (100%, 100%)
	No	0/86	0% (0%, 0%)
Sex *1 swimmer did not continue the survey	Female	*44/85	52% (41%, 63%)
	Male	40/85	47% (36%, 58%)
	Prefer not to answer	1/85	1% (–1%, 4%)
Age group *2 swimmers who gave assent did not completed the full survey	12 and under	31/84	37% (27%, 47%)
	13-14	28/84	33% (23%, 43%)
	15-16	19/84	23% (14%, 32%)
	17 and over	6/84	7% (2%, 13%)
Swim experience	Less than 3 years	9/84	11% (4%, 17%)
	3-5 years	37/84	44% (33%, 55%)
	5-7 years	20/84	24% (15%, 33%)
	7-10 years	16/84	19% (11%, 27%)
	More than 10 years	2/84	2% (–0.8%, 5%)
Stroke *1 swimmer didn't continue the survey	Backstroke	10/83	12% (5%, 19%)
	Breaststroke	15/83	18% (1%, 26%)
	Butterfly	7/83	8% (2%, 14%)
	Freestyle	19/83	23% (14%, 32%)
	Medley	12/83	15% (7%, 22%)
	No specialization	20/83	24% (15%, 33%)
Participation impacted	Full with no pain	56/83	68% (57%, 78%)
	Full with some pain	23/83	28% (18%, 37%)
	Reduced participation	4/83	5% (0.2%, 9%)
	Overall	27/83	33% (22%, 43%)
Performance impacted	No effect	54/83	65% (55%, 75%)
	Minor effect	28/83	34% (24%, 44%)
	Major effect	1/83	1% (–1%, 4%)
	Overall	29/83	36% (25%, 45%)
Volume impacted	No reduction	64/83	77% (68%, 86%)
	Minor reduction	17/83	21% (12%, 29%)
	Moderate reduction	2/83	2% (–0.8%, 6%)
	Overall	19/83	23% (14%, 32%)
Pain	No Pain	54/83	65% (55%, 75%)
	Mild Pain	25/83	30% (20%, 40%)
	Moderate Pain	3/83	4% (–0.4%, 8%)
	Severe Pain	1/83	1% (–1%, 4%)
	Overall	29/83	35% (25%, 45%)

Data preparation and analysis

Data extracted from SurveyMonkey was indexed by a study identification number and stored on a secured password protected server located at Canadian Memorial Chiropractic College (CMCC). Prevalence of shoulder problems from each of the four OSTRC questions was described as a percentage with a 95% confidence interval (CI). Variation in prevalence for each question was examined by age group, sex and years of experience with cross-tabulations and chi-square test statistics. Chi-square tests with a p-value < 0.05 were considered statistically significant. The analysis of the study was generated using SAS software v9.4. (Copyright © 2012-2018, SAS Institute Inc., Cary, NC, USA. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.) To evaluate non-responder bias age, sex and swim group data was collected and compared to the responder characteristics.

Results

Three clubs initially agreed to participate (n=300), but due to the COVID-19 pandemic only two clubs were able to participate (n=166) and parental consent was given for 90 swimmers to participate. Swimmer assent was provided by 86 swimmers, two swimmers completed the assent but did not complete the full survey, with one of these swimmers completing only one question. The completed survey response rate was 50% (n=83/166).

Table 2 describes the survey respondents by age group, sex, swim experience, stroke, consent, assent and responses to all four questions from the OSTRC. Approximately equal number of subjects were female (n=44/84) and male (n=40/84). Almost half (44%) of the swimmers had three to five years of experience. The total number of swimmers in each age group decreased as the age of the swimmers increased.

The prevalence of any shoulder pain was 35% (95% CI 25%, 45%) based on answering question number eleven in Table 1. The prevalence of participation impact was 33 % (95% CI 22%, 42%) based on answering question number eight in Table 1. The prevalence of performance impact was 36 % (95% CI 25%, 45%) based on answers to question number ten in Table 1. The prevalence of volume impact was 23 % (95% CI 14%, 32%) based on answers to question number nine in Table 1.

Table 3 presents cross tabulations of shoulder problem prevalence by age group, sex, and swim experience to compare prevalence for all four OSTRC questions. Based on the chi-square statistics reported, there were no statistically significant relationships between prevalence of shoulder problems and age, sex or years of experience. However, the following orders were seen in the data, but not found to be statistically significant. The prevalence was highest for all four questions in the 12 and under age group followed by the 13 to 14 age group for three ques-

Table 3.
Cross tabulations of swimmer characteristics by shoulder measures

	Participation Impacted	Performance Impacted	Volume Impacted	Pain
Age Group				
Under 12 (n=31)	42% (n=13)	42% (n=13)	32% (n=10)	42% (n=13)
13-14 (n=28)	25% (n= 7)	36% (n=10)	21% (n= 6)	39% (n=11)
15-16 (n=18)	33% (n= 6)	33% (n= 6)	6% (n= 1)	26% (n= 5)
17 & Over (n=6)	17% (n= 1)	17% (n= 1)	33% (n= 2)	0% (n= 0)
	χ^2 = 2.38 df = 3 p = 0.49	χ^2 = 1.33 df = 3 p = 0.72	χ^2 = 4.77 df = 3 p = 0.19	χ^2 = 4.33 df = 3 p = 0.22
Sex				
Female (n=43)	40% (n=17)	40% (n=17)	30% (n=13)	35% (n=15)
Male (n=39)	25% (n=10)	33% (n=13)	13% (n= 5)	33% (n=13)
	χ^2 = 1.59 df = 1 p = 0.20	χ^2 = 0.25 df = 1 p = 0.62	χ^2 = 3.41 df = 1 p = 0.07	χ^2 = 0.005 df = 1 p = 0.94
Years Experience				
Less than 3 years (n=9)	22% (n= 2)	33% (n= 3)	22% (n= 2)	22% (n= 2)
3-5 years (n=37)	46% (n=17)	44% (n=16)	36% (n=13)	42% (n=15)
5-7 years (n=20)	15% (n= 3)	15% (n= 3)	0% (n= 0)	30% (n= 6)
7-10 years (n=16)	31% (n= 5)	50% (n= 8)	25% (n= 4)	38% (n= 6)
More than 10 years (n=2)	0% (n= 0)	0% (n= 0)	0% (n= 0)	0% (n= 0)
	χ^2 = 8.08 df = 4 p = 0.09	χ^2 = 7.61 df = 4 p = 0.11	χ^2 = 10.27 df = 4 p = 0.04	χ^2 = 3.04 df = 4 p = 0.55

tions (pain, performance impacted and volume impacted questions). Prevalence for all four measures of shoulder problems was higher in females than males. Prevalence of pain, participation impact and volume impact was highest in the swimmers with three to five years of experience and performance impact was highest for swimmers with seven to 10 years of experience.

Discussion

The purpose of our study was to understand shoulder problem prevalence among age-group swimmers in Ontario. The OSTRC questionnaire was used to determine the prevalence of shoulder pain and impact on participation, performance, and training volume. Two swim clubs participated and the response rate was 51%. The overall prevalence of shoulder pain was 35%. The prevalence was highest in females and in the 12 and under age group for all four types of shoulder problems.

The overall prevalence of shoulder pain in the current study is similar to a study on age-group swimmers from Australia that found 12-month prevalence of shoulder pain was 38%.[10] However, the overall period prevalence of shoulder pain in our study was lower compared to another study on age-group swimmers that found 51% of athletes had shoulder pain in the past 12 months.[11] A possible explanation to the discrepancy between Tessaro *et al*.[11] and our findings is the time period of prevalence was longer in Tessaro *et al*.[11] and therefore it is reasonable that the prevalence percentage was higher. The prevalence of shoulder problem impact on participation, performance, training volume and pain was higher among females than males which is consistent with findings in a study by Kerr *et al*. 2015[6] and Tessaro *et al*.[11]. The relationship of higher prevalence in females compared to males was not statistically significant in our study and this agrees with other studies that found sex was not a risk factor for shoulder pain/injury.[7,17] Prevalence among age groups was highest in the 12 and under group and decreased as the age increased for three questions (performance impact, participation impact and pain). Tessaro *et al*.[11] found the opposite trend with pain prevalence highest in the males 17 to 18 and females 15 to 16 years old followed by the males 12 to 13 and females 11 to 12 years old. Overall, our study did not find a statistically significant relationship between age group and shoulder problems. Other studies had similar results and found shoulder pain/injury was not significantly different among different age groups indicating age was not considered a risk factor.[7,10,11,18]

The total number of swimmers in each age group decreased as age increased which suggests that athletes leave the sport as they get older, leading to the question of why the swimmers leave and where they go. Various reasons may lead to youth dropping out of sport. If athletes drop out of swimming due to shoulder pain, it is necessary to understand in order to make the sport safer. Shoulder pain/injuries that were incurred through swimming might limit the athlete's ability to take part in not only swimming, but other sports and activities involving overhead arm movement in the future. Injuries, specifically repetitive overuse injuries, have been reported as a common cause of drop out from sport.[15] The results reported here, showing smaller numbers of swimmers in older age groups suggests that research looking at reasons for dropping out are warranted in order to understand the relationship between shoulder problems and dropping out.

Sport for Life Long Term Athlete Development in Sports and Physical Activity (LTADS) was adopted by Swimming Canada which to developed into the Appropriate Athlete Development (AAD) and the Athlete Development Matrix (ADM). The AAD and the ADM was developed to assist coaches, clubs and other personal involved in swimming to develop and deliver stage appropriate programs.[3] The goal of AAD is to provide a framework for athlete development based on growth, maturation trainability, and sports system alignment.[2] The goal of these models is to keep children active in sport for life, develop elite athletes and develop physical literacy.[13] A study of swim coaches in Portugal found that 67% of the coaches were aware of the LTAD.[19] The awareness of the AAD and AMD among Canadian coaches is unknown and worth investigating to improve safety in sport. The results of this study on shoulder problem prevalence illustrates a need for understanding long term prevalence and injury prevention strategies to make swimming safer.

Limitations

The main limitation of this study was the number of participants. Originally, the study was intended to sample from 300 swimmers from three swim clubs, but due to the COVID-19 pandemic we were only able to collect data from two swim clubs. Moreover, many swimmers were not able to train, which resulted in a decreased number of

athletes in the sampling frame. In addition, the sampling frame was not representative of all age-group swimmers because only swimmers from the highest competitive groups were swimming during COVID-19 restrictions. The original target population included a variety of competitive levels. Collectively, these limitations affected our total number of responses, which resulted in a wider margin of error around the prevalence estimate than originally planned. Despite these limitations, our response rate was similar to the previous FINA study that used the same survey and study period.[4] Future work should aim to replicate the findings of the current study with a larger sample and consider including swimmers from a variety of competitive levels.

Another limitation was the inability to confirm if the survey was completed by the swimmer or the parent due to the survey being online. The original study design of in person data collection would have confirmed the swimmer completed the survey. One possible source of bias that was difficult to overcome was if a swimmer was absent from the online Zoom practice because of shoulder problems.

A limitation of the survey tool was all questions (#8 to 10) were asked to the swimmer regardless of their answer to pain prevalence (#11). This meant there was not a focus of modifications to training in the presence of pain alone.

Swimmers had not been training regularly from March to September 2020 due to COVID-19. The swimmers were undertrained when returning to swim training in September 2020 compared to a normal start of the season, which could have affected the overall number of shoulder problems present. The absence from regular training could have over-represented prevalence of shoulder problems because the swimmers were more undertrained. Conversely, the prolonged period away from pool training could have also under-represented the shoulder problems due to allowing previous shoulder problems to fully heal from the rest.

A final limitation is the study design. The purpose was not to delve into what aspect(s) of participation in swimming might explain why some athletes experienced shoulder problems/pain. Several explanatory factors have been explored, which can be grouped under the following categories: shoulder anatomy and physiology (e.g., pectoral length, joint laxity, downward sloping acromion), training (e.g., volume, intensity, stroke/distance specialty, use of equipment such as hand paddles), mechanics and technique (e.g., breathing side) and personal (e.g., years experience, age, sex, history of shoulder pain).[10,11,12,17,18] Our study's results on prevalence of shoulder problems in age group swimmers identifies that a problem exists. Future research with a different design (e.g., longitudinal follow-up of swimmers) and data collection (including some of the factors listed above) would be required to identify causative factors for shoulder problems in age group swimmers to provide better information for identifying risk mitigation strategies.

Conclusion

Sport has many positive aspects and physical activity for life is one of the goals of the LTAD. Understanding the prevalence of shoulder problems in age-group swimmers allows for future studies to investigate strategies to prevent shoulder pain/injuries. Strategies to prevent shoulder problems should start from the national organization and inform the provincial and local organizations on methods to keep sport safe for all swimmers.

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Food cravings during the first week of concussion

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The brain utilizes glucose as its main source of energy. Traumatic brain injuries may alter the brain's ability to shuttle glucose effectively; therefore, the symptoms experienced may be a signal of the dysregulation. The objective of this cross-sectional study was to investigate the presence of any specific food cravings during the first week post-concussion and if the consumption of such a food decreased the symptoms of concussion. The link to the survey was posted on 4 Canadian organization websites from November 2020 to February 2021. Any individual over 18 years old who had suffered one of more concussions in the past 12 months was included. 73 females and 24 males, the majority aged 18-40 years, completed the survey. Participants with combined carbohydrate and sweet cravings reported significantly more symptoms of increased emotions (p=0.04), irritability (p=0.03), sadness (p=0.04), nervousness (p=0.03), and sleep disturbances (p=0.05) than those

Les fringales pendant la première semaine d'une commotion cérébrale

Le cerveau utilise le glucose comme principale source d'énergie. Les lésions cérébrales traumatiques peuvent altérer la capacité du cerveau à transporter le glucose de manière efficace; par conséquent, les symptômes ressentis peuvent être un signal de ce dérèglement. L'objectif de cette étude transversale était d'enquêter sur la présence de toute envie irrésistible de manger un aliment particulier pendant la première semaine suivant la commotion cérébrale et de déterminer si la consommation d'un tel aliment diminuait les symptômes de la commotion. Le lien vers l'enquête a été publié sur les sites Web de 4 organisations canadiennes de novembre 2020 à février 2021. Toute personne de plus de 18 ans ayant subi une ou plusieurs commotions cérébrales au cours des 12 derniers mois était incluse. 73 femmes et 24 hommes, âgés en majorité de 18 à 40 ans, ont répondu à l'enquête. Les participants ayant des envies combinées de glucides et de sucreries ont signalé considérablement plus de symptômes d'augmentation des émotions (p=0,04), d'irritabilité (p=0,03), de tristesse (p=0,04), de nervosité (p=0,03) et de troubles du sommeil (p=0,05) que ceux n'ayant pas ces envies.

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without these cravings. Consumption of the craved food did not change the concussion symptoms.

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KEY WORDS: concussion, craving, food, carbohydrate, signs and symptoms

La consommation de l'aliment objet de l'envie n'a pas modifié les symptômes de la commotion cérébrale.

(JCCA. 2022;66(3):253-264)

MOTS CLÉS : commotion cérébrale, envie de manger, aliments, glucides, signes et symptômes.

Introduction

Concussions continue to be considered the most common type of brain injury. According to the Ontario government concussion guidelines, a concussion is defined as "a brain injury that cannot be seen on X-rays, CT scans or MRIs. It may affect the way a person thinks, feels and acts".[1] They further define a concussion as "a brain injury that changes how the brain functions, leading to symptoms that can be physical, cognitive, emotional/behavioural and/or related to sleep".[1] Although the research about the effects of concussions has become a priority in the health field there are still areas that need to be investigated.

It is well documented that the brain utilizes glucose as its main source of fuel, with resting brain glucose levels being approximately 3 mM.[2] The human brain depends on glucose for survival and glucose metabolism is under tight regulation considering it is critical for the brain's physiology.[3] Many brain disorders originate when there is a disruption of normal glucose metabolism and cell death.[4]

Research has shown that when at rest, the brain shuttles cerebral blood flow to the regions with the highest local glucose metabolism. All regions of the brain are continuously active; however, the areas of greatest usage will have increased blood flow. The human brain accounts for approximately 2% of the body's weight but utilizes about 20% of the total energy derived from glucose.[4] The brain has developed mechanisms by which it can detect and regulate the metabolism of glucose. An article by Rao and Oz[5] discusses gluco-sensing neurons, their presence being discovered in several regions of the brain, and how they may play a role in detecting the present glucose levels in addition to initiating responses to the glucose levels. Qin *et al*.[6] noted that a traumatic brain injury, such as a concussion, could cause a disruption of the blood brain barrier and ultimately affect the uptake and usage of glucose within the brain. This disruption of the uptake may lead to an inadequate amount of glucose being detected in the brain, potentially creating a signal to the body that the glucose requirements of the brain are not being met.[6]

Qin *et al*.[6] anesthetized male mice on which craniotomy was performed. Some mice were administered impact with a 2 ml rod at 3 m/s for 100 ms to a depth of 1 mm, which produced a moderate contusion in the right cortex causing pronounced behavioural deficits but no mortality. The glucose uptake in the brain of these mice was compared to healthy brains for vestibular motor function, water content and glucose uptake. Although this study primarily focused on the effects of an administered COG1410 solution on glucose metabolism, vestibular motor function, as well as blood brain barrier disruption, it is hard to dismiss the significant deficits that the impact produced in the traumatic brain injury group compared to the controls regarding blood brain barrier disruption as well as impaired glucose uptake.

The hypothalamus plays a significant role in energy and weight balance in the body. A condition called hypothalamic obesity is known to develop after damage to the hypothalamus from space occupying lesions or trauma.[7] Hochberg and Hochberg[7] have discussed the ventromedial hypothalamus (VMH) as playing a critical role in hyperphagia post injury. Further investigation noted that the hyperphagia was significant, however, not enough to cause obesity. The current hypothesis is that a disruption in the hormone regulation of leptin and insulin are the reason for the increased fat mass. Hyperphagia following head injury could be a potential explanation for an increased consumption of sugar; the link between leptin and insulin regulation could be a route of exploration later.

Currently, with exception to a case series by Senecal and Kazemi[8] and Germann *et al*.[9] there is no other known literature available that provides a connection between concussions in human subjects and a craving for any specific food.

Based on Senecal and Kazemi[8], Germann *et al*.[9] and the first author's experiences, most athletes with concussion expressed cravings for sweet food and that consuming such food relieved their concussion symptoms. As such, this study represents the first exploration into detecting a potential relationship between the glucose imbalance known to occur post-concussion and the clinical presentation of craving specific foods. Secondly if craved food consumption improved any of the signs and symptoms of concussion in acute phases (one to seven days after concussion). These findings would be the first evidence linking glucose dysregulation to a specific clinical presentation which can be studied as a treatment strategy in the future.

The results from this study will elucidate the phenomenon of any specific food cravings experienced after concussion. Identifying this trend will facilitate discussion about managing nutrition after concussions between doctor and patient. It could open avenues for further research for post-concussion management with nutrition. The aim of this study was to assess if subjects aged 18 years or older with a previous history of concussion in the last year experienced any specific food cravings during the first week of their concussion using an online survey tool.

Methods

A survey (Appendix 1) consisting of 13 questions was administered to eligible participants from National Sporting Organizations (NSO), Complete Concussion Management (CCM), Royal College of Chiropractic Sports Sciences Canada (RCCSS(C)) and Canadian Memorial Chiropractic College (CMCC) students from November 2020 to February 2021. The survey was sectioned into four. One section contained two questions relating to demographics, the second had two questions regarding sports, recreation and background mechanisms, and the remaining questions were sectioned regarding timeline of concussion(s) as well as presence of any food cravings. The data for this study was obtained through a survey using SurveyMonkey. The survey was initially sent to a Fellow of RCCSS(C), sports nutritionist and naturopath, a chiropractor who primarily treats patients with concussion, and a statistician for face validity. Their recommendations were incorporated into the survey.

The survey was directed to any participant (over the age of 18 years old) who has suffered one or more concussions. Further, the participants were males and females who had been diagnosed with a concussion in the last 12 months prior to the survey. Individuals who were younger than 18 or had not experienced any concussion in the last 12 months were excluded. All completed surveys were included in the sample selection. There were no physical risks to the participants of this study. All information was kept confidential. However, there were still some potential privacy concerns due to risks for data loss, and the potential for a server breach. The participation was completely voluntary, and the participants were able to withdraw from the study at any time without consequence. This study was approved by Research Ethics Board of the Canadian Memorial Chiropractic College. (REB approval number 2006B01)

The survey took less than five minutes to complete. Each question was to be answered by selecting the most appropriate response relative to the participant taking the survey. Invitation to complete the survey was posted on CCM website and Facebook page by CCM personnel. In addition, an email to request participation was sent to various NSOs, RCCSS(C) and CMCC students to either post the advertisement on their website and or Facebook page or to send to their members if possible. There was no compensation for participation in this study. The total number of emails sent to the members and/or total number of members of each organization that were able to view the advertisement on their website and/or Facebook page was not provided by the mentioned organizations. The survey software was able to inform us of the compliance of the population. The software was able to inform us if a participant completed, did not complete or withdrew from the study. Upon completion of the study, a summary of the findings will be provided to the organizations that posted and advertised the participation in the study. These organizations will post the result on their websites and or Facebook page or send it to their members.

The primary measure from the survey was the presence of food cravings during the first week post-concussion. Other measures from the survey used included the timeline of the concussion(s) in relation to the emergent cravings. These outcomes were used to assist in determining if there was a pattern that exists across the participants in the study, ultimately revealing the legitimacy of the study's hypothesis. The timeline of interest of the survey was within the first week post-concussion. The data collected involved three main areas of interest including demographics, the mechanism of the injury as well as

timeline and presence of cravings following injury. Other data analyzed included if the consumption of craved food, or lack thereof, had any effects on the participant in terms of their perceived symptoms.

Statistical analysis

All data collected in the survey were categorical variables. The sample characteristics were described using frequency and percentages. The main outcome in the study was a dichotomous variable representing cravings for carbohydrates and/or sweets – yes or no – defined for those respondents who were able to recall whether they had cravings post-concussion (n=71) and the frequency and percentage of those with cravings were used to describe this outcome. The outcome, craving for carbohydrates and/or sweets was cross-tabulated with age and sex, and p-values from an appropriate test of association (either chi-square test or Fisher's exact test dependent on cell sizes) were derived to assess for significant associations. Associations of cravings with eleven symptoms (Emotional, Irritable, Sadness, Nervous, Sleep Disturbance, Headache, Neck Pain, Concentration, Dizziness, Nausea, and Fatigue) were examined using cross-tabulations and Fisher's exact tests due to small cell counts. The statistical analysis for this study was generated using SAS software v9.4. (Copyright © 2012-2018, SAS Institute Inc., Cary, NC, USA. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.)

Results

The survey was distributed to participants aged 18 years old and above through CCM, NSOs, RCCSS and CMCC with the intent to identify those who experienced concussions in the last 12 months and if those individuals experienced specific food cravings during the first week post-concussion. There were 111 records extracted from Survey Monkey. One person entered the survey and then exited without responding to any questions, including the consent question, eight persons reported "No Concussion" in response to question 3 (see Appendix 1), and so did not complete the questionnaire. In addition, eight persons reported, "Yes" to question 3 and one reported "Prefer Not To Say", but then did not answer any further questions. Of those nine, seven were female, six were 18 to 30 years and the other two were 31 to 40, the other two were males, one 18 to 30 years and the other 31 to 40. No one reported an age outside of range. Hence there were 93 participants who responded to the survey. These 93 submissions were completed fully and appropriately and were included in the study. Table 1 illustrates the demographics of the survey respondents in general. Fifty-seven (61%) respondents were aged 18 to 30, 19 (20%) aged 31 to 40, 7 (8%) aged 41 to 50, and 10 (11%) aged 50 and above. Sixty-nine (74%) of these respondents were female while 24 (26%) were male. The reported mechanisms of concussion for all respondents were recorded in this

Table 1.
Demographics of all survey respondents (age ranges, sex, mechanism, history and timing of concussion, n=93).

	Number of respondents	% of total respondents
Age of Respondents		
18-30	57	61%
31-40	19	20%
41-50	7	8%
50+	10	11%
Sex of Respondents		
Female	69	74%
Male	24	26%
Mechanism of Concussion		
Assault	2	2%
Collision	17	18%
Fall	24	26%
MVA	20	22%
Sport	30	32%
# Concussions Past Year		
1	76	82%
2-3	12	13%
≥4	1	1%
Missing	4	4%
Most Recent Concussion		
Within last month	17	18%
2-3 months ago	16	17%
4-6 months ago	17	18%
7-12 months ago	40	43%
Missing	3	3%

Table 2.
Demographics of individuals who responded to the combined carbohydrate and sweet craving questions in the survey (n=71).

	Number of Respondents who Responded to combined carbohydrates and sweet cravings questions	% Total Respondents
Age		
18-30	39	55%
31-40	17	24%
41-50	5	7%
50+	10	14%
Sex		
Female	54	76%
Male	17	24%
Mechanism of Concussion		
Assault	1	1%
Collision	10	14%
Fall	20	28%
MVA	18	25%
Sport	22	31%

table. The most common mechanism of concussion in this group was sport-related at 30 (32%), followed by falls at 24 (26%), Motor Vehicle Accidents (MVAs) at 20 (22%), collisions at 17 (18%), and assaults at 2 (2%). Most participants (82%) reported only one concussion followed by 13% reporting two to three concussions and 1% more than four concussions in the last 12 months. Most participants (53%) reported their most recent concussion within six months and 43% within seven to twelve months prior to completing the survey.

Table 2 references the results collected from respondents who answered questions pertaining to combined carbohydrate and sweet cravings. Of the 93 individuals accounted for in the survey, 22 could not remember if they had experienced any food craving during the first week of their most recent concussion (question 8, Appendix 1) and did not respond to the following questions on craving. However, 71 responded to these questions. Of these 71 persons, 54 (76%) were female and 17 (24%) were male (four did not indicate), 39 (55%) were aged 18 to 30, 17 (24%) aged 31 to 40, five (7%) aged 41 to 50, and 10 (14%) aged 50 and above. Twenty-two (31%) reported their mechanism of concussion in this group as sport-related, 20 (28%) reported fall-related, 18 (25%) to MVA, 10 (14%) to collision, and one (1%) to assault.

Table 3.
Demographics of individuals who responded to having combined carbohydrate and sweet cravings. Information includes age ranges, sex, their respective percentage among total respondents to the combined cravings questions, and Fisher's Exact Two-Sided p-value (n=71).

	Number of Respondents who responded to combined Carb & Sweet cravings question	# With Carbohydrate & Sweets Craving	% With Carbohydrate & Sweets Craving	p-value Test of Association
	71	24	34	Chi-square test
Age				0.45
18-30	39	13	18%	
31-40	17	8	11%	
41-50	5	1	1%	
>50	10	2	3%	
				Fisher's Exact test
Sex				0.39
Female	54	20	28%	
Male	17	4	6%	

Table 4.
Number of symptoms reported by all participants (n=93).

# of Symptoms	N (Total Respondents of Study = 93)	% of total respondents
1-5	3	3%
6-10	15	16%
>10	75	81%

Table 5.
Most common to least common symptoms experienced by all participants, frequency and percentage (n=93).

Symptom	Frequency	% Of respondents
Headache	90	97%
Not feeling right	84	90%
Fatigue	82	88%
Concentration	79	85%
Pressure	76	82%
Light (sensitivity)	76	82%
Neck Pain	75	81%
Slowed Down	75	81%
Dizziness	67	72%
Emotional	66	71%
Noise (sensitivity)	64	69%
Irritable	63	68%
Nervous	62	67%
Balance	58	62%
Drowsiness	56	60%
Nausea	54	58%
Sleep (troubles with)	53	57%
Confusion	45	48%
Sadness	45	48%
Blurred Vision	42	45%
Cravings (General)	32	34%
Combined Carb & Sweet Cravings	24	26%

Further, Table 3 illustrates the demographics of the respondents who reported actually having combined carbohydrate and sweet cravings. Twenty-four respondents totaling 34% reported this specific craving (Chi-Square 0.45). Twenty individuals (28%) reported their sex as female and four (6%) reported as male (Fisher's Exact Two-Sided p-value 0.39).

Table 4 notes the number of symptoms reported by all participants. Three (3%) experienced one to five symptoms, 15 (16%) experienced six to ten symptoms, and 75 (81%) experienced 10 or more symptoms.

Table 5 documents the frequency in which symptoms were experienced by all 93 individuals who completed the survey; 90 (97%) experienced headaches, 84 (90%) experienced "not feeling right", 82 (88%) fatigue, 79 (85%) concentration, 76 (82%) pressure, 76 (82%) light sensitivity, 75 (81%) neck pain, 75 (81%) felt "slowed down", 67 (72%) dizziness, 66 (71%) emotional, 64 (69%) were sensitive to noise, 63 (68%) were irritable, 62 (67%) felt nervousness, 58 (62%) had balance issues, 56 (60%) drowsiness, 54 (58%) nausea, 53 (57%) had troubles with sleep, 45 (48%) confusion, 45 (45%) sadness, 42 (45%) blurred vision, 32 (34%) had general cravings, and 24 (26%) had combined carbohydrate and sweet cravings.

Table 6 illustrates the comparison of cravings with and without individual symptoms by means of the Fisher's Exact Two-Sided p-value. The symptoms of increased emotion (p=0.04), irritability (p=0.03), sadness (p=0.04), nervousness (p=0.03), and increased sleep disturbances (0.05) were statistically significant in individuals with carbohydrate and sweet cravings compared to those without cravings. Headache as a symptom had no evidence for an association with cravings (Fisher's Exact Two-Sided p-value = 1). Neck pain (p=0.19), concentration (p=0.74), dizziness (p=0.26), nausea (p=0.45), and fatigue (p=0.48) were not statistically significant symptoms associated with combined carbohydrate and sweet cravings.

Table 7 demonstrates whether the consumption of the craved food alleviated symptoms. There were 24 respondents who answered this question, 20 (83%) did not experience alleviation of symptoms and four (17%) did experience symptom alleviation.

Discussion

This study aimed to investigate if patients who have experienced a concussion similarly experienced any specif-

Table 6.
Comparison of cravings with and without individual symptoms including Fisher's Exact Two-Sided p-value (n=71).

Symptoms	Without Symptoms		With Symptoms		Fisher's Exact Test Two-Sided p-value
	# With Cravings / # Without Symptom	% Cravings	# With Cravings / # With Symptom	% Cravings	
Emotional	4 / 24	17%	20 / 47	43%	0.04
Irritable	4 / 25	16%	20 / 46	44%	0.03
Sadness	10 / 42	24%	14 / 29	48%	0.04
Nervous	4 / 25	16%	20 / 46	44%	0.03
Sleep disturbance	8 / 36	22%	16 / 35	46%	0.05
Headache	1 / 2	50%	23 / 69	33%	1.00
Neck Pain	2 / 13	15%	22 / 58	38%	0.19
Concentration	3 / 12	26%	21 / 59	36%	0.74
Dizziness	4 / 19	21%	20 / 52	39%	0.26
Nausea	11 / 26	39%	13 / 43	30%	0.45
Fatigue	4 / 9	44%	20 / 62	32%	0.48

ic food craving during the first week post-concussion. A survey study was conducted among individuals aged 18 years old and above who had experienced one or more concussions and had been diagnosed with a concussion in the last 12 months. There were 97 participants who responded to the survey, 93 submissions were completed fully and appropriately and were utilized in the study. The most common mechanism of concussion was sport-related at 32% with falls second most common at 26%. The higher rate of sport-related mechanism may be due to the fact that participant recruitment was facilitated by the RCCSS(C) and national sporting organizations. The fall related concussion rate could be explained by the fact that in recent years, there has been a decline in physical activity amongst adults, indicating that the younger age groups are more likely to engage in sport.[10]

Of the 93 surveys used, 71 participants completed the portion of the study pertaining to combined carbohydrate and sweet cravings following concussion. Over half of the respondents (55%) were 18 to 30-year-old range and 76% of them were female. This is in line with the literature reporting females to be more prone to concussion and lingering concussion symptoms.[11] Of the 71 participants who responded to the combined carbohydrate and sweetness cravings, 24 indicated they had experienced these specific cravings following concussion. The relationship between concussion and combined carbohydrate and sweetness cravings was not statistically significant (Chi Square analysis for age (0.45) and Fisher's Exact Two-Sided p-value for sex (0.39)). We did identify that increased emotions (43% with cravings and symptoms, p=0.04), irritability (44% with cravings and symptoms, p=0.03), sadness (48% with cravings and symptoms, p=0.04), nervousness (44% with cravings and symptoms, p=0.03), and sleep disturbances (46% with cravings and symptoms, p=0.05) were higher and statistically significant in participants with carb/sweet cravings than those without carbohydrate and sweetness cravings.

Table 7.
Result of consuming craved combined carbohydrate & sweet food on symptoms (n=24).

Relief of Symptoms after consuming craved combined carb & Sweet food	Frequency	Percent
No	20	83%
Yes	4	17%

Several studies have demonstrated that sweet cravings are associated with high levels of anxiety, guilt, sadness, loneliness, stress and irritability.[12-15] There is reported

overlap between the neural pathways that guide emotional and behavioral responses with those regulating overconsumption of highly palatable food such as sugar and carbohydrate.[16] Emotional eating has been shown to develop from a desire to mitigate stress.[16-18] Stress levels are partially regulated by the hypothalamic-pituitary-adrenal (HPA) axis.[16-18] The activity of the HPA axis has also been shown to reduce after consumption of sugar containing foods, ultimately releasing hormones that reduce the feelings of stress.[19-21] Preliminary evidence has also demonstrated that people who suffer from post-concussion syndrome have dysfunction of their HPA axis.[19-21] This has been demonstrated by measuring serum cortisol levels, which is the end product of the HPA axis.[18-19] Reduced serum cortisol was associated with more symptoms, more severe symptoms and delayed return to sport in concussed children.[17] Cortisol levels were also associated with more symptoms and delayed medical clearance in an adult sporting population.[18]

There is also the connection between cortisol, sugar cravings and females going through premenstrual syndrome (PMS). Wurtman *et al*.[21] and Brzezinski *et al*.[22] demonstrated that intake of carbohydrate was noted to increase in the luteal phase among women with premenstrual syndrome. Michener *et al*.[23] demonstrated that women with PMS had menstrual cyclic chocolate or high-sweet-fat cravings. PMS patients compared to normal women may have similar disruptions to the HPA axis, which can explain the changes in mood symptoms and sugar cravings during PMS, that are similar to those experienced in concussed patients.[24] Rabin *et al*.[24] demonstrated two HPA axis abnormalities in PMS patients that ultimately demonstrate that women with PMS might have transient or episodic disturbances of their HPA axis. These changes in women may explain why females had a higher reporting of cravings and post concussive mood disturbances, there is a possibility that the disruption to the HPA axis from hormonal changes, and from the concussion itself could be the reason females tend to be at more risk for more severe concussion symptoms and development of post concussive syndrome. However, this needs to be studied further.

Over 50% of total respondents within the 18 to 30-year-old range and over 75% in all age groups were females who reported post-concussion craving for carbohydrates or sugar. Although cravings in general were the least common symptom among all participants, it does appear that it is a commonly occurring symptom in females and in the age group of 18 to 30 years old with sport-related concussion being the most common mechanism of injury. These findings open an area for discussion around young female athletes and concussion symptoms.

It is becoming increasingly more well known that females suffer higher rates of sport-related concussion.[25-26] A systematic review and meta-analysis conducted by Brown *et al*.[27] concluded that females endure a greater severity of symptoms at baseline and post-concussion than males without significantly different symptom profiles. It has also been reported that females demonstrate worse cognitive impairment and longer recovery times.[28-29] It is thought that these differences can be explained by normal hormonal changes associated with the menstrual cycle, physiology, and cerebral blood flow.[30-32] Regarding cerebral blood flow gender differences, functional brain imaging techniques have shown that there is a robust difference between males and females in the frontal lobe area of the brain compared to parietal, temporal and occipital regions.[30] It has also been documented that there are gender related differences in the pattern of glucose metabolism, particularly involving the left frontal lobe as well as higher orbitofrontal cerebral glucose metabolism values in women.[30] Considering the frontal lobe is responsible for a multitude of cognitive processes, such as attention, memory, language, mood, and executive function, it is reasonable to believe that the differences in the frontal lobe between genders could account for the differences in post concussive symptoms.[33] As stated earlier, a healthy brain shuttles cerebral blood flow to the regions with the highest glucose metabolism.[4] With a concussion, there is thought to be a disruption of the blood brain barrier, uptake and usage of glucose within the brain.[6] This disruption of the uptake may lead to an inadequate amount of glucose being detected in the brain, potentially creating a signal to the body that the glucose requirements of the brain are not being met. This could ultimately explain why females reported a higher incidence of carbohydrate and sugar cravings post-concussion.

Those who consumed the craved food mostly reported no changes in their concussion symptoms. Based on the small sample size of respondents who answered the question of consumption of craved food, and the fact that we do not know if the remaining respondents consumed food that they were craving, it is difficult to definitively de-

termine the significance of this finding. As such further investigation with larger sample size is recommended.

Some of the limitations to the study design include a low response rate and recall bias. The proportion of subjects thought to complete the survey was estimated at 10 to 15%. This low rate of response was estimated due to the fact that the advertisement was posted on various websites and sent to the members of the organizations (CCM, NSOs, RCCSS(C) and CMCC) and it was not personally administered. The actual number of responses to the study was 97. This may reduce statistical power and generalizability of study results.

The second major limitation to this study might have been recall bias which is error in the accuracy of the information retrieved by the participants regarding events or experiences from the past. Most of the respondents (53%) indicated their most recent concussion within the last six months whereas 43% reported it to be within seven to 12 months of filling the survey. It is not certain how accurate the information provided can be. Following a literature review investigating recall bias, there was no established cut-off period determined to which a patient can still recall adequate details of an event. However, multiple studies including one authored by Barry and Tomes,[34] found that sustaining a concussion does not necessarily affect the long-term ability to recall an event as much as it affects the detail the individual provides. In addition, the number of concussions sustained did not alter the finding that both the control and concussed groups were equally able to recall the same number of autobiographical memories. Waiting until symptoms completely abated did not improve the level of detail the participants were able to provide, as the majority reported their most recent concussion occurring within a three to 13-month range. In another study by Ryan and Ruff,[35] it was reported that even patients who did not receive treatment following their concussion were seen to improve in their memory recall. For this survey, the participants' most recent concussion was anytime between the time they participated and the past year beforehand. This allowed the best opportunity to collect accurate symptom information according to the studies mentioned above.

Conclusion

Based on a small population survey of adult participants who experienced concussions less than 12 months prior to the administration of the survey, there was no statistical significance between the presence of carbohydrate or sweet cravings and concussion injury. It was identified that increased emotions, irritability, sadness, nervousness, and sleep disturbances were higher and statistically significant in participants with combined carbohydrate and sweet cravings than those without these cravings. Those who consumed the craved food mostly reported no changes in their concussion symptoms. This information, although with some limitations, may provide a basis for research into limbic patterns and glucose metabolism in individuals with head injury and post-concussion syndrome.

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Appendix 1.
Craving during first week of concussion questionnaire

1. What is your age?
   a. 18-30
   b. 31-40
   c. 41-50
   d. Above 50

2. What is your biological sex?
   a. Male
   b. Female

3. Have you ever been diagnosed with a concussion?
   ❒ Yes
   ❒ No

   (IF NO THE PARTICIPANT WILL BE DIRECTED TO THE CLOSING STATEMENT THANKING THEM FOR PARTICIPATION)

4. Please check off all of the following symptoms you have had with your concussion:
   a. Headache
   b. "Pressure in head"
   c. Neck Pain
   d. Nausea or vomiting
   e. Dizziness
   f. Blurred vision
   g. Balance problems
   h. Sensitivity to light
   i. Sensitivity to noise
   j. Feeling slowed down
   k. "Don't feel right"
   l. Difficulty concentrating
   m. Fatigue or low energy
   n. Confusion
   o. Drowsiness
   p. More emotional
   q. Irritability
   r. Sadness
   s. Nervous or Anxious
   t. Trouble falling asleep

5. What was the cause of the concussion?
   a. Motor Vehicle Accident
   b. Fall
   c. Sport-Related
   d. Collision with an object
   e. Other

6. If sport-related, which sport or activity were you participating in?
   a. Baseball
   b. Basketball
   c. Cycling
   d. Diving
   e. Equestrian
   f. Football
   g. Figure-skating
   h. Hockey
   i. Lacrosse
   j. Martial arts
   k. Motor Sports
   l. Rugby
   m. Running
   n. Soccer
   o. Swimming
   p. Volleyball
   q. Other (please specify)

7. How many concussions have you had in last year?
   a. 1
   b. 2-3
   c. 4-6
   d. More than 6

8. When was your most recent concussion?
   a. Within last month
   b. Within last 2-3 months
   c. Within last 4-6 months
   d. 7-12 months ago

9. Have you experienced any food cravings during the first week of your most recent concussion?
   ❒ Yes
   ❒ No
   ❒ Cannot remember

   If yes, what kind of food? (Choose as many as applies)
   i. Sour
   ii. Spicy
   iii. Salty
   iv. Sweet
   v. Protein (meat, chicken, fish, etc.)
   vi. Carbohydrates (bread, rice, pasta, chips, etc)
   vii. Fatty food
   viii. Others (please specify)

   If you answered "No" or "cannot remember" to question 9, please skip questions 10-13 and go to exit page.

10. Were/Are your symptoms of concussion (headache, dizziness, fogginess, moodiness, fatigue, etc.) alleviated or improved after consuming the craved food?

    ❒ Yes
    ❒ No
    ❒ Cannot remember

    If so which one of the craved foods? (Choose as many as applies)
    i. Sour
    ii. Spicy
    iii. Salty
    iv. Sweet
    v. Protein (meat, chicken, fish, etc.)
    vi. Carbohydrates (bread, rice, pasta, chips, etc)
    vii. Fatty food
    viii. Others (please specify)

11. Have you continued to crave after it was consumed?
    ❒ Yes
    ❒ No
    ❒ Cannot remember

12. In the case of resolution of concussion symptoms, did your cravings for this particular food continue?
    ❒ Yes
    ❒ No
    ❒ Cannot remember
    ❒ Symptoms are currently ongoing

13. In the absence of another concussion, has the cravings re-emerged after a period without the cravings?
    ❒ Yes
    ❒ No
    ❒ Cannot remember
    ❒ Symptoms are currently ongoing

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Recognition and conservative management for a spectrum of sport-related scapholunate interosseous ligament injuries: a case series

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This case series presents four cases of scapholunate interosseous ligament (SLIL) injury. We discuss the process of early recognition and highlight difficulties encountered in current diagnostic and conservative management strategies. The cases profile interdisciplinary management of four scapholunate (SL) injuries that have different clinical presentations and injury mechanisms. Three sport-related SL injuries were managed conservatively by a sport specialist chiropractor and one sport-related case was self-managed. Management strategies included early wrist immobilization, soft tissue manual therapy, low-level laser therapy, proprioceptive and strengthening exercises, and early orthopedic referral. This case

Reconnaissance et gestion conservatrice d'un spectre de blessures du ligament interosseux scapho-lunaire liées au sport: une série de cas.

Cette série de cas présente quatre cas de blessures du ligament interosseux scapho-lunaire (LISL). Nous discutons du processus de reconnaissance précoce et soulignons les difficultés rencontrées dans les stratégies actuelles de diagnostic et de gestion conservatrice. Ces cas illustrent la prise en charge interdisciplinaire de quatre lésions du ligament scapho-lunaire (SL) dont les tableaux cliniques et les mécanismes de blessure sont différents. Trois lésions scapho-lunaires liées au sport ont été prises en charge de manière conservatrice par un chiropraticien spécialiste du sport et un cas lié au sport a été auto-soigné. Les stratégies de prise en charge comprenaient une immobilisation précoce du poignet, une thérapie manuelle des tissus mous, une thérapie par laser à faible niveau, des exercices proprioceptifs et de renforcement, et une demande de consultation

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series highlights: (1) the spectrum of SL injuries (2) the importance of early specialty referral, (3) the paucity of literature with respect to conservative management of these injuries and (4) the role of manual therapy and rehabilitation professionals as part of the healthcare team in detecting and helping manage these wrist injuries.

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KEY WORDS: scapholunate interosseous ligament, scapholunate instability, scapholunate dissociation, conservative management, rehabilitation, chiropractic

d'un orthopédiste le plus tôt possible. Cette série de cas met en évidence : (1) le spectre des lésions du ligament scapho-lunaire, (2) l'importance d'une orientation précoce vers un spécialiste, (3) la rareté des documents scientifiques concernant la gestion conservatrice de ces blessures et (4) le rôle des professionnels de la thérapie manuelle et de la réadaptation en tant que membres de l'équipe de soins de santé dans la détection et la gestion de ces blessures du poignet.

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MOTS CLÉS : ligament interosseux scapho-lunaire, instabilité scapho-lunaire, dissociation scapho-lunaire, gestion conservatrice, réadaptation, chiropratique

Introduction

Injuries to the hand and wrist can lead to physical impairment and disability resulting in a reduction in quality of life in those whose livelihood rely on the use of the upper extremity.[1-3] Hand and wrist injuries are the most expensive injury types when considering health care and productivity costs, with dollar values exceeding $740 million USD annually.[4,5] The most common wrist injuries include sprains, strains, fractures, and dislocations, all of which may be encountered by primary care providers and rehabilitation specialists in community, athletic, and teaching settings.[4,6,7] When sprains occur, ligamentous structures are injured in isolation or in conjunction with bony and muscular structures.[7] At the wrist, ligamentous injury may pose diagnostic and management challenges due to the intricate anatomy and biomechanics. Additionally, variations in inter-carpal articulations and the unique morphology of each individual carpal bone contribute to the difficulties in clinical diagnosis.[8-12]

The stability and biomechanics of the wrist is largely determined by the summative contributions of the components of the wrist ligamentous complex.[13,14] The ligaments provide passive restraint to joint motion but are also rich in mechanoreceptors and sensory nerve endings that contribute an important afferent component to a reflexive muscular stabilization that exists around a joint, often referred to as dynamic stability.[15,16] Thus, damage to ligamentous structures may not only impair static stability and carpal biomechanics but may also impair the neuromuscular stabilization process that takes place about the wrist during motion.[16-18]

The scapholunate interosseous ligament

A sensory-rich articulation at the wrist that is susceptible to injury is the scapholunate (SL) joint.[19-21] The scaphoid is the most radially located carpal in the proximal carpal row, whereas the lunate lies between the scaphoid and the medially located triquetrum.[22] The scaphoid and the lunate are bridged by a C-shaped intrinsic ligament called the scapholunate interosseous ligament (SLIL), which is anatomically divided into 3 components: the dorsal, volar, and membranous parts[10] (Figure 1). The dorsal component is the thickest and strongest and contributes the most to mechanical stability, while the volar component is second strongest. Both of these regions are classified as true ligaments.[19,20] The membranous component is atypical as it is composed of fibrocartilage and does not contribute much to mechanical stability.[19,20]

The SLIL has been shown to act as the primary stabilizer for the SL interval, but also contributes to stabilization of the entire carpal unit during motion.[10,19-21] Specifically, the SLIL facilitates static positioning of the scaphoid and the lunate at rest while also checking their limits of motion during wrist flexion, extension, radial and ulnar deviation[23,24] – motions highly utilized with occupational and athletic tasks[7]. The SLIL is surrounded superficial-

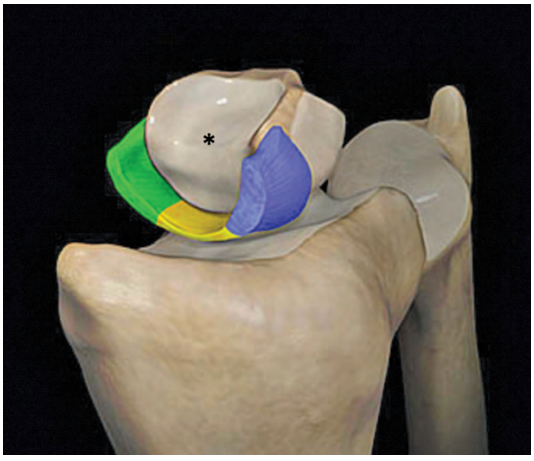

Figure 1.
The scapholunate interosseous ligament, with the right scaphoid removed. The lunate is denoted by the asterisk. The dorsal (blue), proximal/membranous (yellow), and volar (green) portions of the SLIL are identified. (Image permissions courtesy of Radsource LLC)[61]

ly by multiple secondary stabilizers that also play a role in carpal biomechanics and wrist stability.[25-27] Isolated disruption of these secondary stabilizers has been found to be insufficient to cause frank carpal instability at rest but may be enough to alter carpal kinematics when under load.[10,26,27] In contrast, isolated disruption of the SLIL can result in SL instability – the most common and severe of carpal instabilities.[10] These anatomical and biomechanical relationships between the stabilizers that cross the SL interval contribute to the diagnostic and management challenges that are encountered with SL injuries.[10,23] Diagnosis is also made challenging due to the extensive differential diagnoses that exist for wrist injuries including scaphoid or distal radius fracture, injury to the distal radioulnar joint or triangular fibrocartilage complex (TFCC) or injury to other ligaments that span the radiocarpal and intercarpal articulations.[28,29] It is also essential to consider the presence of co-morbid rheumatological conditions such as rheumatoid arthritis, as synovitis associated with the disease can predispose SLIL weakening and may lead to instability.[30,31]

The spectrum of scapholunate instability

In 1980, Jack Mayfield[25] suggested that ligamentous injuries at the wrist lead to a broad continuum of mechanical dysfunction, with SL instability being the first stage of a predictable four stage pattern of perilunar instability (Table 1). In 1993, orthopedic surgeon Kirk Watson[32] further classified SL injury as a spectrum itself, and described three stages of SL instability which included:

Table 1.
Jack Mayfield's four stages of perilunar instability (SL = scapholunate)

Stages of perilunar instability	**Description**
Stage I perilunar instability: *Scapholunate dissociation*	Disruption of the SL ligament with widening of the SL interval. Exacerbated on clenched fist radiograph.
Stage II perilunar instability: *Perilunate dislocation*	Lunate remains normally aligned, and capitate bone is dislocated (typically dorsally). Capitolunate joint is disrupted. This stage may be associated with a scaphoid fracture.
Stage III perilunar instability: *Mid-carpal dislocation*	SL and lunotriquetral ligament disruption, and capitolunate dislocation
Stage IV perilunar instability: *Lunate dislocation*	Stage III plus a ruptured dorsal radiocarpal ligament resulting in volar dislocation of the lunate into the carpal tunnel

Table 2.
Table adapted from original 1993 paper by Kirk Watson and colleagues. (SL = scapholunate)

Scapholunate Instability Classification	**Diagnostic description**
Pre-dynamic instability	Rotary subluxation of the scaphoid only identifiable on physical examination (e.g., positive Watson's scaphoid shift test). No SL widening on static or stress-view wrist radiographs.
Dynamic instability	Rotary subluxation identified during physical exam, and SL widening identified on stress radiographs (e.g., clenched fist or ulnar deviation views) or other special studies (e.g., fluoroscopy).
Static instability	Rotary subluxation identified during physical exam, and SL widening on static wrist radiographs. Radiographic findings include, foreshortening of the scaphoid, "ring sign", SL diastasis, overlapping of the scaphoid and the capitate, and increased SL angle on the lateral view.

pre-dynamic, dynamic and static instability (Table 2). The development of these two conceptual frameworks is afforded by an understanding of the aforementioned relationships between the stabilizers and biomechanics of the SL joint and other surrounding inter-carpal joints.

Recognition of Watson's SLIL injury spectrum may further assist the astute clinician in the early detection of such injuries, particularly in those without obvious static radiographic instability. This may subsequently influence the initiation of prompt management. Unfortunately, current literature is lacking with respect to how to best manage SLIL injuries.[21,33,34] For example, for acute and complete tears surgery may be required in attempts to restore articular congruency, stability, and biomechanics.[21] However, there is insufficient evidence to declare a gold standard procedure as surgical outcomes are inconsistent.[21,33,34] For chronic instabilities, response to surgery is also mixed.[21]

For incomplete tears without radiographic evidence of instability, non-surgical management may have some benefit.[10,35] Case reports have described implementing neuromuscular rehabilitation of the dynamic stabilizers of the wrist that are thought to be "SL joint friendly".[28,35,36] These include the flexor carpi radialis, extensor carpi radialis longus, flexor carpi ulnaris and the abductor pollicis longus and although these muscles' tendons do not directly attach to the proximal carpal row, they are thought to contribute to normal intercarpal kinematics while maintaining appropriate positioning of the scaphoid and the lunate when the SLIL is incompetent on its own.[15,36] Additionally, the use of an arch of motion called the dart-thrower's motion (DTM, Figure 2a-c) in rehabilitation has been

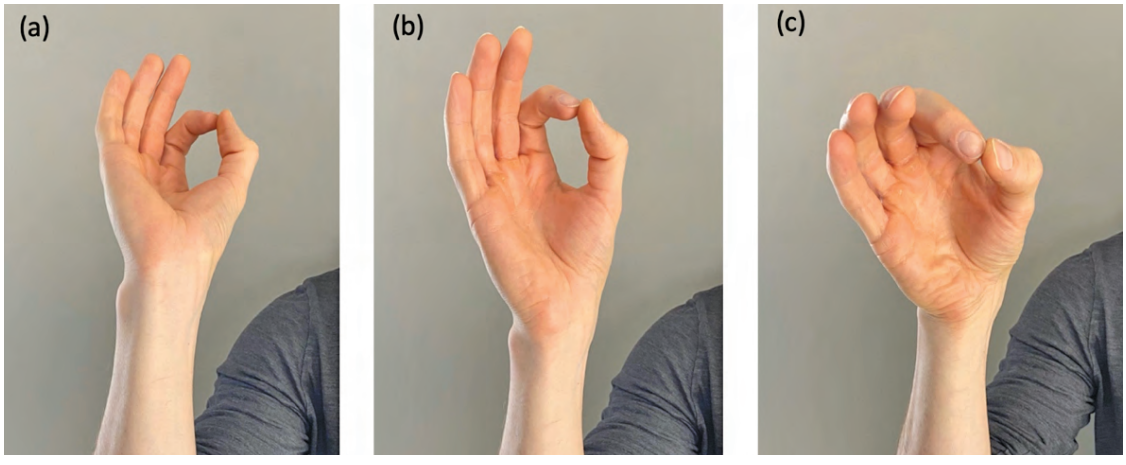

Figure 2.
The different positions of the dart thrower's motion (DTM). The beginning stage starts in a position of radial-extension (a), transitioning through neutral (b) and finishing in a position of ulnar-flexion (c).

described, as it has been shown to place minimal strain on the SLIL and is a commonly used application in post-surgical SLIL rehabilitation.[28,36-39] These approaches have been extrapolated from basic science literature, rehabilitation concepts that exist for other anatomical locations, and biomechanical research of the wrist. However, there is limited evidence to describe the efficacy of these applications.[17,18,40] Also, to our knowledge there are no randomized clinical trials or guidelines to suggest the ideal conservative rehabilitative strategies for SLIL injuries.

While considering the paucity of literature, it is still inevitable that rehabilitation clinicians will attend to patients who have sustained SLIL injuries. For example, primary care providers such as chiropractors or other manual therapy and rehabilitation professionals may be the first health care provider to assess an injury to the wrist, as many therapists work directly with athletes and working-class populations.[41-43] As experts in the diagnosis and conservative management for ailments of the musculoskeletal system, these professionals are well positioned to recognize and initiate management for such injuries. We present four cases that highlight the manual therapy and rehabilitation professionals' role in the diagnosis and initiation of interdisciplinary conservative management for confirmed sport-related injuries to the SLIL.

Case 1 presentation

An 18-year-old elite male international level gymnast presented to a sports specialist chiropractor with a four-day history of right wrist pain. The wrist pain began following vaulting practice during which he planted and twisted hands-first on the vault. This maneuver resulted in loaded wrist extension combined with ulnar deviation. During the moment of injury, the patient reported that he felt "one of his bones pop out of place". Following this incident, training ceased due to immediate pain and swelling located at the right dorsoradial wrist. The athlete reported that he was unable to perform any degree of active wrist range of motion in all directions immediately following the injury, including an inability to actively hold a cellular device. The patient did not report any subjective neurological symptom descriptors in the upper extremity. Past health history was unremarkable for any underlying connective tissue or rheumatological conditions in the athlete or his immediate family. There was no history of previous injury to the affected right wrist.

Physical examination revealed mild swelling located over the dorsal SL interval of the right wrist with no visible bruising. Active and passive wrist ranges of motion were limited to 25 degrees in flexion and extension (normal ranges: 75 degrees flexion, 70 degrees extension[44]), 0 degrees ulnar deviation, and 15 degrees radial deviation (normal ranges: 30 degrees ulnar deviation, 20 degrees radial deviation[44]). Peripheral vascular examination revealed adequate peripheral perfusion and pulses at both radial and ulnar arteries. Give-way 4/5 weakness due to pain was elicited with resisted wrist flexion and extension. There was mild hypoesthesia over the right dorsal wrist in a non-dermatomal distribution. Carpal ballottement (Figure 3) over the scaphoid and lunate recreated the patient's chief complaint. Palpation of the dorsal and volar distal radioulnar joint was tender. Watson's scaphoid shift test

Figure 3.
The scapholunate ballottement test. The examiner uses a pinch grip to stabilize the lunate on the volar and dorsal side of the wrist. While stabilizing, the examiner applies an alternating volar-to-dorsal shearing motion at the adjacent scaphoid to assess the integrity of the SLIL. A positive tests results in excess intercarpal motion, typically in the presence of pain.

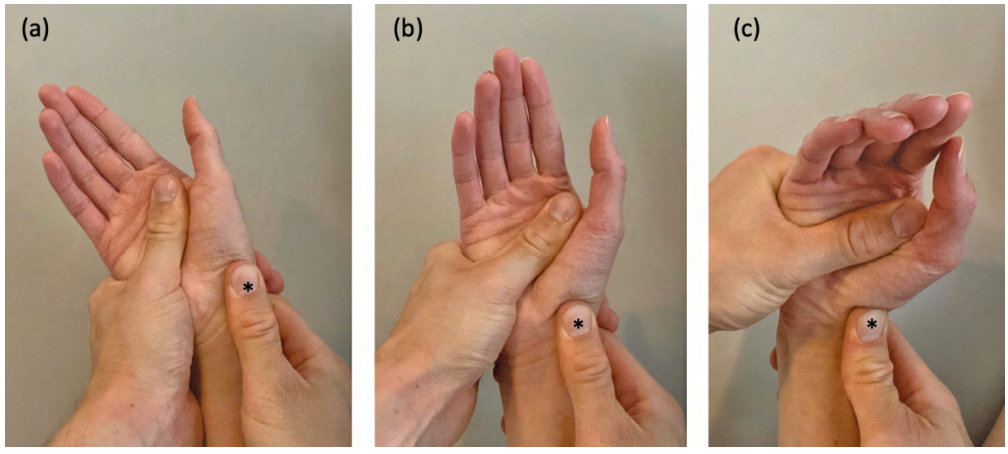

Figure 4.
Watson's scaphoid shift test. The examiner places a volar-to-dorsal pressure on the scaphoid tubercle with their thumb (*) beginning with the affected wrist in ulnar-extension (a). While maintaining pressure, the wrist is brought through the neutral position (b) and into radial-flexion (c) where the examiner then removes their thumb pressure. A positive test results in a palpable "clunk" with or without pain, as the scaphoid relocates from a dorsally subluxated position.

(Figure 4) was painful but negative for a palpable "clunk" on the right, and negative on the uninjured left side. Triangular fibrocartilage complex provocation tests (Figure 5) were negative bilaterally.

The constellation of clinical findings suggested an acute SLIL injury with a differential diagnosis of a scaphoid fracture or other carpal instability. Wrist radiographs including anterior-posterior, lateral, oblique, and bilateral clenched fist stress views were obtained. The radiographs did not reveal any signs of bony injury or SL interval widening and thus no signs of a dynamic or static SL instability. Despite a negative imaging report, the athlete was referred to a sports medicine physician the same day in hopes of obtaining advanced imaging due to the potential presence of a traumatic pre-dynamic instability. He was also instructed to purchase an over-the-counter wrist

Figure 5.
Triangular fibrocartilage complex (TFCC) provocation tests. The triangular fibrocartilage complex compression test (a) is performed with the patient's affected limb placed on a flat surface with the elbow flexed such that the forearm is perpendicular to the floor. While stabilizing the affected limb proximal to the radiocarpal joint, the examiner grasps the hand and places the wrist in ulnar deviation and applies an axial load with or without a shearing motion. Ulnar sided wrist pain is considered a positive test. The ulnomeniscal-triquetral dorsal glide test (b, c) is performed with the patient's wrist placed on a flat surface in the pronated position. With the examiner placing a thumb contact on the dorsal ulna (b) a dorsal counter force is applied by contacting the volar pisotriquetral complex using the distal phalanx of the index finger (c). Ulnar sided wrist pain and/or laxity is considered a positive test.

support to immobilize the wrist until further investigation was completed. A standard wrist brace with dorsal and volar metal stays was purchased and the patient adhered to the immobilization recommendations.

An MRI was obtained four-days following the initial consult (eight days after injury) and revealed disruption of the volar aspect of the SLIL, however the dorsal component was intact. The surrounding dorsal extrinsic ligament complex revealed enhanced signal, suggestive of mild sprain. At this time, the sports medicine physician instructed the athlete to halt training, continue to immobilize the wrist and to begin conservative therapy while awaiting consultation with a hand and wrist specialist. The conservative management was provided by a sports specialist chiropractor two times per week and began with wrist/forearm isometric strengthening exercises, low-level laser therapy (LLLT) over the dorsal and volar scapholunate interval, and static myofascial therapy to the forearm musculature for symptomatic relief. The athlete was also instructed to temporarily modify his training in such a way as to not to load the wrist in any degree of extension.

Consultation with the hand and wrist specialist occurred three weeks following the MRI. At this time active right wrist range of motion had improved and was near full. The hand and wrist specialist concluded that based on the physical examination, absence of detectable instability on radiographs, but presence of partial SLIL tear on MRI that the athlete continue to be managed conservatively, as a case of pre-dynamic SL instability due to an "acute on chronic" ligament irritation was suspected. Conservative care continued and proprioceptive and strengthening exercises gradually progressed from isometric to isotonic exercises using pain, range of motion and self-reported function as a guide. A graduated exposure and reintegration into sport specific activity that involved loaded wrist extension was permitted with the aid of supportive wrist taping using zinc-oxide athletic tape. The athlete occasionally encountered some aggravation during pommel horse competition, but it did not prevent the athlete from competing. This pain remained dependent on the volume of pommel horse training and competition. The athlete was lost to follow-up as he moved back to his home country and to our knowledge, he is still competing at a high level.

Case 2 presentation

A 23-year-old female chiropractic student presented to a chiropractic teaching clinic in January 2018 with sharp pain and stiffness in her right wrist following a kick-boxing session involving repetitive axial loading of the wrist while using a punching bag and performing repetitive burpee exercises. The wrist pain began one day after the exercise session with a pain rating of 3/10 at rest and 8/10 with movement as measured by the numeric pain rating scale (NPRS). Aggravating movements included wrist flexion and extension with pain located at the dorsoradial wrist. Grasping objects and resisting wrist motion in radial and ulnar deviation also reproduced the chief complaint. There was no subjective report of clicking, locking, or grinding at the time of presentation. Importantly, prior to this kickboxing incident, the patient had been self-managing fluctuating bilateral diffuse wrist discomfort, which was aggravated during activities involving loaded wrist extension, including chiropractic technique practice. Her medical history revealed no known connective tissue or rheumatologic disorders in the patient or her immediate family.

Physical examination revealed minor edema over the dorsal SL interval, with no bruising. Active and passive right wrist ranges of motion were limited due to pain to 10 degrees in radial deviation, and 50 degrees in flexion and extension. All other ranges of motion were maintained. Active and passive combined wrist flexion and radial deviation recreated the chief complaint of dorsoradial wrist pain. Resisted ranges of motion with the wrist in neutral position was graded as 5/5 with no pain, however isolated resisted finger flexion of digits 1 to 3 reproduced dorsal wrist pain on the affected right side. Carpal ballottement over the right SL interval reproduced the patient's chief complaint. Watson's scaphoid shift test was positive on the right for pain and a palpable clunk, but negative on the left. Triangular fibrocartilage complex provocation tests were negative bilaterally. Upper extremity neurovascular examination was normal bilaterally. Notably, the Beighton Score for generalized joint hypermobility was scored as 7/9, indicating generalized joint hypermobility (GJH).[45] The only components the patient was unable to perform were the forward bend test and right sided thumb apposition, with the latter limited due to pain.

Due to suspicion of a SLIL injury, wrist radiographs

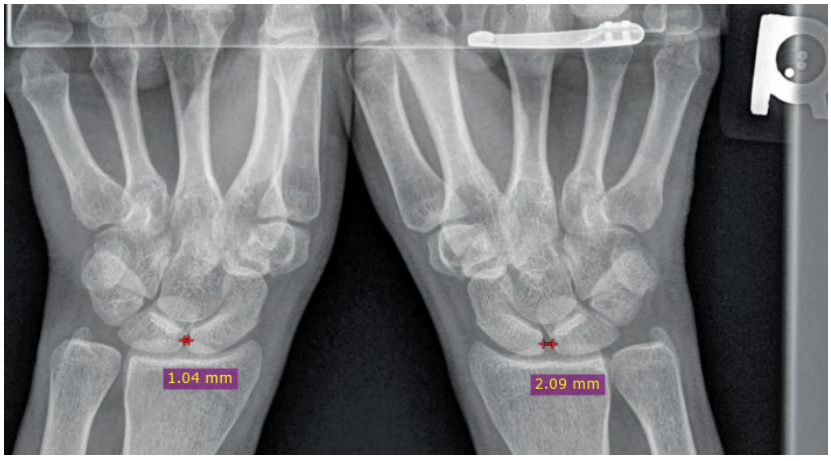

Figure 6.
Case 2: Initial stress radiographs (e.g., clenched fist view) of the bilateral wrists taken in January 2018 demonstrate mild widening of the right scapholunate interval when compared to the asymptomatic left side. A normal SL interval in adults should be <2mm.

were obtained. Figure 6 identifies widening of the SL interval of the right wrist compared to the asymptomatic left wrist. Measurements were obtained during a clenched fist stress view, indicating a dynamic SL instability. The patient was referred to a hand specialist immediately where she was instructed to begin conservative management, as her injury was deemed to be non-surgical. Conservative management included immobilization of the affected wrist for six weeks, followed by wrist flexor/extensor isometric strengthening, LLLT over the dorsal and volar scapholunate interval, and gradual implementation of proprioceptive exercises including the DTM (Figure 2a-c). Treatment was prescribed at a frequency of two times per week for eight weeks following immobilization, including daily at-home exercises, however compliance to the prescribed rehabilitation was inconsistent.

In April 2019 (15 months later), the patient presented with worsening right wrist pain and concern about the implications on her future career due to pain while performing chiropractic therapeutic procedures. There was no new injury to trigger this second consultation. During evaluation, dorsal wrist swelling remained consistent with that of the initial consultation. Active and passive wrist flexion and extension remained limited to 60 degrees with pain. Radial and ulnar deviations were now both reduced and painful. Pronation and supination did not reproduce pain. Watson's scaphoid shift test and SL ballottement remained positive on the right. Grip strength remained full, graded as 5/5, however reproduced pain over the dorsal right wrist. Due to worsening pain and loss of function, the patient was sent for follow-up radiographs (Figure 7), which revealed increased widening of

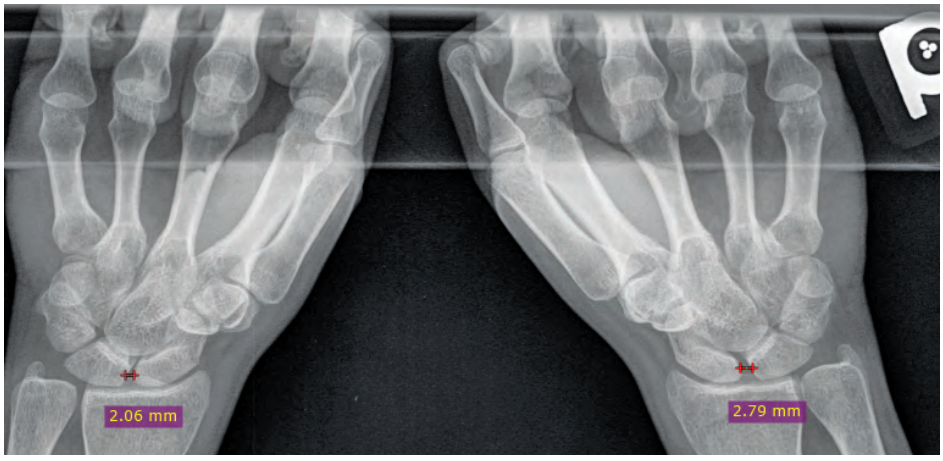

Figure 7.
Case 2: Follow-up stress radiographs taken in April 2019 demonstrating progression of the right scapholunate interval widening. Note the additional presence of widening of the scapholunate interval in the newly symptomatic left wrist.

the SL interval during bilateral clenched fist wrist views. Importantly, there was also an increase in the size of the SL interval in the currently asymptomatic left wrist. These findings confirmed a dynamic SL injury on the right. At this point, she was immediately re-referred to the hand and wrist specialist, instructed to immobilize the wrist while waiting for an appointment, and informed to modify her athletic activities and chiropractic training, so as to not place her wrist into positions of forceful extension. Her pain at rest eventually resolved at the end of the six-week immobilization period. The consultation with the hand and wrist specialist occurred in June 2019 where the injury was deemed to still be non-surgical. At this time, she was instructed to monitor her symptoms and continue conservative care, which included the same treatment approach, frequency and duration as previously described. Compliance to the treatment recommendations and at-home exercises remained inconsistent.

In November 2019 the patient presented for a third time with continued right wrist pain, and new onset left wrist pain. The right wrist was described as sharp pain over the dorsal SL interval and aggravated with the same maneuvers described above. The left wrist pain originated while exercising where she began experiencing feeling a "clunk" during maneuvers that involved axially loaded wrist extension. The patient reported she had been compensating with the left wrist due to the right-sided wrist pain. Watson's scaphoid shift test on the left was negative but mildly painful. Wrist flexion combined with ulnar deviation reproduced the chief complaint on the left. Triangular fibrocartilage complex provocation tests on the left were positive for ulnar sided wrist pain. The left wrist was subsequently diagnosed with a suspected TFCC injury with a suspicion of a clinically relevant dynamic SL instability.

At this time the patient became compliant with a bi-weekly conservative management strategy for eight weeks. During the eight weeks, isometric wrist strengthening was progressed to isotonic strengthening. Proprioceptive exercises included the use of the DTM that were eventually progressed to DTM while holding light weight (e.g., 1 kilogram). After eight weeks, she continued with at-home wrist strengthening exercises using pain and function as a guide for further progression, while also modifying her athletic and chiropractic activities. In February 2020 she reported a 90% improvement in right wrist discomfort in all ranges of motion except for loaded wrist extension, which still produced sharp dorsal wrist pain. This pain was described as transient and did not persist upon removal of this provocative movement.

In March 2021 the patient returned for a re-evaluation. Her chief complaint remained as wrist pain that was aggravated with loaded wrist extension. Both right and left wrists exhibited a positive Watson's scaphoid shift test, with pain present only on the right. Palpable clunking was now present during bilateral SL ballottement. As of late 2021, the patient still reported pain when performing certain chiropractic therapeutic procedures, and as such was instructed to continue to use technique modifications that did not produce pain (e.g., using supine thoracic spinal manipulative therapy instead of prone procedures). She is continuing to perform at-home strengthening and proprioceptive exercises and is still occasionally managed conservatively by a sports specialist chiropractor which she describes as being beneficial for the reduction of pain during periods of exacerbation. No further hand specialist consultation has taken place as of this writing.

Case 3 presentation

A 26-year-old male chiropractic student noticed severe left wrist pain the morning after a round of golf. There was no identifiable trauma that occurred during the golf round; however, he described the wrist as being so painful that he "couldn't even lift his comforter off himself." There was reported redness and generalized swelling at the dorsoradial wrist that was painful to self-palpation. Suspecting an osseous or ligamentous injury, the patient began to self-manage by applying an over-the-counter rigid brace for two weeks, combined with 500mg of acetaminophen daily for three days. Due to a successful reduction in pain, he continued to self-manage for five weeks which included a combination of gentle active range of motion exercises and isometric strengthening of the wrist in neutral position. He also modified his daily activities by refraining from golf and avoiding all chiropractic training procedures that involved loaded wrist extension.

Approximately seven weeks after the onset of wrist pain, the patient presented to a chiropractic teaching clinic for an examination as there was remaining pain with loaded wrist flexion and extension. History revealed no previous wrist trauma, however mild wrist discomfort had been identified in years past while playing golf and

during certain chiropractic training procedures that involved loaded wrist extension. At the time of presentation, chiropractic technique training remained as the chief aggravating factor for his wrist pain. Remaining personal and family health history was unremarkable for any connective tissue or rheumatologic disorders.

Physical examination revealed full pain-free active and passive wrist ranges of motion, that produced a pain-free "click and snap" perceived by the patient at the dorsal wrist. Physical tests including Watson's scaphoid shift test and TFCC provocation tests were negative bilaterally. Neurovascular examination of the upper extremity was normal bilaterally. Due to suspicion of a golf-related SLIL injury, left wrist radiographs were obtained. SL interval widening was identified on static PA projection (Figure 8a), which subsequently worsened during an ulnar deviation stress view (Figure 8b). The diagnosis of a static SL instability resulted in a prompt referral to a hand and

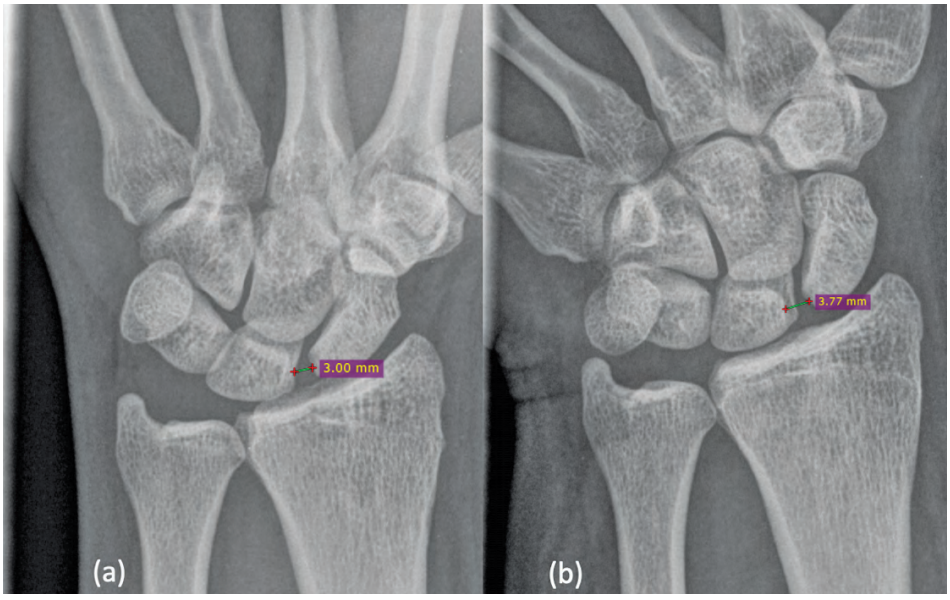

Figure 8a-b.
Case 3: Widening of the scapholunate interval on PA projection (a) that increases with ulnar deviation stress view (b).

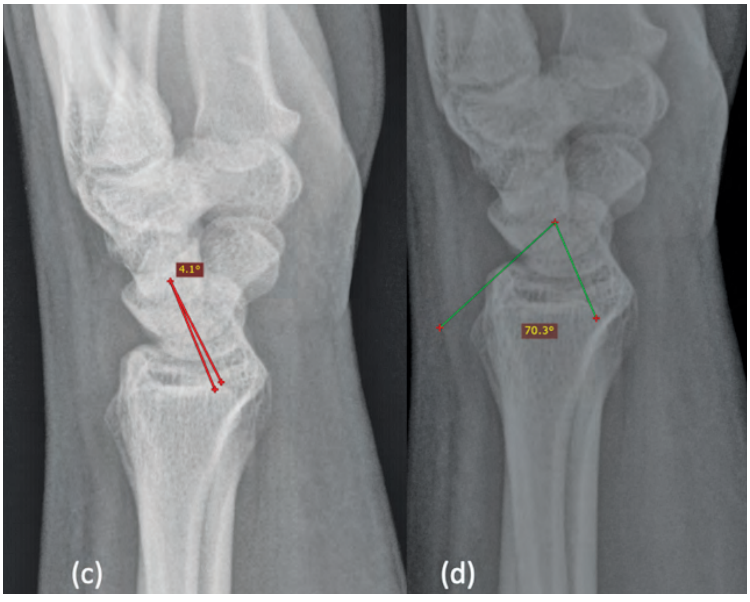

Figure 8c-d.
Case 3: The capitolunate angle is normal (c). The scapholunate angle is measured at 70 degrees, the upper limits of normal (d).

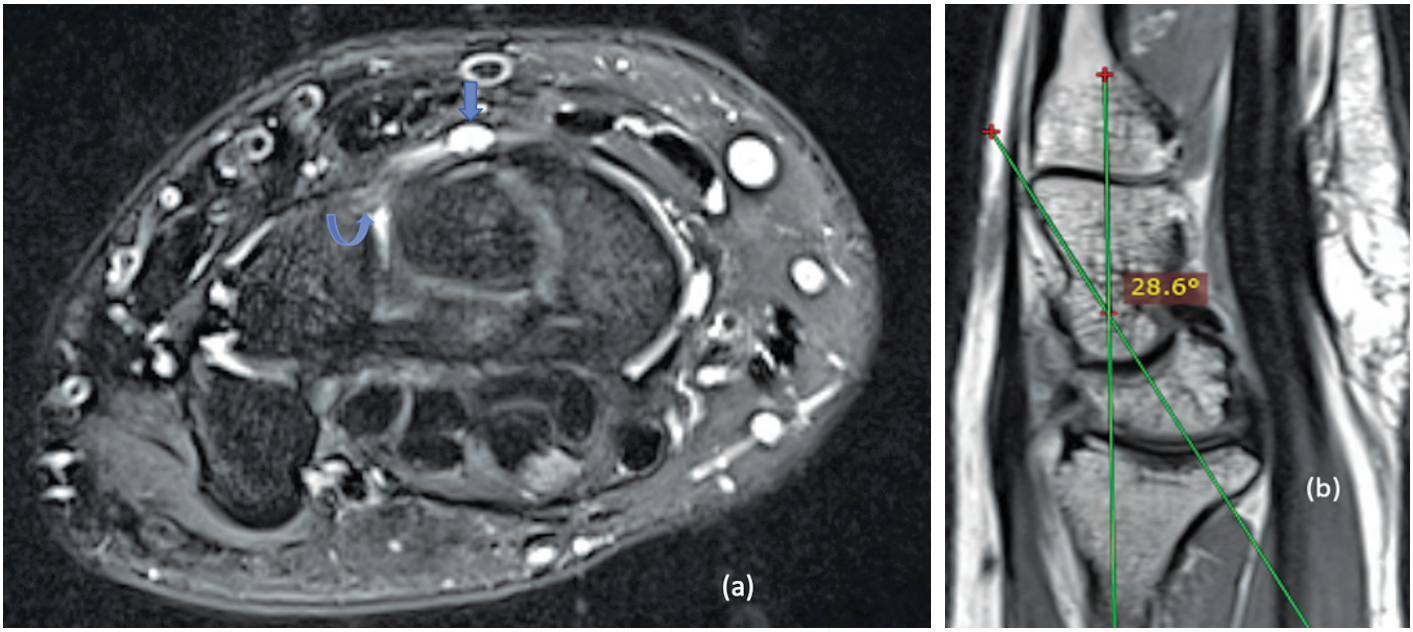

Figure 9. *Case 3:*
Axial PD FS (a) demonstrates high signal within the intact scapholunate ligament (curved arrow) and dorsal ganglion cyst with fluid signal continuous to the scapholunate joint (blue arrow). Sagittal PD (b) through the capitolunate joint demonstrates a normal capitolunate angle of 28.6 degrees (normal = <30 degrees).

wrist specialist who subsequently ordered an MRI that revealed fluid signal within an intact dorsal SLIL suggestive of previous injury, and the presence of a dorsal ganglion cyst that was continuous with the SL joint (Figure 9a). Although a static instability was identified on radiograph the hand and wrist specialist deemed the findings on advanced imaging to be non-surgical, and the patient was instructed to continue with his current approach of wrist strengthening.

The patient continued to self-manage using isometric and eventually isotonic strengthening exercises for the wrist and forearm muscles. Weight bearing activities at the wrist, including push-ups, were slowly implemented using pain as a guide for self-progression. Eighteen months later, the patient reported the ability to still recreate a "click and pop" in the left dorsoradial wrist during maximum wrist flexion and extension, that remained painless. Previously aggravating positions such as loaded wrist extension was no longer bothersome (e.g., push-ups and chiropractic technique training) and the patient was able to return to golf with no limitations. No bracing or taping to provide additional stability was required. He is currently training for golf season one to two times per week in an indoor practice facility with no reported functional limitations or discomfort during or after the activity. He continues to use prophylactic activity modifications during his chiropractic training to limit his exposure to loaded wrist extension (e.g., using a forearm contact instead of loaded wrist extension during side posture lumbar manipulation procedures).

Case 4 presentation

A 34-year-old female yoga instructor and chiropractic student presented to a chiropractic teaching clinic in September 2021 with left dorsoradial wrist pain. The wrist pain began three years prior following pregnancy, where the patient described repetitively supporting herself in an axially loaded wrist position while breast feeding. The wrist pain that developed was significantly worsened during a subsequent increase in physical training and yoga instruction.

Minimal pain was reported at rest, but pain was aggravated with maximal wrist flexion and extension, particularly loaded wrist extension. Examples of provoking

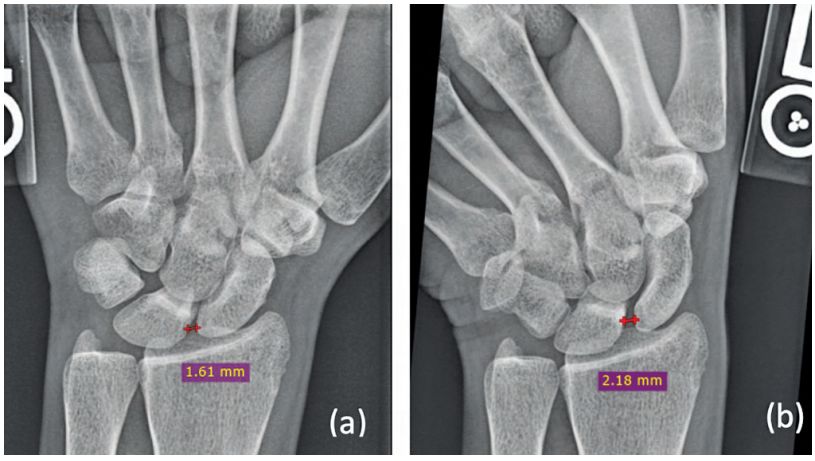

Figure 10a-b.
Case 4: Radiographic examination of the left wrist demonstrating a normal scapholunate interval in the PA view (a), with an increase in the interval measurement with ulnar deviation stress view (b).

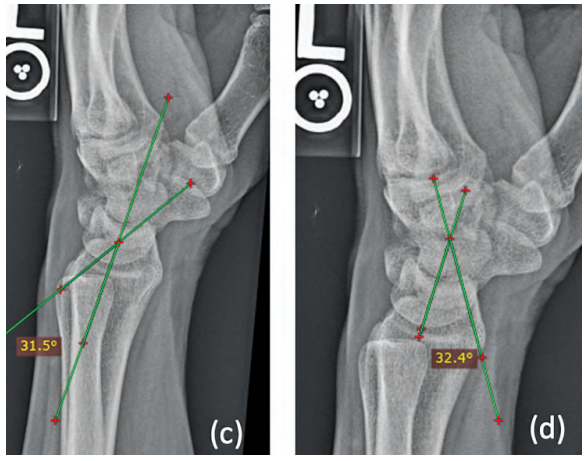

Figure 10c-d.
Case 4: Radiographic examination of the left wrist demonstrates a normal scapholunate angle (c) and a widened capitolunate lunate angle (d).

positions included the push-up or downward-dog yoga positions and manual therapy training during her chiropractic curricula. Her pain was reported as sharp and rated as 6-7/10 on the NPRS during these activities and was located at the anatomical snuffbox and dorsoradial wrist. A sensation of "clicking and popping" during active pronation and supination of the wrist was reported to be non-painful. Since the onset of wrist pain, the patient described using modified wrist positions during sport and recreational activities, such as performing push-ups on her fists, which was moderately effective in preventing pain. Her past medical history revealed no personal or family history of connective tissue or rheumatologic disorders.

Approximately two months prior to the consultation in September 2021, the patient had seen a different chiropractor for the same wrist complaint. The chiropractor administered LLLT to the dorsal and volar wrist surfaces, and applied intercarpal high velocity, low amplitude adjustments. The patient reported that the adjustments exacerbated her pain.

Physical examination in September 2021 revealed no swelling or bruising. Passive range of motion of the affected wrist was pain-free in all directions, however resisted supination and loaded wrist extension both reproduced the chief complaint. Tenderness was located near the snuffbox and the dorsal SL interval. There was surrounding wrist extensor muscle hypertonicity. Watson's scaphoid shift test was positive with a painful clunk on the left and negative on the right. Triangular fibrocartilage complex provocation tests were also positive on the affected left wrist.

Due to the suspicion of a SLIL injury, left wrist radiographs were ordered which revealed widening of the SL interval with the ulnar deviation stress view (Figure 10b), but not the static posterior-anterior (PA) view (Figure 10a). An increase in the capitolunate angle was also identified on the lateral view (Figure 10d). These findings led to a diagnosis of a dynamic SL instability and conservative care began immediately.

Conservative management was prescribed one time per week for eight weeks and included manual and instrument assisted soft tissue therapy of the wrist flexors and extensors and LLLT to the dorsal and volar SL interval. However, the focus of management was active rehabilitation that included isometric strengthening of the wrist flexors and extensors and dynamic wrist stabilizers within pain free ranges. During management, the patient reported the greatest pain reduction from the active care portion of the management plan. As wrist function and tolerance to load improved, rehabilitation progressed to include isotonic strengthening and proprioceptive exercises that included external perturbation from the treating practitioner. This included providing an unexpected force to the wrist and

hand in different planes of motion to challenge the dynamic stabilizers of the wrist. Additionally, the DTM was incorporated into rehabilitation with the intent of minimizing stress to the SLIL during active strengthening.

By the sixth week of conservative management, the patient reported that her wrist was "feeling great". She was now able to use 3 lbs weights during the DTM exercises and progressed to perform some weightbearing activities with her wrist approaching 40-50 degrees of extension, including the downward-dog and upward-dog yoga postures. She continued to perform push-ups on clenched fists prophylactically and reported no pain during or after these exercises. She was also instructed to modify some of the therapeutic procedures she is learning during her chiropractic training in attempts to limit maximal wrist extension as this position remained painful. Currently, the patient is continuing with conservative management and gradual progression of her at-home rehabilitative exercises.

Discussion

Scapholunate interosseous ligament injuries can pose both diagnostic and management challenges. The featured cases illustrate the variability in how these injuries may present and the varying degrees of activity limitation that may result.

In studying these four cases, we identified a lack of consistent relationship between severity of pain and extent of ligamentous injury when investigated via stress radiographs and advanced imaging. In cases 1, 2 and 4 none of the patients presented with identifiable instabilities on static radiographs. Not until stress radiographs or advanced imaging was obtained were injuries to the SLIL confirmed. Additionally, these three cases had very different injury mechanisms, initial pain levels and degrees of dysfunction, suggesting that these factors may not be accurate predictors of injury severity on their own.

Case 2 highlights the progression of a dynamic SL instability in a hypermobile individual who was not compliant to initial management recommendations. It is difficult to construe a direct effect of poor compliance or GJH with respect to the outcomes of this case, even considering the well-established relationship between ligamentous laxity in GJH and joint pain at other regions in the body.[46,47] Case 4 highlights a successful implementation of an active rehabilitation plan resulting in a meaningful reduction of pain that allowed for a return to modified yoga activity. In this case, the atraumatic onset of wrist pain was in close temporal proximity to pregnancy. It is well-known that pregnancy can induce ligamentous laxity due to increases in the levels of certain hormones such as relaxin and progesterone.[48,49] Musculoskeletal disorders, including those of the hand and wrist, are common during pregnancy[49] and there are case reports to suggest pregnancy-induced laxity of the SLIL can present as a dynamic SL instability[50]. These concepts raise suspicion as to the potential contribution of pregnancy-induced hormonal changes to the eventual repetitive use mechanism of SLIL injury that was observed in Case 4. In the context of Cases 2 and 4, further studies investigating the potential relationships between GJH or pregnancy-induced ligamentous laxity and injury to the SLIL should be conducted. Establishing a better understanding of these potential relationships may be particularly important when there is suspicion of an SLIL injury in the absence of an identifiable acute trauma.

Case 3 highlights a successful implementation of immobilization with respect to pain reduction. Multiple sources suggest the use of wrist immobilization after acute SLIL injury[10,21], however empirical evidence is lacking specific criteria with respect to the ideal duration and type of brace to use. It is difficult to determine if the early bracing strategy improved the prognosis for the individual or helped facilitate a full return to sport, however, early suspicion of injury permitted immediate intervention and early resolution of pain, which ultimately allowed for progression of self-prescribed isometric and isotonic wrist strengthening exercises.

Case 1 also responded favourably to partial wrist immobilization. Supportive athletic wrist taping was used to prevent provocative ranges of motion during gymnastics and served as an exogenous form of stabilization, although in a more dynamic environment when compared to Case 3. Importantly, taping the wrist permitted the athlete in Case 1 to tolerate load with the wrist in an extended position that was otherwise too painful to perform without the tape. This ultimately assisted the athlete in returning to sport.

In addition to providing an extrinsic support to the wrist, other physiological mechanisms may explain the response to taping that we observed. Proposed mechanisms include but are not limited to: improvement of local

strength and proprioception[51] and local pain inhibition of the injured joint that was taped[52,53]. It is important to note that these mechanisms remain controversial and to our knowledge have not been demonstrated at the SL joint, specifically. Due to limited evidence supporting rigid bracing and athletic taping for SLIL injuries, we recommend that efficacy studies be performed to determine the best approach and timing for wrist immobilization following SLIL injury. We also recommend that studies continue to investigate the mechanisms of action for various types of taping which may inform our clinical applications for both athletes and non-athletes.

Within our series, three cases included early referral to hand and wrist specialists which facilitated advanced imaging, confirmed the diagnosis, and determined that the cases were non-surgical, despite the presence of ligamentous injury. Without interdisciplinary collaboration in the diagnostic process, there may have been greater uncertainty surrounding the most appropriate care. The recommendations from the hand and wrist specialists to proceed with conservative management may have been due to the lack of consensus on gold standard surgical procedures to treat more subtle instabilities, combined with the mixed outcomes and overall unpredictable prognosis found within the existing surgical literature.[21,33] Additionally, surgery is typically only considered in the presence of static SL instability or significant arthritis (e.g., scapholunate advanced collapse [SLAC]), combined with significant pain and disability.[21,33] Thus, the recommendation for non-invasive methods of management including immobilization for a period of six to eight weeks with gradual implementation of range of motion, strength, and proprioceptive exercises, seems reasonable.

Additionally, implementing LLLT seemed appropriate in our cases as it has been shown to be safe[54,55] and there is preliminary evidence to suggest mild pain reduction in various disorders of the elbow, wrist, and hand[56,57]. The mechanisms of action for LLLT include changes in local tissue mitochondrial metabolism, which in turn may have a positive influence on local blood flow, clearance of metabolic by-products, and reduction of proinflammatory neuropeptides that accumulate at the location of injury.[58,59]

We recognize that certain conservative management recommendations were made in the absence of high quality literature addressing the efficacy of these interventions for SLIL injuries[10], emphasizing the need for future research to investigate the efficacy of these applications for SLIL injuries, specifically.

Case 4 highlights a successful implementation of active rehabilitation using concepts of motor control[15,18], conscious proprioception[15,17,18], and biomechanics[10,23]. We extrapolated findings from kinematic and orthopedic literature which led to the use of the DTM during rehabilitation to reduce SLIL stress while maintaining ranges of motion and strengthening dynamic stabilizers.[15,37-39] Kinematic studies have identified that the arch of motion from wrist radial-extension to ulnar-flexion (e.g., like that of throwing a dart), places the least amount of strain on the SLIL.[37-39] This movement is the only exception to the complex intercarpal motion that occurs during all wrist movement as the DTM results in null movement of the proximal carpal row, with nearly all motion taking place at the mid-carpal joint.[37-39] It is important to recognize this inherent stability in the proximal carpal row during the DTM, as multiple every-day activities and sporting tasks require this arch of motion. For example, activities such as hammering a nail, pouring a pitcher of water, throwing a javelin, and holding a golf club all require combinations of radial-extension and ulnar-flexion.[37,39] Since the identification of this kinematic relationship, dart-thrower's orthoses have been prescribed post-surgically to reduce strain at the repaired SLIL while permitting safe and early rehabilitation.[37,39] Actively using this arch of motion also utilizes musculature that is thought to be "SL joint friendly".[15,36] Thus, utilizing this motion in conservative therapies in the absence of surgery may be an avenue to implement greater degrees of motion without placing the SLIL at risk of further injury. Extrapolating what exists within the surgical, biomechanical, and basic science literature was necessary during our approach to the conservative management of the four cases presented, as empirical evidence remains limited.

It is also important to recognize that the individuals included in this series had active lifestyles that required extensive use of their hands and upper extremity in sport and their healthcare training. Considering this, we provided advice to modify certain activities in attempts to limit exposure to aggravating wrist positions. This advice was a staple of our conservative management, and in collaboration with each patient, we were able to identify reasonable ways to modify their activities. Cases 2, 3 and

4 provide examples of successful activity modification that was implemented during their chiropractic training to avoid positions of loaded wrist extension. An example of these modifications includes using supine thoracic spinal manipulative procedures instead of prone procedures. The patient in Case 3 reported that he continues to use this strategy in a prophylactic manner to avoid further injury. We also assisted Case 4 in identifying ways to perform certain yoga positions to facilitate a return to instruction. For example, substituting positions that typically involved extended wrists and fingers with closed fists with the wrists in a neutral position (e.g., during downward and upward dog postures).

The role of manual therapy and rehabilitation professionals

As manual therapists we may often consider our hands-on therapeutic skills as our largest asset. However, when presented with wrist pain we must consider the underlying etiology and question whether joint manipulation is the best strategy to treat a given condition. A negative response to carpal manipulation was reported in Case 4, however we do not have enough information to draw conclusions as to why. One hypothesis includes the challenge of applying therapeutic forces across the extremely small articulations of the wrist without influencing other nearby structures. More importantly, it is already understood that the presence of an identifiable instability is a contraindication to manipulation at other regions in the body.[60] Thus, before attempting to manipulate joints at the wrist it may be prudent to ask ourselves if an individual who is presenting with wrist pain is suffering from "just a sprain", or if there may be a mild but clinically relevant instability that warrants further investigation?[2] If this is the case, it is reasonable to believe that facilitating motion beyond a joint's physiological end range may not be favourable in an already hypermobile or dynamically unstable joint. Therefore, it is our opinion that having a better understanding of carpal biomechanics is essential. This may decrease the likelihood of performing procedures that may not be helpful for a given condition, while also helping inform our clinical decision-making during the diagnostic process, as illustrated in the cases above.

Conclusion

In conclusion, this case series highlights several important considerations and clinical decisions with respect to the recognition and management of SLIL injuries including the value of stress radiographs and advanced imaging to identify subtle injuries to the SLIL. As members of the healthcare community, manual therapists and rehabilitation professionals must acknowledge when collaboration is necessary to aid in accurate diagnosis while keeping patient-centeredness in mind. As identified in the cases presented, there may be value in implementing conservative management strategies including bracing/immobilization, activity modification, and a rehabilitation program that considers the stability and biomechanics of the SL articulation. It must be emphasized that this was permitted by extrapolating and synthesizing information from basic science, biomechanical and orthopedic literature, suggesting that more research in controlled environments is necessary to be more confident in our conservative approaches. Future investigations should aim to identify the appropriate frequency, duration and type of bracing and exercise that is most effective for these injuries and how these parameters may change with differing severities of injury.

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Capitellar osteochondritis dissecans in an elite pre-adolescent gymnast: a case report and overview

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Objective: *Following sports injury, a timely and accurate diagnosis is important, so as to initiate appropriate care as soon as possible. This is perhaps even more paramount in pediatric athletic trauma, particularly during the pre-puberty through adolescent years of rapid skeletal growth. This paper presents the diagnosis and management of osteochondritis dissecans in its third most common location, the elbow, a presentation of which chiropractors should be aware, including the importance of timely diagnosis and appropriate treatment.*

Clinical features: *A 9-year-old elite gymnast presented at a chiropractic clinic with elbow pain and restricted range of motion after a fall during training. Following multidisciplinary involvement, the diagnosis was eventually made as osteochondritis dissecans.*

Intervention and outcomes: *The patient underwent successful arthroscopic surgery in order to remove the*

Ostéochondrite disséquante capsulaire chez une gymnaste pré-adolescente d'élite : rapport de cas et vue d'ensemble

Objectif : *À la suite d'une blessure liée au sport, il est important de poser un diagnostic précis rapide, afin d'entreprendre les soins appropriés le plus tôt possible. Ceci revêt peut-être encore une plus grande importance dans le cas d'un traumatisme sportif chez les jeunes, surtout pendant les années de croissance rapide du squelette, de la prépuberté à l'adolescence. Cet article présente le diagnostic et la gestion de l'ostéochondrite disséquante dans sa troisième localisation la plus fréquente, le coude, un cas que les chiropraticiens devraient connaître, y compris l'importance d'un diagnostic rapide et d'un traitement approprié.*

Caractéristiques cliniques : *Une gymnaste d'élite de 9 ans s'est présentée dans une clinique chiropratique avec une douleur au coude et une limitation de l'amplitude des mouvements après une chute pendant l'entraînement. Après une intervention multidisciplinaire, le diagnostic a finalement été posé comme étant une ostéochondrite disséquante.*

Intervention et résultats : *La patiente a subi avec succès une chirurgie arthroscopique afin de retirer le*

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osteochondral fragment, followed by a specific regimen of rehabilitation exercises, which helped to enhance and accelerate optimal healing for her return to athletic activity.

Summary: *This case reminds the practicing chiropractor of the valuable role he/she can play in a multidisciplinary management of pediatric sports trauma, particularly in diagnosis and post-surgical care. A literature review presents a synopsis of the reported clinical presentations, diagnostic assessment and therapeutic options for capitellar osteochondritis dissecans.*

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KEY WORDS: capitellum, osteochondritis dissecans, pre-adolescent sports injury, chiropractic

fragment ostéochondral, suivie d'un régime spécifique d'exercices de réadaptation, qui a contribué à améliorer et à accélérer la guérison optimale pour son retour à l'activité sportive.

Résumé : *Ce cas rappelle au chiropraticien en exercice le rôle précieux qu'il peut jouer dans une prise en charge multidisciplinaire des traumatismes sportifs chez les jeunes, notamment dans le diagnostic et les soins post-chirurgicaux. Un examen des documents scientifiques présente un synopsis des tableaux cliniques signalés, de l'évaluation diagnostique et des options thérapeutiques de l'ostéochondrite disséquante du capitulum.*

(JCCA. 2022;66(3):282-292)

MOTS CLÉS : capitulum, ostéochondrite disséquante, blessure sportive chez les préadolescents, chiropratique

Introduction

Most commonly, osteochondritis dissecans (OCD) occurs at the femoral condyle or the talar dome.[1] The humeral capitellum is the third most frequent location, and in young patients, may become a debilitating injury. OCD of the elbow typically begins with a local injury, followed by subsequent separation of the articular cartilage and subarticular bone of the capitellum.[2] Additionally, the radial head, olecranon and trochlea have been reported as rare sites of elbow OCD.[3,4]

OCD was first described in 1888 by König, who proposed three etiologies for loose intraarticular bodies: direct acute trauma causing osteochondral fracture; minimal trauma leading to osteonecrosis and fragmentation; and spontaneous occurrence with no antecedent trauma.[1,5,6] OCD is currently defined as an acquired lesion of subchondral bone, with possible involvement of the overlying cartilage, variable amounts of resorption, fragmentation and sclerosis, but not resulting from an osteochondral fracture.[6] The main population affected by elbow OCD is adolescent athletes engaging in repetitive overhead throwing, weightlifting and gymnastics.

Case presentation

A 9-year-old elite gymnast presented to a chiropractic clinic with acute right elbow pain, two days after injuring it during her gymnastics floor exercises training session. She recalled that she was in the middle of a sustained handstand when her arm suddenly gave way with a loud "crack", resulting in her tumbling to the floor. Immediately, she was unable to resume training. She initially rated the pain intensity at 7/10. The pain became sharper and increased in intensity into the evening and through the night, and the patient elevated the intensity rating to an 8/10.

Upon presentation to the chiropractor two days later, the pain was now more of a dull ache with the intensity decreased to 5/10. The pain was localized to the medial and lateral aspects of the elbow joint, with the distal portion of the biceps at the elbow also painful. On initial presentation she was unable to flex her arm at the elbow. Relevant past history included a right elbow dislocation at age three, and fractures to her radius and ulna in 2016, some five years prior to her current presentation. From a training intensity standpoint, this patient started recreational gymnastics at the age of three, and began competitive gymnastics at the age of five. At age five she trained five hours per week (two days x 2.5 hours), and this increased year by year until she was 10 years old, when she trained 19.5 hours per week (three days x five hours and one day x 4.5 hours).

It should be noted that the COVID pandemic signifi-

cantly affected her training schedule (when she was 9-10 years old), given the lockdown measures and the capacity limits that were established. As a result of the capacity limits and lockdown measures throughout the pandemic, she trained only 4.5 hours per day, three days a week. In previous years she had sustained a variety of assorted lower limb and pelvic injuries, all successfully treated with Active Release Technique (ART), joint mobilization and manipulation. ART is a 'hands on' movement-based soft tissue therapy technique.

Clinical findings

Maintaining her arm in full extension provided the greatest relief, with attempted active flexion causing the most pain; passive flexion caused less pain but was still very guarded and limited. There was no visible swelling of the elbow on inspection. She was able to cautiously pronate the hand, however was unable to supinate without pain. With the patient seated and her arm abducted at 90 degrees, she was unable to horizontally move her arm across her body without pain. She also described that, post-injury, she occasionally felt a "pinching" feeling in her right thumb. Palpation of the distal triceps, medial and lateral aspect of brachialis, brachioradialis, pronator teres and supinator, as well as the elbow extensor group, were all extremely tender on light palpation. A 128 Hz tuning fork over the lateral aspect of the right elbow (lateral humerus and radial styloid) elicited a jump sign from the patient, with tuning fork over the left elbow eliciting no patient reaction. Given the severe limitations in ROM, extreme tenderness on palpation and the positive tuning fork findings, a decision was made to order radiographs. While not definitive, an initial review of the radiographs led to a suspicion of a fracture, so a recommendation was made for the patient to present to the hospital; she was not treated at the chiropractic clinic.

Upon presentation at the hospital, a second set of images was obtained, which were read as normal (Figure 1). She was diagnosed with complex regional pain syndrome and was advised to see a rheumatologist. Approximately two days later, the patient's mother received a call from the hospital advising her of the presence of a focal osteochondral abnormality involving the capitellum, measuring 0.7 x 0.9 cm, along with recommendation for orthopedic consultation and MRI study.

Upon review of the x-rays by two radiologists, the consensus was that the diagnosis was most likely Panner's disease, given the patients age, with consideration given to osteochondritis dissecans as a potential differential that would be ruled in/ruled out with an MRI. Due to the COVID-19 pandemic, an MRI was not available until nearly one month following her initial visit. The

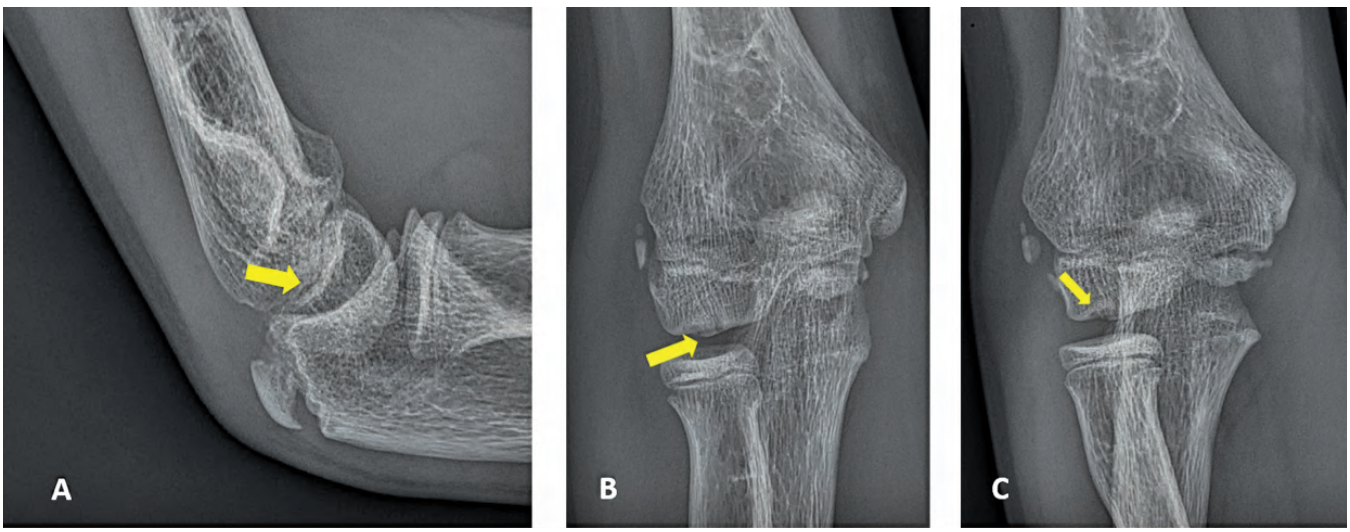

Figure 1.
A & B. Osteochondral fragment at distal capitellum; C. Osteochondral defect.

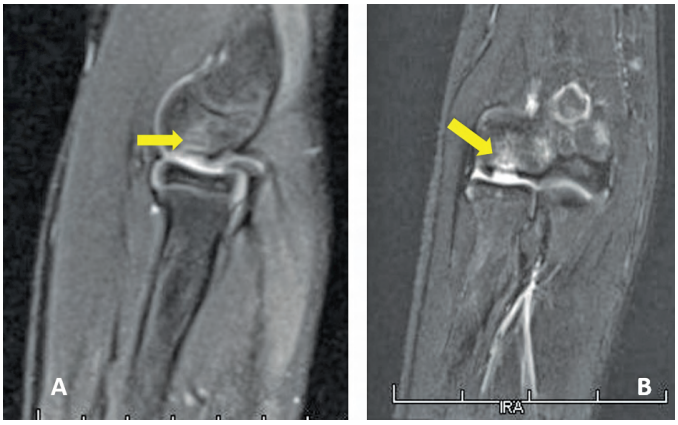

Figure 2.
MRI. A & B. Osteochondral defect is noted along with adjacent bone edema.

MRI confirmed the diagnosis of OCD (Figure 2), as there was an osteochondral defect on the articular surface of the capitellum measuring 0.7 x 0.7 x 0.2 cm. Subchondral bone marrow changes were also visible, along with a single tiny subchondral cyst. Within the anterior joint recess, there was a crescentic shaped osteochondral body measuring approximately 0.7 x 0.8 cm, the displaced osteochondral fragment from the capitellar defect.

Approximately one month after the MRI, a surgical consultation was arranged for this patient. The surgeon recommended immediate surgery and noted that there might be additional surgery forthcoming. Given the magnitude of the injury, the parents sought out a second sports medicine physician's opinion, as well as another orthopedic surgeon's opinion. All doctors unanimously agreed that surgery was the best course of action. Elective surgeries were not being performed at that time due to a COVID-19 pandemic lockdown. The surgeon did however assure the parents that once hospitals were able to resume surgeries, given the patient's age and the size of her lesion, coupled with the fact that the cartilage looked healthy and her growth plates were still open (the latter two points being positive from a recovery standpoint), she would be at the top of the surgical wait list. Approximately three months after her initial presentation, and now 10 years old, the patient finally underwent surgery. According to the surgeon, everything went very well with no complications. The surgery was a microfracture procedure of the capitellum with removal of the osteochondral

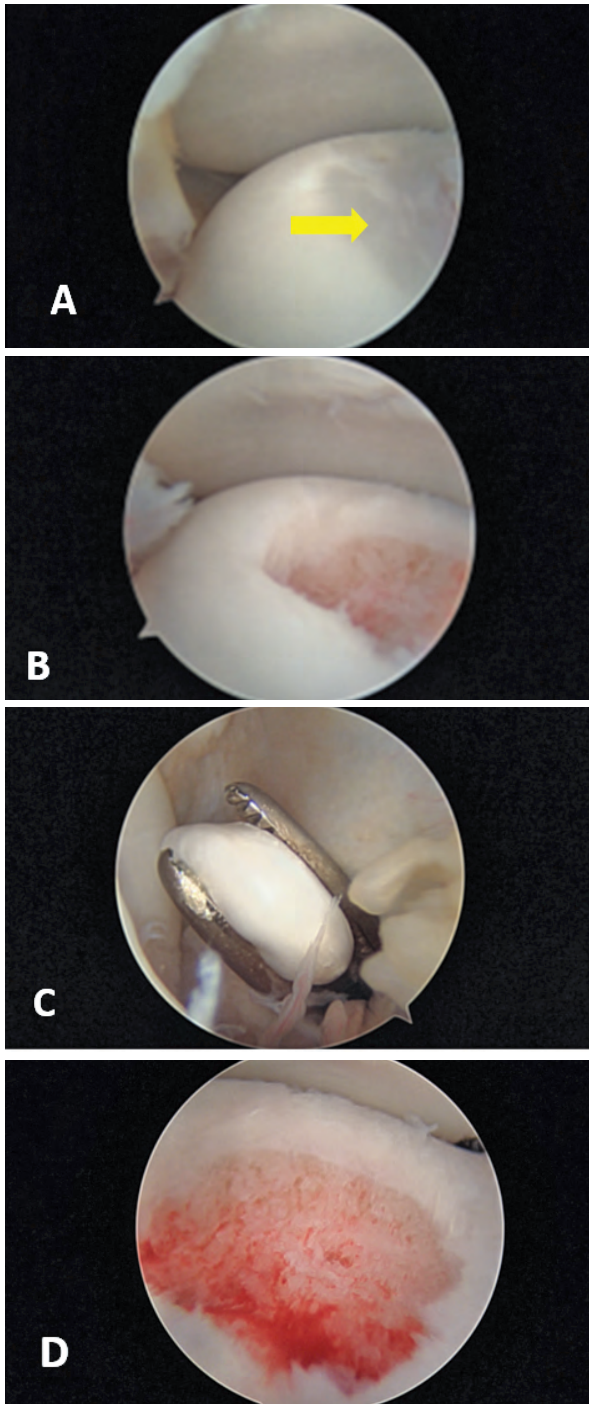

Figure 3.
Arthroscopic surgery. A. Region of chondral defect prior to debridement; B. Chondral defect following initial debridement; C. Free chondral body (joint mouse); D. Chondral defect following final debridement.

defect (fragment) and subsequent abrasion to smooth out the involved injured capitellum (Figure 3).

Post-surgical rehabilitation and return to sport

A comprehensive four-phase rehabilitation program was prescribed for the patient, that ran for a course of six months following surgery. Each phase had an anticipated timeline, with goals, bracing, range of motion parameters, exercises, inflammation control and criteria for progression to the next phase included. The rehabilitation program was devised by the orthopedic surgeon, then provided to, and supervised by, a physiotherapist. While there was no direct communication between the physiotherapist and the orthopedic surgeon, any information that was received by the patient and her parents at any of the six post-surgical consults was relayed to the physiotherapist.

Phase 1 was considered the "Early Protection Phase" and was to cover weeks 1 to 4 of the rehabilitation program. The goals in this phase were multiple and included:

- Protect the healing tissue from load and shear forces
- Decrease pain and effusion
- Maintain wrist and shoulder mobility
- Restoration of full passive elbow flexion
- Gradually restore elbow extension

The brace was to be locked at 75 degrees, and was to be unlocked for exercise. The use of a tensor was also advised to control swelling. Range of motion instructions dictated that immediate motion exercise happened on day one and that full passive elbow flexion be initiated immediately. The patient was instructed to begin passive flexion and extension of the elbow with 500 reps to be done three times daily. The brace was to be worn for comfort as necessary during these exercises, with an intention to progress to passive elbow extensions as tolerated.

The minimum range of motion goals were broken down on a week-by-week basis and were as follows:

- Week 1 – 20 to 100 degrees of flexion
- Week 2 – 10 to 120 degrees of flexion
- Week 3 – 0 to 150 degrees of flexion
- Week 4 – Full flexion and extension

Suggested exercises included:

- Putty grip strengthening
- Wrist flexion and extension stretching
- Wrist curls and neutral wrist curls
- Shoulder pendulums
- Active Range of Motion (AROM) of the shoulder in flexion/extension/abduction/internal and external rotation (in brace)

Inflammation control for Phase 1 suggested the use of ice for 15-20 minutes six to eight times daily, with the criteria to proceed to Phase 2 being full passive elbow flexion and minimal pain and swelling.

Phase 2 was referred to as the "Intermediate Transition Phase" and took place post-operatively through weeks 4 to 6. The goals of this phase included full elbow ROM and to improving muscle strength and endurance. The brace was to remain locked at 75 degrees and to be unlocked for exercise. The range of motion goals included a gradual increase in the ROM, maintenance of full passive elbow flexion and progression to elbow extension of 180 degrees by week 6. Exercises suggested in the previous phase were to be continued in this phase with the criteria to advance to Phase 3 of the program being full ROM and minimal pain and swelling.

Phase 3 occurred between weeks 6 to 12 post-surgically, and was referred to as the "Remodelling Phase". The goals of this phase were to continue to improve muscle strength and endurance and to increase functional activities. The brace could now be unlocked; however, it was still to be worn until week 12. Exercises for this phase included:

- Multiangle isometric biceps
- Multiangle isometric triceps
- Concentric of biceps and triceps with load

The criteria to be able to progress to phase 4 included no pain, swelling or inflammation and full, pain-free range of motion. Strength was also to be within 80% of the contralateral extremity. Phase 4 was the last phase of the rehabilitation program and was referred to as the "Maturation Phase", which happened through weeks 12 to 26 post-operatively. The goal of this phase was a gradual return to full unrestricted activities and sport. Generally, two to three months post-operation, low impact sports such as swimming were permitted. High impact sports like tennis, baseball, basketball and gymnastics were allowed at six to eight months post-surgery.

Exercises suggested/not suggested for this phase were numerous and included:

- Biceps curls and triceps extensions
- PNF patterns
- Core stability
- Proprioceptive exercises
- Progress resistance as tolerated
- Emphasis on entire upper extremity strength and flexibility
- Progress in sport programs depends on patient variables
- Avoid axial load until 6 months

The patient successfully completed all four phases of the rehabilitation program. The physiotherapist confirmed that the ranges of motion in the elbow returned to pre-injury levels. Strength testing with a dynamometer at her final physiotherapy appointment confirmed that her right arm strength was, in fact, superior to her left arm strength, registering 60 pounds in the right arm and 55 pounds in the left. Her return to sport commenced in week 10 of the rehabilitation program, and consisted of leg and core conditioning only, with no axial loading of the arms. This continued for approximately seven weeks with nine hours per week of training. In week 18 of the program, the training increased to 12 hours per week, with some beam and floor work added into her training, along with continued training on her leg and core conditioning. At week 22, the patient was instructed by the surgeon to re-introduce some exercises with controlled axial loading, namely planks, push-ups and modified handstands, with the assistance of a wall for stability. The surgeon also advised at that same follow-up that the patient was to avoid bars, handsprings, and any repetitive skills that would place excessive weight/load on the arm. It is noteworthy to mention that at week 18 of her rehabilitation, in addition to her gymnastics, the patient took up diving one to three hours a week. The injury and the rehabilitation took a mental toll on her, and diving provided a much needed physical and mental outlet where she could avoid the limitations on her skills in the gym. It is also worth mentioning that exactly six months minus a day, at her final follow-up with the surgeon, the patient was given the go-ahead from the surgeon to resume full gymnastics training with no limitations.

Discussion

The etiology of OCD is considered to be multifactorial, including repetitive biomechanical stresses, inflammation, weak vasculature to the capitellum, and perhaps genetic factors.[6] Although the exact etiology is unknown, the speculation is that repetitive weight-bearing and excessive valgus compression force microtrauma acting on the immature capitellum promotes vascular insufficiency.[7,8]

Cadaveric anatomical and biomechanical evaluation has shown the central portion of the radial head to be considerably stiffer than the lateral capitellum, creating a biomechanical incongruity that may promote increased strain on the lateral portion of the capitellum during loading activities.[9]

The vascular anatomy of the distal humerus, combined with an immature capitellum lacking significant metaphyseal collateral blood flow, potentially sets the stage for OCD development, where blood flow can be disrupted in a scenario of repetitive trauma.[3,10] Focal avascular necrosis of the capitellum ensues, with accompanying subchondral osseous changes. This results in loss of support for the suprajacent articular cartilage, with its eventual breakdown, and, once this structural foundation for the articular cartilage is compromised, formation of loose fragments.[7,8] Studies of twins suggest a possible genetic component.[11]

Hefti *et al*.[12] devised a classification system based on sequential changes observable on magnetic resonance imaging findings as follows:

1. A small signal change in the subchondral bone without clear margins
2. Osteochondral lesion with clear margins, no underlying fluid between the fragment and bone
3. Fluid partially visible between the fragment and underlying bone
4. Fluid completely surrounding fragment, fragment remains in situ
5. Fragment becomes a loose body

According to recent studies, capitellar OCD's incidence is higher than previously believed. Partly due to children competing in various athletics at younger ages, the incidence of elbow OCD, particularly at the capitellum, is quickly increasing.[13,14] Capitellar OCD patients are classically adolescents between 11 and 17 years old[15];

boys are affected more than girls[2]. Participants in repetitive overhead sporting activities, including baseball pitching, football throwing, overhead weightlifting, volleyball, javelin and gymnastics are prone to developing elbow OCD.[2,3,4,10,13,15-19] Juvenile OCD does have a better prognosis than in adults.[2]

Axial-loading sports, such as gymnastics and weightlifting, as well as overhead throwing, as in baseball pitching or football, generate repetitive compressive forces through the radiocapitellar joint.[3,10,16,18] Additionally, in baseball pitchers and football quarterbacks, the overhead throwing transmits repetitive shearing forces across the radiocapitellar joint during the late cocking and early acceleration pitching phases.[3,10,16,18] Kida *et al*.[4] found that baseball players who began competing at a younger age, and played for a longer period, were at greater risk for developing capitellar OCD.

Clinical presentation

Loss of elbow extension is an early sign. There is frequently an onset of insidious lateral elbow pain in the dominant arm, which is related to the sports activity. The pain and stiffness will get progressively worse.[4,10,17] Kida *et al*.[4] reported that patients who played through the pain presented with a higher grade of osteochondral lesion.

If there are one or more loose bodies, or joint mice, present, then catching, clicking or locking of the elbow may manifest as a later sign.[10] On examination, the loss of elbow extension may be mild, with lateral elbow tenderness, with or without crepitus on movement. The crepitus is especially noted on pronation and supination.[15] When active pronation and supination, with the elbow extended, reproduces pain at the radiocapitellar joint[3,10,20] this is a positive radiocapitellar compression test. Effusion of the elbow joint may be present as well.[13]

Elbow OCD patients are most commonly boys, ranging in age from 11 to 23 years. The dominant elbow capitellum is the usual site. Its prevalence in adolescent overhead athletes appears to be higher than previously thought.[15] Up to 20% of patients can have bilateral involvement.[13]

Diagnosis

A rapid and accurate diagnosis is key in order to affect proper treatment.[2] Initial x-ray examination of the elbow involves an anteroposterior (AP) in full extension, 45-degree flexion AP, and a lateral.[15] The 45-degree flexion view may better depict the lesion.[21] Although the first study may be negative, a subsequent set of films will show capitellar lucencies, flattening, sclerosis, fragmentation and intra-articular loose bodies. The anterolateral aspect of the capitellum is the most frequent site affected.[3,10] The diagnosis of OCD can be confirmed with the demonstration of these osseous defects.[19] However, due to the relatively lower sensitivity of plain radiography, additional imaging is often indicated when OCD is suspected.[21]

It has been reported that CT and MRI demonstrate greater accuracy.[21]MRI is very useful in assessing the size of the lesion, the status of the articular cartilage, and the extent of accompanying soft tissue edema.[22] Additionally, MRI can reveal lesions at an earlier stage, when x-rays still appear normal.[3,10,22] MRI is also valuable in assessing the stability and viability of the OCD fragment.[23] Early findings on MRI manifest as uniform low-signal-intensity changes on T1-weighted imaging in the superficial capitellum; T2-weighted images are normal. With progression, changes are demonstrated on T1 and T2 imaging.[15] When gadolinium contrast is seen to enhance the OCD lesion, this points to good vascularity of the fragment and better viability.[3] CT scans might be more sensitive and better depict loose bodies.[2]

The MRI findings in unstable OCD lesions were initially reported by De Smet *et al*., using the knee.[24] These criteria were then applied to OCD in the elbow, and they correlated well with findings at surgery.[25] On MRI, unstable lesions demonstrated a thin line of high-signal intensity between the OCD lesion and its underlying bone, as well as a discrete, round, focus of high-signal intensity, indicating a fluid-filled cystic osteochondral defect, on T2 imaging.[26] Evaluation of these criteria in 25 capitellar OCD patients by Jans *et al*.[27] found them to correlate 100% with lesions that were unstable at surgery.

Additional studies assessed the ability of MRI and other imaging modalities to predict intraoperative stability, and found that preoperative MRI findings directly related to a lesion's intraoperative stability.[28] Hence, MRI is still considered the best imaging tool to evaluate OCD stability. Ultrasound of the elbow has also shown promise as a predictor of unstable OCD lesions.[29]

Differential diagnosis

Panner's disease, a self-limiting capitellar osteochon-

drosis, is the main differential consideration, as it is also linked to overuse of the elbow. In contrast to OCD, Panner's involves the physeal plate. The blood supply to the capitellum is compromised, leading to necrosis, bone softening and collapse, causing the capitellar knob to flatten. This is followed by regeneration and recalcification.[15]

Panner's disease typically affects a younger age group, usually boys under 10 years of age.[3,20,30] They present with activity-related pain and tenderness along the lateral aspect of the elbow and capitellum. Fissuring, lucencies, contour changes and fragmentation of the capitellum can be seen on x-ray examination. Panner's disease exhibits an irregular epiphysis, while OCD demonstrates a well-defined subchondral lesion. Later films of Panner's patients demonstrate reossification, coinciding with symptom relief.[10,20]

Although recovery can be slow, even taking a year or two, most children with Panner's disease require little treatment, and heal completely. It is a benign self-limiting disorder, which usually resolves with rest;[2,15] surgery is contraindicated. As the child grows, the bone matures, the capitellum regains its original shape, and the symptoms typically totally resolve, with no long-term residual problems.[15]

Treatment

The chosen therapies are dependent on several criteria, including symptom severity, and the size, location and stability of the lesion. Deciding whether an OCD lesion is stable or unstable is important in determining the initial approach to treatment. A variety of classification systems have been employed to evaluate the stability of an OCD lesion, utilizing the clinical examination, imaging and findings at surgery.[15] Many authors have actively encouraged the use of the MRI characteristics noted above in contributing to the determination of lesion stability.[3,10,18,20,22,27,28,31]

In general, stable lesions are typified by an immature capitellum with an open growth plate, and flattening or radiolucency of the subchondral bone, in a patient with (almost) normal elbow motion.[15,32,33] Generally, stable lesions can be reversible, healing completely with no surgery.[32]

A high potential for spontaneous healing of OCD in patients with open capitellar growth plates has been reported.[33] OCD lesions which are stable can usually be treated non-surgically: rest, activity modification (cessation of repetitive stress on the elbow), physiotherapy and chiropractic.[2,15] Additional therapy can include anti-inflammatory medications, and brief periods of immobilization when symptoms are particularly severe.[15]

There are those who promote using a hinged elbow brace for 1 to 6 weeks during the first part of the resting period, in order to permit some intermittent range of motion exercises and prevent stiffness, while others recommend simple rest without immobilization.[10,20] Following a period of rest, physical therapy is initiated, avoiding strengthening until the patient is asymptomatic.[10]

Resolution of symptoms is often achieved in the majority of stable OCD patients in 6 to 8 weeks, with prescribing muscle strengthening exercises and a gradual return to activity once the patient is asymptomatic.[32-34] The majority of patients who do respond to conservative care can begin light overhead throwing in three to four months, with return to competitive play by six months.[3,10,14,20] It should be noted that only a minority of OCD lesions are classified as stable.[32,33]

A study by Matsuura *et al*.[34] reported that patients presenting with stable OCD lesions who were compliant with conservative therapy had a greater than 84% rate of healing; however, the healing rate dropped to less than 23% in those who were non-compliant. Patients treated conservatively who showed no improvement at six months did undergo subsequent surgery.[34]

Patients with closed growth plates or those with unstable OCD lesions, even if undisplaced, who are treated non-surgically demonstrate extremely low healing levels.[8,33,35,36] Unstable lesions (closed physis, fragmentation and range of motion reduced by more than 20°), achieve much better outcomes via the surgical route.[32,37] Unstable lesions, and stable lesions not responding to conservative care, typically require surgical intervention.[2]

Possible surgery choices include arthroscopy to remove loose bodies, abrasion chondroplasty, microfracture, retrograde drilling, in situ fixation, osteochondral autograft transplantation system (OATS), and costal osteochondral transplantation (COT).[21,31,38-45] Surgical management most commonly consists of arthroscopic debridement, bone marrow stimulation (by microfracturing the subchondral bone) and removal of loose fragments. This is the standard initial surgical choice for capitellar OCD patients.[2,46] Due to its minimally invasive nature,

encouraging results are typically reported, there is a low risk of morbidity, and it facilitates early postoperative recuperation. A majority of studies report substantial clinical improvement, even up to nine years post-surgery.[34,47-49] The open surgery options are reserved for more advanced cases, or those patients with failed previous surgery.[2]

Post-surgery and prognosis

Anywhere from 80-90% of patients return to playing sports, varying from one to five months after surgery.[50-51] Complications are typically minor, such as transient nerve palsies, and only occur in 7 to 14% of cases.[48,52] Major complications, including deep infection and permanent nerve damage, are rare, with an incidence of 0.5 to 5%.[53,54] The aims of postoperative rehabilitation are to reduce pain and swelling and restore optimum ranges of motion. Recovery following an arthroscopic procedure is faster than following open surgery.[13]

Passive exercises usually begin within a few days post-surgery. At approximately eight weeks after arthroscopic surgery, resistive exercises are introduced; 12 weeks following open surgery. Throwing-type exercise program can start when the patient experiences no pain with normal range of motion.[13]

While it may appear logical to expect that OCD patients are prone to early degenerative arthritic changes in the elbow, the relationship has not yet been clarified.[2] Data are available on OCD of the knee and ankle, reporting that large lesions of the knee appear to predispose to osteoarthritis, however, the evidence is limited.[55] However, no such relationship has been demonstrated for the ankle[56], with only 4% of ankle OCD patients developing any degenerative changes even up to twenty years following their surgery[57].

Sparse data are available regarding the risk of long-term osteoarthritic changes for elbow OCD. Research by Bauer *et al*.[58] studied elbow osteoarthritis among 31 OCD patients, with an average follow-up time of 23 years. Only one-third had degenerative changes on x-ray, with 42% complaining of pain and/or reduced ranges of motion at their follow-up.[58]

It has been reported that younger patients are more likely to maintain an asymptomatic elbow, with no x-ray evidence of osteoarthritis over the long term.[2] Furthermore, larger lesions appear to be more prone to arthritic changes over time.[2] Takahara *et al*.[59] noted poorer long-term results in patients with large cartilage lesions, as compared to those with smaller lesions. Additionally, there is no evidence that surgical debridement protects against degeneration.[59]

With more young athletes becoming competitive earlier, it appears that there is a move toward developing screening programs for adolescent overhead throwers, perhaps involving more cost-effective imaging algorithms, in order to diagnose OCD sooner, thus facilitating the use of more conservative therapies.[15]

Limitations

There are a myriad of factors contributing to the outcome of any individual case, including, but not limited to: management of patients in a primarily uncontrolled environment, patients possibly introducing a variety of confounding factors outside of the doctor's office, which may affect progression or outcome, as well as the possible natural progression options of osteochondritis dissecans in its various locations. For example, some cases can appear to undergo remission, with self-reattachment of the osteochondral fragment, rather than progression to a mobile "joint mouse".

Based on these limitations, drawing generalized conclusions regarding the care and outcome of patients with osteochondritis dissecans of the capitellum is inappropriate. The overview presented along with our case offers a summary of several presenting factors, diagnostic approaches and management strategies for these patients. Finally, the authors data collection relied heavily on dialogue with the patient's mother, and access to some health care records which were not composed by the authors.

Summary

This case report demonstrates the importance of a timely diagnosis for the effective management of osteochondral trauma, particularly in pediatric athletes. Our patient experienced a somewhat multidisciplinary journey, wherein the chiropractor was solely the portal of entry. Although the primary therapy for OCD is often surgery, chiropractic can also play a role in a comprehensive post-surgical rehabilitation protocol necessary to afford pediatric athletes the ability to achieve a safe and successful return to competitive sport.

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Symptomatic tibial tunnel ganglion cyst presenting four years following an ACL hamstring autograft reconstruction: a case report of a rare complication of ACL surgery

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Objective: *To highlight a case of an athlete with a symptomatic pretibial cyst 4-years post-ACL reconstruction surgery.*

Case presentation: *A 23-year-old female soccer athlete presented with right-sided knee pain, locking and catching, and diminished sensation along the anteroinferior knee. She had a history of an ipsilateral ACL hamstring autograft four years prior. Physical evaluation revealed a visible and palpable swelling medial to the patellar tendon, limited and painful range, and hypoesthesia within the infrapatellar branch of the*

Kyste ganglionnaire symptomatique du tunnel tibial se présentant quatre ans après une reconstruction par autogreffe du ligament croisé antérieur: rapport de cas d'une complication rare de la chirurgie du LCA.

Objectif : *Mettre en évidence le cas d'un athlète présentant un kyste ganglionnaire symptomatique du tunnel tibial quatre ans après une chirurgie de reconstruction du LCA.*

Exposé de cas : *Une athlète de soccer âgée de 23 ans s'est présentée avec une douleur au genou droit, un blocage et un accrochage, et une diminution de la sensation le long du genou antéro-inférieur. Elle avait subi une autogreffe du ligament croisé antérieur ipsilatéral quatre ans auparavant. L'examen physique a révélé un gonflement visible et palpable en dedans du tendon rotulien, une amplitude limitée et douloureuse, et une hypoesthésie dans la branche sous-rotulienne du nerf saphène. L'IRM a révélé un kyste ganglionnaire*

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The involved patient provided consent for case publication.

saphenous nerve. MRI revealed a tubular ganglion cyst along the anterior aspect of the tibial tunnel, medial to the patellar tendon, and anterior to the ACL graft.

Summary: *Post-surgical ganglion cyst formation in the reconstructed ACL is a rare complication that can present years following ACL surgery. This case aims to bring awareness to this condition as a potential long-term complication in the ACL-reconstructed athlete.*

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KEY WORDS: ACL, ganglion cyst, knee, reconstruction, complication, chiropractic

tubulaire le long de la face antérieure du tunnel tibial, en dedans du tendon rotulien et en avant de la greffe du LCA.

Résumé : *La formation d'un kyste ganglionnaire post-chirurgical dans le LCA reconstruit est une complication rare qui peut se présenter des années après la chirurgie du LCA. Ce cas vise à attirer l'attention sur ce problème comme une complication potentielle à long terme chez l'athlète dont le LCA a été reconstruit.*

(JCCA. 2022;66(3):293-299)

MOTS CLÉS : LCA, kyste ganglionnaire, genou, reconstruction, complication, chiropratique.

Introduction

Anterior cruciate ligament (ACL) graft reconstruction surgery is the preferred management strategy for active young patients wishing to return to pivoting and cutting sports.[1] The main purpose of ACL reconstruction (ACL-R) surgery is to mimic the native ACL in terms of its structure, orientation of collagen fibers, and insertion.[1] Previous literature has demonstrated that only 65% of ACL-R patients will return to their pre-injury level of sport participation and only 55% returning to competitive level sports.[1,2]

The risk of ACL ruptures for female adolescent athletes was reported as 1 in 10,000 athlete exposures and 1.5 times more likely than males across all sports.[3] Specifically, the recommended first-line management from a post-operative perspective includes manual therapy, rehabilitation exercises, and soft tissue therapy with the goal to restore knee function.[4,5] As such, chiropractors are well positioned to manage pre- and post-operative care for athletes with ACL-R.

Furthermore, ACL-R has been associated with several complications including knee pain and stiffness, secondary meniscal and cartilage injury, graft rupture, or hardware failures.[6-8] A recent meta-analysis reported a re-rupture rate of 3.5% out of 226 patients who underwent ACL-R.[9] One retrospective study reported 6.5% of 70,457 ACL-R cases had a subsequent surgery on either knee within one year of an ACL-R.[10] While some complications may appear in the short-term, there are some complications that may appear years following an ACL-R.[6-8] One rare long-term complication is the formation of a tibial tunnel or pretibial ganglion cyst.[11] A pretibial cyst typically manifests over a number of years and while some are incidentally discovered on follow-up imaging, some pretibial cysts can cause joint pain, locking, and swelling.[11] This is important in the management of athletes with ACL-R as clinicians should include a pretibial cyst on a differential diagnosis list in athletes who develop mechanical symptoms post-operatively. The purpose of this case report is to highlight the clinical and imaging presentation and diagnosis of a unique complication of a symptomatic tibial tunnel cyst that presented four years post-ACL-R in a young female soccer athlete.

Case presentation

A 23-year-old, female, former competitive soccer athlete presented for evaluation of right-sided knee pain which began two months prior and was recently exacerbated from a lower limb workout that involved jumping and kneeling. She described her pain as dull and stiff in nature and experienced swelling after walking greater than 30 minutes. She also reported occasional clicking and locking of her knee with a "giveaway sensation". Her previous medical history was significant for a complete right ACL rupture while playing soccer that was surgically reconstructed with a hamstring autograft four years prior. She denied any history of rheumatological conditions or previous knee injuries. Following her ACL-R, she reported a

Figure 1.
Visual mapping of the boundaries of hypoesthesia of the patient's right knee that measured 9 cm horizontally (left) and 8 cm vertically (right).

successful return to sport and denied any subsequent knee complaints or injuries. She maintained a healthy lifestyle with resistance training 6 days per week.

Physical examination of her right knee revealed mild anteromedial joint effusion with full ranges of motion and end-range flexion producing pain at the anteromedial joint line and passive extension producing a pinching sensation at end-range. She was able to complete a duck walk test but experienced pain in the right knee. She demonstrated apprehension with provocation tests of the meniscus including a right Thessaly's test with internal foot rotation and a McMurray's test. No laxity was noted with a McMurray's test however, a pivot shift on the right was graded as 2+. Similarly, an anterior drawer test was graded as 2+ on the right-side. Palpation of the right knee revealed pain over the medial joint line and a focal area of hypoesthesia within the territory of the infrapatellar branch of the saphenous nerve that measured 9x7 cm (Figure 1). Notably, Wilson's, and valgus and varus stress tests of the right knee and Lachman's tests were negative for laxity with a firm endpoint bilaterally. Neurological exam of the lower limbs including myotome and dermatomal testing (light touch and pin prick) of the L2-S1 levels were normal. Patellar and Achilles reflexes were graded as 2+ bilaterally with the exception of the right patellar reflex which was difficult to elicit and graded as 1+ with a Jendrassik manoeuvre.

Due to a concern for mechanical symptoms, she was referred back to her surgeon to obtain additional imaging to rule out any potential intra-articular joint lesions and laxity of the graft. The surgeon sent her for MRI of the knee and confirmed the diagnosis of a large pretibial cyst.

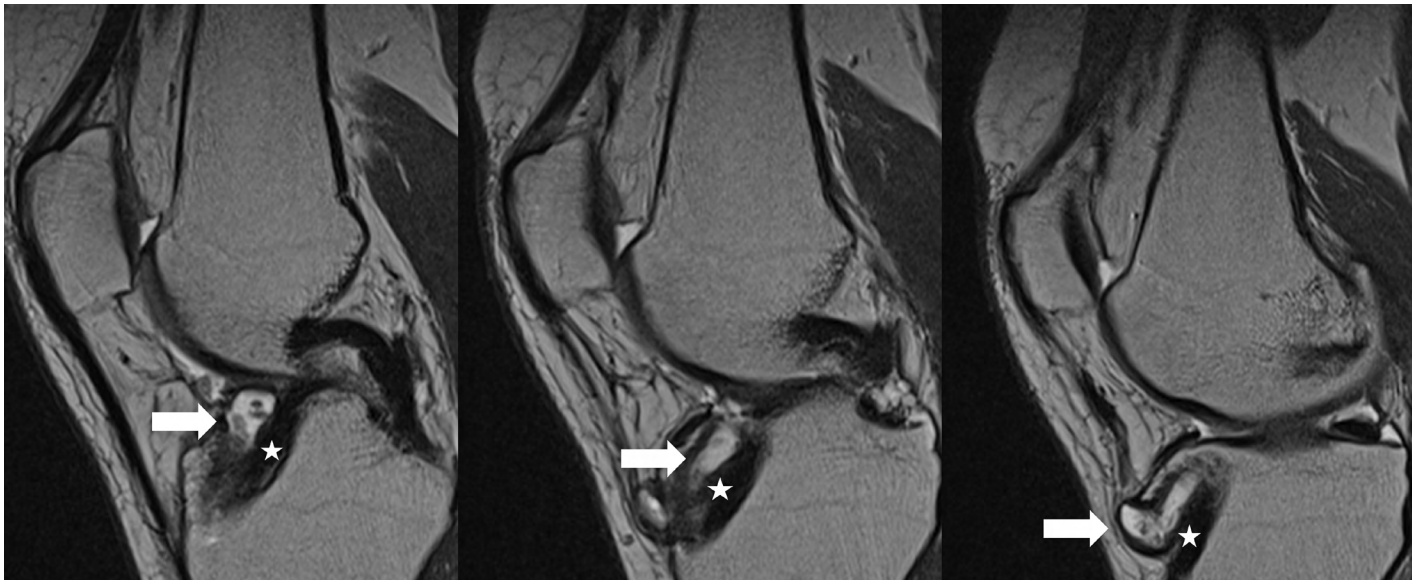

Figure 2.
Sequential MRI, T2 sagittal slices through the ganglion cyst (white arrow), demonstrates its course through the tibial tunnel, and its anterior position relative to the ACL graft (white star).

Imaging (Figures 2 and 3)

Axial, coronal, and sagittal proton density fat saturated (PD FS), and sagittal T2 weighted MRI images demonstrate a tubular unilocular high signal intensity cystic mass with internal low signal debris (measuring 34 x 14 x 13 mm in size) arising from the central aspect of the tibiofemoral joint. It extends obliquely through the entirety of the post-surgical tibial tunnel (excavated for the ACL graft) and extrudes through the anterior medial tibial cortex. The cystic structure focally bulges the intact medial aspect of the patellar tendon/patellar retinaculum just proximal to its insertion at the tibial tuberosity, and abuts the anterior aspect of the ACL graft along its course through the tibial tunnel. There is no corresponding bone marrow edema. The ACL graft, PCL, collateral ligaments, and the meniscus demonstrate normal signal intensity and morphology.

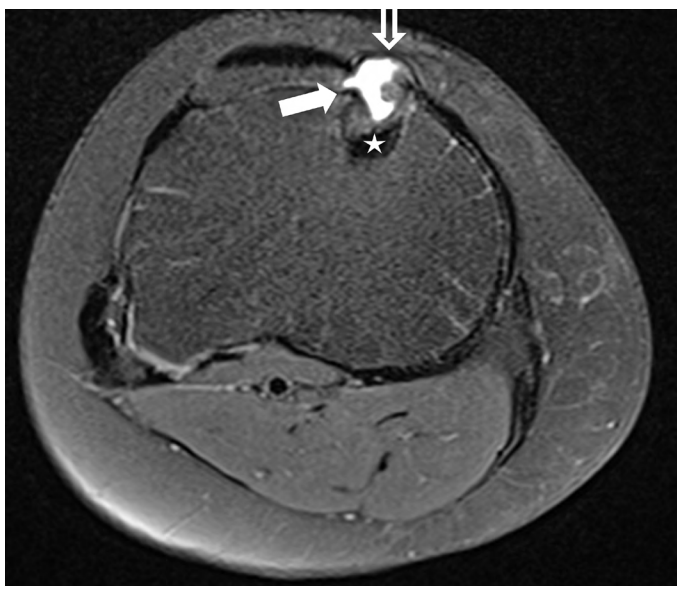

Figure 3.
Sequential MRI, PDFS axial slices through the ganglion cyst (white arrow), demonstrates its extension through the anterior cortex of the proximal tibia, and confinement by the medial patellar retinaculum (white outlined arrow). The ACL graft is represented by the white star.

Discussion

During ACL-R surgery, femoral and tibial tunnels are made to accommodate the graft.[11] The tibial tunnel is drilled parallel to the slope of the intercondylar roof, commonly known as the Blumensaat line, to ensure correct anatomical position of the graft and isometry to the native

ACL.[11] Although rare, some patients can develop a tibial tunnel ganglion cyst that can originate within or adjacent to the osseous tibial tunnel made during ACL-R.[10] Normal widening of the tibial tunnel can appear in the first three months and is anticipated to stabilize and decrease in size one year after reconstruction.[11] Furthermore, small amounts of fluid may be present within these tunnels during the first year after ACL-R, but are typically reabsorbed within 18 months following surgery.[11] An association between tibial tunnel width and development of a pretibial cyst has not been established. It is believed that cyst formation can occur during this period based on several hypotheses. Excess micromotion of the graft near the graft-bone interface can interrupt normal ligamentization and lead to the formation of a synovialized tract within the osseous tunnel.[11] Alternatively, partial necrosis of the graft from a traumatic event can lead to the formation of a slowly growing ganglion cyst.[11] Higher rates of pretibial cyst formation have been reported with hamstring autografts and the use of bioabsorbable interference screws.[10-12] The following section aims to highlight the clinical and imaging presentation of tibial tunnel cysts, followed by considerations for the non-surgical management of these patients.

Clinical presentation

There are few reported studies on the incidence or prevalence of pretibial cysts in the ACL-R knee. In one prospective study of 89 ACL-R patients, only two cases developed a tibial tunnel cyst approximately 12-months following surgery.[13] The average timeline for the onset of cyst presentation is however much longer with most cases presenting greater than three years post-operation.[10,12,14] Data from a recent scoping review[15] reported a mean age of patients with tibial cysts of 31-years-old (range 14 to 57) and the range of time to presentation following surgery between two and 70 months.

Tibial tunnel cysts are generally asymptomatic and incidentally discovered on post-operative follow-up imaging.[10,12] However, patients with symptomatic pretibial cysts can present suddenly with pain and swelling near the graft site on the anterior tibia.[10,13-16] Furthermore, some patients may report feelings of instability, but pretibial cyst formation has not been associated with failure of the graft.[10,11,13-15] Depending on the size of the cyst, patients may report pain and limited terminal knee extension as the cyst would contact the roof of the intercondylar notch before full extension of the knee.[10] Similarly, patients may report pain and limited end-range flexion as the cyst would contact the posterior cruciate ligament.[10]

In this case, our patient presented similarly to others in the literature[14-16] and was asymptomatic following her ACL-R until four years post-operation. One of the first sport-related cases was reported in a 16-year-old female basketball player.[16] In this case, her pretibial cyst was identified more than five years after her ACL reconstruction with a hamstring autograft.[16] Similar to our case, this patient also presented with anteromedial knee pain as well as a stable Lachman and pivot shift test.[16] One other article documents three pretibial cysts that formed following a sport-related ACL-R.[14] The authors reported that these patients experienced varying symptoms which included swelling and joint-related pain more than three to five years post-operatively without complaints prior to cyst formation.[14] Given our patient's clinical findings, the constellation of joint locking, giveaway instability, joint line tenderness, and positive McMurray's test poses a challenge for the correct diagnosis considering other ACL-R complications including secondary meniscal tears.[1,10,17] We suspect the large 34 mm diameter of the tibial tunnel cyst to be the causative factor for this patient's symptoms. In other symptomatic cases, the diameter of the tibial cyst has ranged from 5.5 to 20 mm.[13-16] Our patient also presented with hypoesthesia within the territory of the infrapatellar branch of the saphenous nerve. Based on our patient's cyst extrusion, we suspect that the cyst caused a compressive peripheral neuropathy to this sensory nerve.

Imaging presentation

Magnetic resonance (MR) is the modality of choice to evaluate tibial tunnel cysts.[10,11] The cyst typically appears as a uni- or multilocular fluid-filled signal on all MR pulse sequences with well-defined margins.[10,12,18] Due to its origin in the osseous tibial tunnel, extension of the cyst can be seen into the pretibial space, the intercondylar notch, as far as the popliteal fossa without evidence of graft disruption.[10] In our case, the tubular cyst extended anteriorly along the tibial tunnel into the pretibial soft tissues. Furthermore, palpable swelling was appreciated in cysts greater than 10 mm in diameter.[13-16] In some cases, reactive marrow edema can be visualized adjacent to the pretibial cyst which indicate signs of pressure erosion and

bony remodeling[10,15], this is something that was not seen in our case.

Two main categories of tibial tunnel cysts have been reported in the literature based on their pathophysiology: communicating or non-communicating cysts.[10] Non-communicating cysts are believed to arise from a sterile foreign-body reaction against fixation hardware near the graft[10], and do not communicate with the tibiofemoral joint. Alternatively, communicating cysts are described to be continuously connected with the synovial fluid within the knee joint space.[10] It is believed that communicating cysts arise due to an incomplete attachment between the graft and the osseous tunnel.[10,12] Classification of a communicating cyst requires histological evaluation for the presence of chondroitin sulfate.[10]

Non-operative management considerations

Generally, surgical removal of the cyst by curettage is the most commonly cited management strategy for pretibial cysts.[10,11,13-16] However, in some rare cases, recurrence of the cyst is possible leading to multiple surgical revisions.[16] There are no studies on the non-operative management for pretibial cysts. Clinicians should take a precautious approach to manual therapy including joint manipulation due to the potential of ganglion cyst rupture. Similarly, clinicians should approach rehabilitation in a shared decision-making model with patients to ensure safe and appropriate exercises to mitigate injuries to the pretibial cyst.

Summary

This case report details a unique case of a pretibial cyst 4-years following an ACL-R. Discussion surrounded the clinical and imaging presentation of a pretibial cyst and precautions for clinicians to consider when managing patients with a pretibial cyst. This case posed a diagnostic challenge from a clinical perspective as test results can be conflated with other intra-articular knee joint lesions following an ACL-R including secondary meniscal tears, hardware failures, graft ruptures, or cyclops lesions. This case highlights the importance of obtaining timely imaging to assist with the proper diagnosis. Although rare, it is important for clinicians to have an index of suspicion for longer-term complications including tibial tunnel cysts that can arise in athletes years following an ACL-R.

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Can a structural leg length discrepancy contribute to persistent concussion symptoms? A case report

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In the past several years, concussions and post-concussion syndrome (PCS) have become more commonly recognized conditions. However, with limited physiological explanation for post-concussion syndrome, there is also limited evidence supporting effective treatment. The vestibular system plays a role in postural reflexes and coordinated eye and cervical spine movements and is often disrupted in patients with prolonged concussion symptoms. This disruption has contributed to some of the most debilitating symptoms in PCS patients including dizziness, nausea, and balance deficits. Ongoing, post-concussion, vestibulo-ocular/cervical-ocular disruption due to an underlying

Une différence structurelle de longueur de jambe peut-elle contribuer à la persistance des symptômes de commotion cérébrale? Un rapport de cas

Au cours des dernières années, les commotions cérébrales et le syndrome post-commotion cérébrale (SPC) sont devenus des problèmes de santé plus couramment reconnus. Cependant, l'explication physiologique du syndrome post-commotion cérébrale étant limitée, les preuves d'un traitement efficace sont également limitées. Le système vestibulaire, qui joue un rôle dans les réflexes posturaux et les mouvements coordonnés des yeux et de la colonne cervicale, est souvent perturbé chez les patients présentant des symptômes de commotion prolongés. Cette perturbation a contribué à certains des symptômes les plus débilitants chez les patients atteints de SPC, notamment des vertiges, des nausées et des déficits d'équilibre. Une perturbation vestibulo-oculaire/cervico-oculaire continue, post-commotion cérébrale, due à une

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structural leg length discrepancy as a contributing factor has not been previously described in the literature. A case of PCS with initial conservative treatment of their structural leg length discrepancy and subsequent vestibulo-ocular/cervical-ocular rehabilitation is presented.

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KEY WORDS: leg length discrepancy, leg length inequality, concussion, vestibular system, post-concussion syndrome, proprioception, vestibular-ocular reflex, cervico-ocular reflex

différence structurelle sous-jacente de longueur de jambe comme facteur contributif n'a pas été décrite précédemment dans les documents scientifiques. Nous présentons un cas de SPC avec un traitement conservateur initial de la différence structurelle de longueur de jambe et une réadaptation vestibulo-oculaire/cervico-oculaire ultérieure.

(JCCA. 2022;66(3):300-309)

MOTS CLÉS : différence de longueur de jambes, inégalité de longueur des jambes, commotion cérébrale, système vestibulaire, syndrome post-commotion cérébrale, proprioception, réflexe vestibulo-oculaire, réflexe cervico-oculaire.

Introduction

The vestibular system provides the body with the sense of balance and the information about the body's position that allows rapid compensatory movements in response to both self-induced and externally generated forces.[1] We are normally unaware of its function, however, the vestibular system plays a key role in both postural reflexes and coordinated eye and cervical movements.[1] The human body integrates the vestibular, oculomotor and somatosensory system to allow humans to optimally navigate and function within complex visuospatial environments while maintaining postural control and visual equilibrium.[2,3] Highly specialized networks interact on multiple levels of the craniospinal axis to regulate gait, maintain balance, allow postural control, and coordinate eye and cervical spine movements.[2]

The ability of an individual to perceive the direction of gravity is essential for balance and orienting themselves in their environment.[4] Clemens *et al*.[5] proposed a model of gravity perception that included information from both the head and the body. Fraser *et al*.[4] did a series of experiments to determine the extent of the contribution of these inputs by measuring subjective visual vertical (SVV) for the input from the head, and subjective haptic vertical (SHV) for the input from the body.

Haptic refers to the perception of objects through the sense of touch and proprioception. SHV is the individual's sense of vertical through haptic stimulus only. Anastasopoulos *et al*.[6] suggested that SVV was strongly influenced by vestibular and ocular input while SHV is overwhelmingly influenced by somatosensory input and may be independent of vestibular imbalance.

Although positional compensation due to SVV and SHV may vary, Fraser *et al*.'s[4] multi- study article adds a further layer by suggesting that these two estimates may inform each other through an "indirect pathway". This "indirect pathway" is the perceived position sense of the cervical spine relative to the other two systems. They suggest that the neck converts one estimate of vertical into the reference frame of the other in order to inform the overall position to the brain[4]. The paper by Fraser *et al*.[4] was published directly on the heels of the paper by Marshall *et al*.[7] further adding to their position that concussion symptoms likely have a cervicogenic component[7].

When the vestibular system becomes injured/damaged, normal body functions such as balance, sense of orientation in space and eye movements while the head is moving are all negatively affected.[1] As research on the vestibular system continues to emerge, there have been several pathological conditions that have been linked to disruptions in vestibular function. A common condition among athletes is concussion and post-concussion syndrome (PCS). Concussions are heterogeneous injuries resulting in physical, cognitive, emotional and sleep related symptoms.[8] It is estimated that there are 1.6 to 3.8 million sport-related concussions (SRC) annually in the

United States.[2] The physical symptoms include vestibular-oculomotor impairment through the vestibulo-ocular reflex (VOR) and it may delay recovery if left untreated.[8] Symptoms arising from the vestibulo-ocular system have become amongst the most debilitating and disabling when associated with concussion[2] and have been identified as a prognostic factor for worse symptom burden, decreased cognitive performance, and longer recovery[3].

Up to 81% of athletes exhibit vestibular-associated signs following concussion.[3] Most concussion cases resolve in seven to 10 days, however 10 to 15% of cases can develop persistent symptomatology that lasts weeks, months or even years.[7] While PCS has been defined by the International Classification of Disease (ICD) as the persistence of three or more symptoms for four weeks or more, there is yet to be a clear physiological explanation for its development.[7]

While vestibular rehabilitation has shown to be an effective intervention for treatment of post concussive disorders, there are still a significant number of patients who have undergone this treatment with little to no success.[9] This raises the question of why, and what could be interfering with the improvement in vestibular symptoms in these cases.

Leg length discrepancies (LLD) are quite common accounting for three to 15% of the population and are present with both structural and functional scoliosis.[10] In many of the cases, the cause is unknown, and the difference is within 2cm. Any inequalities smaller than 2cm are thought to rarely cause a problem.[10] Symptomatic leg length discrepancies have most commonly been treated with internal or external shoe lifts. Custom foot orthoses and heel lifts were found to reduce spinal curves in juvenile patients with mild idiopathic scoliosis and have shown to be an indicated treatment regimen in the presence of certain types of functional scoliosis.[11]

To our knowledge, there are no case reports or other studies in the literature describing a possible link between persistent vestibulo-ocular-cervical concussion symptoms and a congenital/structural leg length discrepancy or inequality. The purpose of this case report is to describe the treatment of persistent post-concussion symptoms in a patient found to have a congenital leg length inequality utilizing heel lift therapy and subsequent vestibular rehabilitation following leg length optimization.

Case presentation

A 59-year-old female, former dragon boat athlete presented to the chiropractic clinic with a chief complaint of low back pain that she had had for greater than 30 years. Recently, she had begun to experience calf pain and spasm with walking and standing. She also reported a complicated concussion history that she felt had left her with ongoing balance and dizziness issues amongst other potential concussion related symptoms since her first concussion. She had seen a neurologist who recommended a balance specialist physiotherapist which helped somewhat at the time. Details of the program were sparse due to the length of time since her participation (14 years prior to presentation). She reported several other co-morbidities including depression, bipolar disorder, previous bulimia, high blood pressure (medicated) and pre-diabetes. Other past medical history included bilateral knee replacement surgery with another surgery done on the left knee to repair a fracture of the prosthesis cement; chronic difficulty breathing (MD determined that it was not due to asthma); previous pulmonary emboli due to DVT following her knee surgeries (which she had examined due to current calf pain and was cleared); and three previous MVA's starting in 1999 with an increase in neck pain each time. She also reported the previous use of orthotics that did include a heel lift correction but was no longer wearing them.

Her concussion history included an initial concussion following a dragon boating accident in which she had fallen out of the boat and was struck on the head by another dragon boat. This incident occurred 14 years prior to presentation at the chiropractic clinic. A second concussion 10 years prior to presentation was reported and occurred when she was climbing a scaffolding and hit her head as she ascended. This was not a work related incident. A third concussion seven years prior to presentation was reported and occurred when she was acting as a volunteer, felt ill during an event and fell and hit her head. She reported that she was no longer allowed to be a volunteer following this accident due to safety concerns surrounding her dizziness and balance issues. The patient was asked to fill out a SCAT 5 symptom scale and had 20/22 symptoms and a severity score of 72/132 (See Figure 1).

The patient reported her height as 166 cm (5'5 ½") and weight as 128 kg (282 lbs) (BMI – 46). A seated neuro-

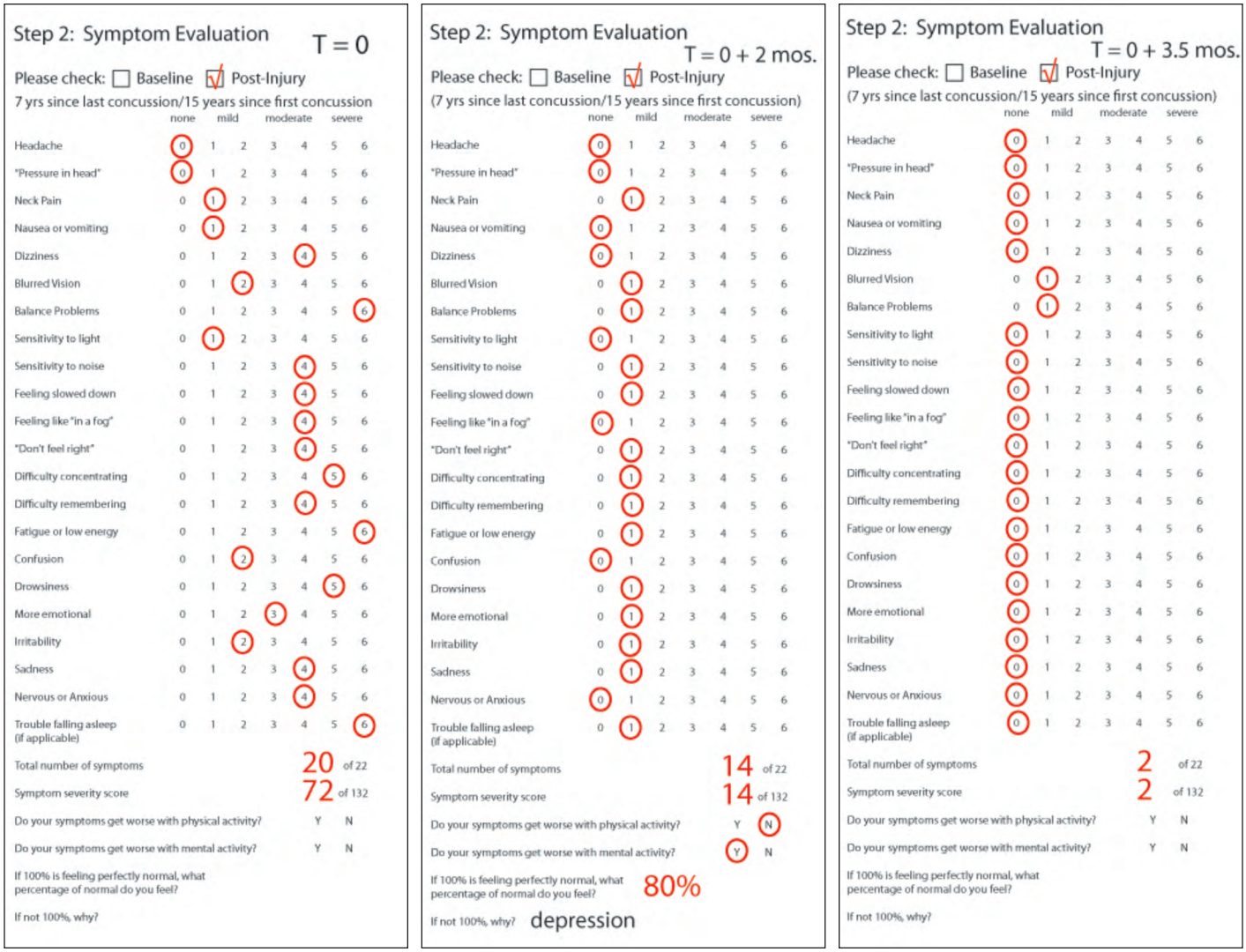

Figure 1.

SCAT 5 Concussion Symptoms Severity and Total Symptom Score of the Patient
a) Time = 0 (1st assessment) b) Time = 0 + 2 months c) Time = 0 + 3.5 months

logical exam found the following: her upper and lower limb neurologic exams including motor, sensory and reflexes were within normal limits (WNL); pathologic reflexes including Hoffman's (negative bilaterally) and plantar response (down going bilaterally) were WNL; and cerebellar testing including upper and lower limb rapid alternating movement, point to point, graphesthesia and stereognosis (bilaterally) were WNL. Her cranial nerve exam was WNL except for the following: on H-pattern testing, the patient reported increased dizziness (she felt she was spinning, not the room) with transition (smooth pursuit) and repeat transition (saccades) with both horizontal and vertical (from midline to upper quadrant bilaterally) with no nystagmus noted; increased dizziness (similar to above) and double vision with convergence reaching approximately 10 to 12 cm to her nose before her

eyes would diverge; and fixed gaze testing increased her dizziness (similar to above) with both cervical spine rotation and cervical spine flexion which she reported was the worst of the movements. Modified Balance Error Scoring System (m-BESS) revealed two errors with double leg stance (feet together), six errors with tandem stance and eight errors with single leg stance (16 errors total). No other neurologic testing was undertaken due to her increase in symptoms. On standing and prone examination, a moderate right thoracolumbar scoliosis was noted (32° on x-ray) with significant hypertonicity of the erector/multifidus musculature (part of her low back complaint). Iliac crest height palpation in standing revealed a notably lower left iliac crest. A prone leg length check revealed a left short leg (approximately 3/4" – 1 inch (2 cm – 2.54 cm), prone palpation of the posterior inferior iliac spine suggested they were even side to side, and prone left hip extension revealed a decreased anterior translation of the left sacral base. These findings suggested a structural leg length inequality with a short-left leg and a corresponding left sacral base dysfunction.

Following the history and physical exams, the patient was diagnosed with a suspected structural short left leg, chronic PCS, and suspected lumbar spinal stenosis. Her plan of management included:

1. Progressive heel lift therapy to determine optimal correction;
2. A seated wedge if needed;
3. Once her optimal heel lift height was determined (evaluated by improving signs and symptoms and SCAT 5 scores), begin soft tissue therapy on the remaining affected tissue; begin visual/vestibulo-ocular/cervical-ocular retraining based on her "new normal"; and
4. Swimming/aquatic therapy to help with weight loss/improve fitness goal.

The patient attended six visits over a period of six weeks. Minimal soft tissue therapy was applied to her lower back and cervical paraspinal musculature. The patient was asked to use a seated wedge while sitting with the side and size of the wedge determined by her response to a self H-pattern assessment while seated (i.e., try both sides and go with the side with lesser dizziness following the test). The heel lift was progressed as tolerated from an A lift (1/8") to a D lift (1/2") with her symptoms being monitored, a SCAT 5 symptom scale completed, and her convergence, H-pattern and fixed gaze being retested (with the heel lift in her shoe). On the seventh visit, after a week with the D lift, she reported an increase in low back and calf pain and the decision was made to return to the C lift. Her lower back and calf spasms returned to prior, better levels and it was felt the C lift was the correct size.

Following her return to a C heel lift, her convergence had improved to 0.5 cm at which point her eyes diverged and she had only minimal dizziness, her H-pattern testing caused no dizziness or unsteadiness, and her fixed gaze testing caused only minimal dizziness with rotation or flexion. Unfortunately, due to time constraints on this visit, modified BESS testing was not able to be completed. Also of note, the hypertonicity of her cervical, thoracic, and lumbar spine musculature had decreased considerably both subjectively and objectively.

The patient attended six more visits over a six-week period (treatment was discontinued due to the shutdown associated with the COVID pandemic). During this phase of treatment, more aggressive soft tissue therapy to her cervical, thoracic, and lumbar spine, manual therapy (including spinal manipulative therapy to the thoracolumbar spine) and vestibulo-ocular-cervical exercises utilizing a laser pointer mounted on a bike helmet were initiated.

An early exercise prescribed was one designed to re-establish neck proprioception during cervical spine rotation. The patient, while wearing their C heel lift, stood with their feet in a comfortable position, the laser pointed at a target on the wall (approximate distance to the wall of 152 cm (60") to 214 cm (84")). The patient closed their eyes, rotated their head side to side four to five times in each direction, then attempted to stop in their neutral start position. Any deviation of the laser pointer from the target was noted and the head was corrected to the target before the next repetition. The patient was asked to progress the exercise once the repositioning was successful on a regular basis through the BESS protocol foot positions using the short leg, with lift, as the non-dominant leg.[12]

Another main exercise was to maintain the laser pointer on a central target, determine the left/right/up/down limits of her gaze without symptoms (66 cm (26")) and place targets for these positions (See Figure 2). While maintaining the laser centrally, she was to transition her gaze

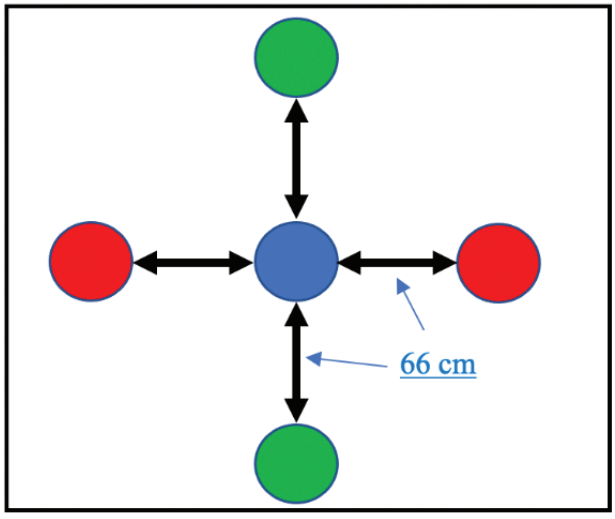

Figure 2.
Schematic of targets

to each of the targets while returning to centre after each movement to a metronome (40 bpm). This was done both seated and standing 92 cm (36") from the wall. She was asked to try for one minute but was nauseous and dizzy after 40 seconds. Due to her increased symptoms, her time was reduced to 30 seconds (seated and standing) 1X every other day. Over the next five weeks, she was able to progress to one minute seated and standing once per day, five days per week with little to no increase in symptoms. Following her last visit, she was asked to complete another SCAT 5 symptom scale which had improved to 2/22 symptoms and 2/132 severity. Again, unfortunately due to the shutdown, her m-BESS was not retested. Over this period, her SCAT 5 symptom scales were as follows (see Table 1):

Table 1.
Patient's total symptoms and symptom severity

Time	Number of symptoms (X/22) (SCAT 5 Symptom Scale)	Symptom Severity (X/132) (SCAT 5 Symptom Scale)
At initial	20/22	72/132
Initial + 2 months	14/22	14/132
Initial + 3.5 months	2/22	2/132

The patient was unable to begin pool therapy to address goal #4 of her treatment plan, again, due to the shutdown. Due to her continued, but improved, walking issues, radiographs of her lower back and pelvis were ordered approximately six weeks following presentation and revealed the aforementioned scoliosis, severe DDD from L3 to L5, moderate DDD L1/2 and L5/S1, a Grade 1 isthmic spondylolisthesis at L5/SI, moderate facet arthrosis from L2 to S1, mild DJD of bilateral SI and hips and moderate osteopenia. The radiographs were taken recumbently.

Discussion

The vestibulo-ocular reflex (VOR) regulates gaze stabilization during head acceleration, the vestibulo-spinal reflex (VSR) coordinates head, neck, and trunk positioning during dynamic body movements, and the cervico-ocular reflex (COR) is an ocular stabilization reflex initiated with cervical spine rotation.[2] When dysfunctions develop within these systems, it can have adverse effects on related subsystems generating complex symptoms and impairments with difficulty localizing them to one neural subsystem. Symptoms stemming from the vestibulo-ocular system include dizziness, gait instability, fogginess, blurred vision, and difficulty focusing.[2] Common visual symptoms include blurred vision, diplopia, difficulty reading or motion sensitivity which have been found to arise from deficits with accommodation, convergence, pursuits, saccades, and fixations.[2] Symptoms arising from the vestibulo-ocular system have become amongst the most debilitating and disabling when associated with concussion.[2] On the first SCAT 5 (see Figure 1 a), the patient reported symptoms consistent with vestibulo-ocular findings including: dizziness, balance problems, feeling like "in a fog", blurred vision, difficulty concentrating and remembering and nausea or vomiting. Objectively, the patient had deficits in smooth pursuits, near point convergence, fixations and saccades that resulted in dizziness and balance issues.

Concussions are heterogeneous injuries which, to this day, are still considered one of the least understood injuries.[7,8] There is no clear physiological explanation for PCS and evidence surrounding possible causes of PCS is limited. However, it has been proposed that PCS can be divided into subtypes; physiologic PCS, vestibulo-ocular PCS, and cervicogenic PCS[2], with theories surrounding

their mechanism that include metabolic dysfunction, continued axonal dysfunction, psychological factors, altered cerebral blood flow and dysfunction of the cervicogenic pain and proprioceptive mechanisms[7]. Due to the vast developing nature of concussions and PCS and the little evidence surrounding causes, post-concussion examinations should at minimum include full neurological, and cerebellar function, with a thorough assessment of balance, gait, cognitive function, and the patient's vestibular system.[2] Vestibular oculomotor screening (VOMS) has begun to be used as a part of the concussion assessment.[8] The VOMS assessment tool evaluates vestibular and oculomotor systems after concussion and assesses seven components; smooth pursuit, horizontal and vertical saccades, horizontal and vertical VOR, visual motion sensitivity and near point convergence (NPC).[8] With proper rehabilitation of the vestibular system, the scores of the VOMs should improve from the baseline test post-concussion. Although not all of the VOMS assessment was completed with our patient, her smooth pursuit, saccades, fixations and near point convergence all improved from baseline after heel lift therapy followed by vestibulo-ocular-cervical rehabilitation.

Vestibular rehabilitation programming is designed to improve function of the VOR and COR by including depth perception training, somatosensory retraining, dynamic gait training and aerobic conditioning. The exercises have shown to improve fixation, pursuit, predictable and unpredictable saccades, vergence, and accommodation.[2] A study focusing on weekly cervical spine and vestibular rehab treatments in subacute and chronic concussion patients resulted in 73% of athletes becoming asymptomatic and cleared for return to sport compared to 7% in the control group.[9] The benefits of vestibular rehabilitation for the post-concussion population have been reproduced in other studies, and moderate level evidence to support this theory in a 2017 systematic review of the literature.[13] In our case, the patient had previously participated in vestibular rehabilitation (although her recollection of the details of the program were sparse) with limited success. Following heel lift therapy to optimize her structural leg length discrepancy, she again participated in vestibular rehabilitation further improving her SCAT 5 symptom scale from 14/22 symptoms and 14/132 symptom score to 2/22 and 2/132 respectively (See Figure 1b and c).

Disruption or injury to the vestibular system has been linked to other biomechanical issues including, but not limited to, adolescent idiopathic scoliosis (AIS).[14,15] Despite the high prevalence of the condition, the etiology behind AIS remains unclear. Since the vestibular system influences the vestibulospinal pathways, the hypothalamus, and the cerebellum, it is plausible to believe that this could account for the morphological and neurosensory changes observed in AIS.[14] It could also be that AIS patients use strategies to compensate for possible head position changes and spinal asymmetry caused by morphological deformations of the spine through vestibular and somatosensory systems.[16] In both theories, it is made clear that there are changes to the vestibular system in this population. Our patient had a 32° scoliosis, likely since she had reached skeletal maturity based on her long history of back pain. It is likely she would have had an AIS diagnosis until the functional nature of her scoliosis due to the LLD was discovered.

Subjective visual vertical (SVV) is a sensitive sign of verticality perception.[15,17,18,19] It relies on both visual and vestibular input and is reported to be the most sensitive sign of vestibular tone imbalance in the roll plane.[6,15,19] Vestibular tone imbalance can be the result of lesions in the central and/or peripheral vestibular pathways. In a study by Cakrt *et al*.[15], they found that patients with adolescent idiopathic scoliosis (AIS) had a significantly larger deviation in SVV versus age-matched controls. Their findings suggest that scoliosis in AIS may be the result of a vestibular impairment due to an imbalance in these vestibular pathways. Correspondingly, it also suggests those with scoliosis have a slightly askew sense of verticality from a visual standpoint despite the ability of the body to adapt to the vestibular deficits. In their study[15], more than 20% of patients with AIS had an average deviation in their SVV of more than 2°. Unfortunately, there was no measurement of leg lengths mentioned in the study by Cakrt *et al*.[15]

Scoliosis patients are also well known to present with leg length discrepancies.[10] Back pain, lower extremity pain and degenerative conditions have been shown to correlate with inequalities in leg length.[20] A common theory is that if you can restore leg-length inequalities through the use of custom-made stabilizing orthotics and/or lifts then you can improve the proprioceptive sensory feedback and ability to coordinate body movements, postural alignment and balance.[11] Custom foot orthoses and heel

lifts were found to reduce spinal curves in juvenile patients with mild idiopathic scoliosis and have shown to be an indicated treatment regimen in the presence of certain types of functional scoliosis with few adverse effects.[11] In our case, the addition of a heel lift through a progressive approach saw marked changes in muscle hypertonicity and pain in the lower back and neck both subjectively and objectively. Once the pain began to return with the D size lift, the decision was made to return to the C lift and the pain once again subsided to previous levels.

The approach to applying heel lift therapy and the endpoint for height of the correction have limited consensus in the research. A systematic review by Campbell *et al*.[21] acknowledges these limitations and suggested that for traumatic based LLD's (eg. post surgery or fracture) an immediate full correction is warranted, while a chronic, long standing LLD may only require partial correction due to the patient's adaptation to their LLD. Our approach, in this case, was a progressive one to allow the patient to adapt to the change while monitoring for improvement or increase in symptoms. Our case demonstrated the recommendation by Campbell *et al*.[21] by only requiring a partial correction for patients with a chronic LLD (a C heel lift is 3/8" compared to the patient's ¾ - 1" structural difference).

It has yet to be investigated how other tools can be implemented in concussion treatment to target biomechanical changes such as foot orthosis and heel lifts, which have also shown to increase proprioceptive ability.[22,23] If the use of custom-made stabilizing orthotics and/or heel lifts can improve the proprioceptive sensory feedback and ability to coordinate body movements, postural alignment, and balance in scoliosis patients, then the same effect could be possible with patients suffering from PCS if an LLD is identified as in our case.

Limitations

The authors acknowledge the limitations of this case report including subjectively reported measures, and a lack of evidence supporting management using heel lifts. There is also a lack of validity and reliability in the evaluation of LLD generally, including the method used in this assessment. There was also a lack of confirmation of an LLD through a full, bilateral lower body radiograph which would be considered the gold standard, although the routine use of radiographs to check for LLD is not recommended due to unnecessary radiation exposure.

There is also an inherent limitation in all case reports that their results cannot be generalized – they are instead meant to report rare findings and potentially stimulate further research in this area which is the hope of this report.

Summary

This case highlights a unique clinical consideration in a patient with prolonged, post-concussion, vestibulo-ocular-cervical symptoms following several concussive events. Assessing and providing successful conservative treatment for an LLD, followed by vestibular/ocular/cervical rehabilitation in a patient with prolonged post-concussion symptoms has not been previously reported in the literature to our knowledge.

Although speculation on hypothesis in case reports is not usually included, the lack of other reports or studies in the literature linking structural LLD and persistent concussions symptoms may warrant its inclusion in the current report. The lack of similar case reports in the literature begs the following questions: 1) Are these cases so rare that this particular patient is unique and interesting but adds no further value for stimulating future investigation? and/or 2) Has this theoretical link not previously been reported because assessing for LLD in acute or persistent concussion is not a routine part of patient assessment?

The authors of this report suggest it is likely the latter. There is no mention of assessing for LLD in any studies on concussion to our knowledge. In the majority of individuals with LLD, they have been able to compensate for this discrepancy in such a manner that they aren't even aware that they have an LLD let alone seek out treatment for it. We suspect that the vestibulo-ocular-cervical system easily adapts to their LLD under normal circumstances but the adaptation(s) may narrow their ability to then adapt to an injury causing concussion ultimately contributing to ongoing or more severe symptoms and even affecting their capacity to recover.

The authors suspect that if the concussive injury is severe enough, or if there have been repeated concussive injuries (as in our case) that pushes the patient outside of their vestibular-ocular-cervical adaptation to the LLD, the patient's ability to recover becomes more difficult, takes longer, and some aspects may not achieve full recovery leading to prolonged, persistent symptoms. Interestingly, the suggestion that the neck's proprioceptive feedback is

able to integrate the SVV and SHV[4] may also prolong recovery if that system has chronic injury related issues. It would also make sense, although there is no supporting literature on this, that the larger the LLD, the greater the adaptation needed to stabilize their vestibulo-ocular-cervical system resulting in a narrower window of potential adaptation to a concussive injury. Thus, the length of time to recovery may in fact be proportional to the size of the underlying structural LLD (with all other aspects of recovery being equal).

In our case, the patient reported chronic lower back pain (likely reducing her SHV), mild, chronic neck pain (likely reducing the integration) and she would likely have an offset of 2° or more SVV due to her 32° scoliosis. The addition of the heel lift reduced both her lower back and neck pain (with the addition of vestibular rehabilitation) and likely improved her SVV. It is possible that the improvement of these three systems followed by vestibular rehabilitation led to her recovery.

Further research studies could explore the relationship of structural LLD and persistent vestibulo-ocular-cervical concussion symptoms. If such a relationship exists, as this case report would suggest, the addition of a simple, inexpensive heel lift may be an effective first step in the treatment of this potential sub-category of post-concussion patients with persistent vestibulo-ocular-cervical symptoms. Once the LLD is optimized, a vestibular/ocular/cervical rehabilitation program may then be more effective in reducing any remaining vestibulo-ocular-cervical symptoms.

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