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JCCA December 2020 Sports Chiropractic Special Issue: 12th Edition

Mohsen Kazemi, RN, DC, FRCCSS(C), FCCPOR(C), MSc, PhD[1]
Assistant Editor

(JCCA. 202;64(3):164)

KEY WORDS: sports, chiropractic

MOTS CLÉS : sports, chiropratique

It has been twelve years since the inaugural edition of Sports Chiropractic special issue was published. We have since come a long way in showcasing Sports Chiropractic publications. This year with its unprecedented challenges has not hampered our efforts to bring you another special issue on Sports Chiropractic. In fact, I believe this issue is one of our best thus far with a great variety of topics. In this issue you will find a systematic review, a Clinical Practice Guideline appraisal and summary, a small RCT, a retrospective data analysis, a survey, psychometric assessment of a concussion tool, a case series and two case reports. I marvel at how the quality of the papers has been consistently improving over the years. I hope you will enjoy this issue and be encouraged and empowered by it.

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

[1] Canadian Memorial Chiropractic College

Corresponding author: Mohsen Kazemi, 6100 Leslie Street, Toronto, ON M2H 3J1
E-mail: mkazemi@cmcc.ca
Tel: 416-482-2340

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Incidence and risk factors for musculoskeletal disorders of the elbow in baseball pitchers: a systematic review of the literature

Chris Grant, BSc, DC, FRCCSS(C)[1]
Taylor Tuff, BSc, DC, FRCCSS(C)[1]
Melissa Corso, BSc, MSc, DC, FRCCSS(C)[1,2,4]
James J. Young, DC, MSc, FCCS(C)[1]
Paula J. Stern, BSc, DC, FCCS(C)[1]
Elie Côté, MD[3]
Pierre Côté, DC, PhD[2,4]

Objective: *To determine the incidence and risk factors of musculoskeletal disorders of the elbow in baseball pitchers.*

Design: *Systematic review.*

Data Sources: *Medline, CINAHL, Cochrane, PubMed and SportDiscus from onset to July 7, 2018.*

Eligibility Criteria: *Eligible studies included randomized controlled trials, cohort studies and case-control studies. Independent pairs of reviewers screened titles and abstracts for eligibility. Relevant articles were critically appraised for internal validity using the SIGN criteria. We included low risk of bias studies in our best evidence synthesis.*

Objectif : *Établir l'incidence et facteurs de risque de troubles musculosquelettiques du coude chez le lanceur de baseball.*

Méthodologie : *Revue exhaustive.*

Sources des données : *Medline, CINAHL, Cochrane, PubMed et SportDiscus depuis le début jusqu'au 7 juillet 2018.*

Critères d'admissibilité : *Les études admissibles étaient des essais comparatifs à répartition aléatoire, des études de cohortes et des études de cas-témoins. Des pairs examinateurs indépendants ont trié des titres et des résumés satisfaisant les critères d'admissibilité. On a évalué la validité interne des articles pertinents en utilisant les critères SIGN. On a tenu compte d'un faible risque d'études faussées dans notre meilleure synthèse de preuves.*

[1] Division of Graduate Studies, Canadian Memorial Chiropractic College, Toronto, Canada
[2] Faculty of Health Sciences, Ontario Tech University, Oshawa, Canada
[3] Department of Ophthalmology & Vision Sciences, University of Toronto, Toronto, Canada
[4] Centre for Disability Prevention and Rehabilitation at Ontario Tech University and CMCC

Corresponding author:
Chris Grant, Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, ON M2H 3J1
E-mail: chris.grant016@gmail.com
Tel: 647-967-2443.

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Results: *We retrieved 4502 articles, 39 were critically appraised and nine had a low risk of bias. These were included in the evidence synthesis. The incidence of musculoskeletal disorders of the elbow ranges from 2.3% in adolescent pitchers to 40.6% in youth pitchers. Evidence suggests that pitch characteristics, inadequate rest, biomechanical and anthropometric factors may be risk factors of UCL tears.*

Summary/Conclusion: *Baseball pitchers develop musculoskeletal disorders of the elbow. There is little high-quality evidence to understand the etiology. Preliminary evidence suggests the risk factors are multifactorial.*

PROSPERO Trial Registration Number: CRD42018092081

(JCCA. 2020;64(3):165-179)

KEY WORDS: baseball, elbow, epidemiology, injury

Résultats : Sur les *4 502 articles retenus, 39 ont été évalués d'une façon critique; neuf présentaient un risque de parti pris. Ceux-ci ont été inclus dans la synthèse de preuves. L'incidence des troubles musculosquelettiques du coude variait de 2,3 % chez les lanceurs adolescents à 40,6 % chez les jeunes lanceurs. Les données semblent indiquer que les caractéristiques du lancer, un repos insuffisant, des facteurs biomécaniques et anthropométriques pourraient être des facteurs de risque de déchirure du ligament collatéral de l'ulna (LCU).*

Résumé/conclusion : *Les lanceurs de baseball développent des troubles musculosquelettiques au coude. Il existe peu de preuves de grande qualité permettant de comprendre l'étiologie de ces troubles. Les données préliminaires semblent indiquer que les causes sont multifactorielles.*

Numéro d'enregistrement d'essai PROSPERO : CRD42018092081

(JCCA. 2020;64(3) : 165-179)

MOTS CLÉS : baseball, coude, épidémiologie, blessure

Introduction

Musculoskeletal disorders of the elbow are a considerable source of disability in baseball pitchers.[1] In high school pitchers, the elbow is the second most commonly injured area (18.9%) after the shoulder (34.2%).[2] Musculoskeletal disorders of the elbow affect 12.4% of professional baseball pitchers every season and these pitchers are more likely to require surgery, or to be placed on the disabled list compared to other players.[1,3] In Major League Baseball, 90.3% of medial ulnar collateral ligament (UCL) reconstruction surgeries are performed on pitchers, requiring an average of 17.8 months on the disabled list.[4]

Several risk factors for musculoskeletal disorders of the elbow in baseball pitchers have been proposed including overuse[5,6], pitch velocity[6], pitch types[5,7], changes in glenohumeral rotation[8–10], humeral torsion[11], and poor throwing biomechanics[12]. Despite methodological limitations related to study design, population at risk, case definition, and measurement of exposure, guidelines have been developed in an attempt to reduce injury rates in pitchers.[5,6,9,13–18] A few systematic reviews have been published recently on the topic of arm injuries in baseball players.[19–21] Norton *et al*.[20] examined the risk factors for shoulder and elbow injuries in adolescent baseball pitchers and found age, height, playing for multiple teams, pitch velocity and arm fatigue to be independent risk factors for throwing arm injuries. However, no risk factors specific to elbow injuries were identified in this review. Agresta *et al*.[21] investigated prospective cohort studies and randomized controlled trials looking at both youth and professional baseball players and identified that pitching greater than 100 innings per year, being aged nine to 11 years, being a pitcher or a catcher, training greater than 16 hours per week and having a history of elbow pain were significant risk factors for elbow injury among youth baseball players. Through a systematic review and meta-analysis Salamh *et al*.[19] identified that the only statistically significant risk factor for adolescent baseball pitchers was pitching with arm fatigue. A systematic review of the available evidence is needed to determine the incidence and risk factors specific to musculoskeletal disorders of the elbow in baseball pitchers across all age groups. The purpose of

our systematic review is to synthesize the best available evidence on the incidence and risk factors for musculoskeletal disorders of the elbow in baseball pitchers of all ages and levels of play. Incidence refers to the number of new cases of a disorder in a population initially free of the condition (those without the disorder of interest at the beginning of the study).[22] Risk factors are characteristics associated with an increased or decreased incidence of developing a disorder.[22]

Methods

Registration and reporting

We registered the review with the International Prospective Register of Systematic Reviews (PROSPERO) on March 24, 2018 (CRD42018092081). Our systematic review complies with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[23]

Eligibility criteria

Population: Our review targeted baseball pitchers of all age groups and levels of play that sustained an elbow musculoskeletal disorder.

Outcomes: The outcome of interest was musculoskeletal disorders of the elbow, defined as any physical complaint sustained by a player that results from a baseball game or baseball training, irrespective of the need for medical attention or time-loss from baseball activities.[24] We included all reported elbow musculoskeletal disorders affecting the bones (humerus, radius, ulna), joints (elbow joint, proximal radioulnar joint) and soft tissues (muscles, tendons, ligaments, connective tissue, nerves and blood supply). Eligible articles reported on at least one type of musculoskeletal disorder of the elbow: 1) physical complaint (i.e. elbow pain); 2) disorder requiring assessment of a player's complaint by a qualified medical practitioner[24]; 3) time-loss (inability to participate in practice or a game[24]); or 4) UCL tear requiring surgical repair.

Study characteristics: Eligible articles met the following criteria: 1) English language; 2) published in peer-reviewed journals; 3) randomized controlled trials, cohort studies and case-control studies; 4) study population including baseball pitchers of any age or level of play; and 5) measured the incidence or risk factor(s) for musculoskeletal disorders of the elbow. We excluded the following articles: 1) letters, editorials, commentaries, unpublished manuscripts, dissertations, government reports, books and book chapters, conference proceedings, meeting abstracts, lectures and addresses, and consensus development statements; 2) cross-sectional studies, pilot studies, case reports, case series, qualitative studies, literature reviews, clinical practice guidelines, laboratory studies and studies without methodology; 3) cadaveric or animal studies; 4) studies solely analyzing softball pitching; and 5) studies that do not differentiate between injury rates of pitchers and positional players.

Data sources and searches

We developed our search strategy with a health sciences librarian (Appendix A). A second librarian reviewed the search strategy for completeness and accuracy using the Peer Review of Electronic Search Strategies (PRESS) Checklist.[25] We searched MEDLINE, CINAHL, Cochrane, PubMed and SportDiscus from the beginning of the database to July 7, 2018.

We developed the search strategy in MEDLINE, which was subsequently adapted to the other bibliographic databases. The search terms included subject headings specific to each database (e.g. MeSH in MEDLINE) and free text words relevant to baseball injury epidemiology. We downloaded the search results into a database created using EndNote x6 (Thompson Reuters Corp, New York, New York).

Study selection

We used a two-phase screening process. In phase one, pairs of independent reviewers (from a pool of six reviewers) screened citation titles and abstracts to determine eligibility. In phase two, the same pairs of reviewers independently reviewed the full text of possibly relevant articles to make a final determination of eligibility. Reviewers met to resolve disagreements. If consensus could not be reached, a third reviewer was used.

Quality assessment and data extraction

Two independent reviewers (from a pool of seven reviewers) critically appraised each eligible article. We assessed the internal validity of articles using the Scottish Intercollegiate Guidelines Network (SIGN) criteria.[26] The SIGN criteria were used to qualitatively evaluate the impact of selection bias, information bias and confounding

on study results. We did not use a quantitative score, or a cut-off point to determine the internal validity of studies. All reviewers were trained to critically appraise studies using the SIGN criteria. Consensus between the reviewers in each pair was reached through discussion, with the involvement of an independent third reviewer if necessary. We contacted authors when we needed additional information for the critical appraisal to be accurate and valid.

Data extraction

Only articles with a low risk of bias were included in our synthesis. The lead author (CG) extracted data from articles with a low risk of bias and built evidence tables. A second reviewer (TT) independently checked the extracted data. Disagreements were resolved through discussion.

Data synthesis and analysis

We conducted a qualitative best-evidence synthesis due to the heterogeneity of study popualtions.[27] The evidence was stratified according to level of play (youth, adolescent and high school, and professional) and type of elbow disorder (physical complaint, musculoskeletal disorder requiring medical attention, time-loss musculoskeletal disorder and UCL tear requiring surgical repair).

We computed reviewer agreement for the screening of titles and abstracts and reported kappa statistics with 95% confidence intervals (95% CIs).[28] The percentage of agreement for critical appraisal of articles was calculated for the studies with high and low risk of bias.

Role of the funding source

No funding was provided for this systematic review.

Results

Article selection

We retrieved 4502 articles, removed 1157 duplicates, and screened 3345 papers for eligibility (Figure 1). Of those, 39 articles were critically appraised and nine had a low risk of bias. The inter-rater agreement for phase one screening of articles was k = 0.71 (95% CI = 0.65-0.76). The inter-rater agreement for phase two screening of articles was k = 0.62 (95% CI = 0.43-0.80). The inter-rater agreement for critical appraisal of articles was k= 0.68 (95% CI = 0.44-0.91).

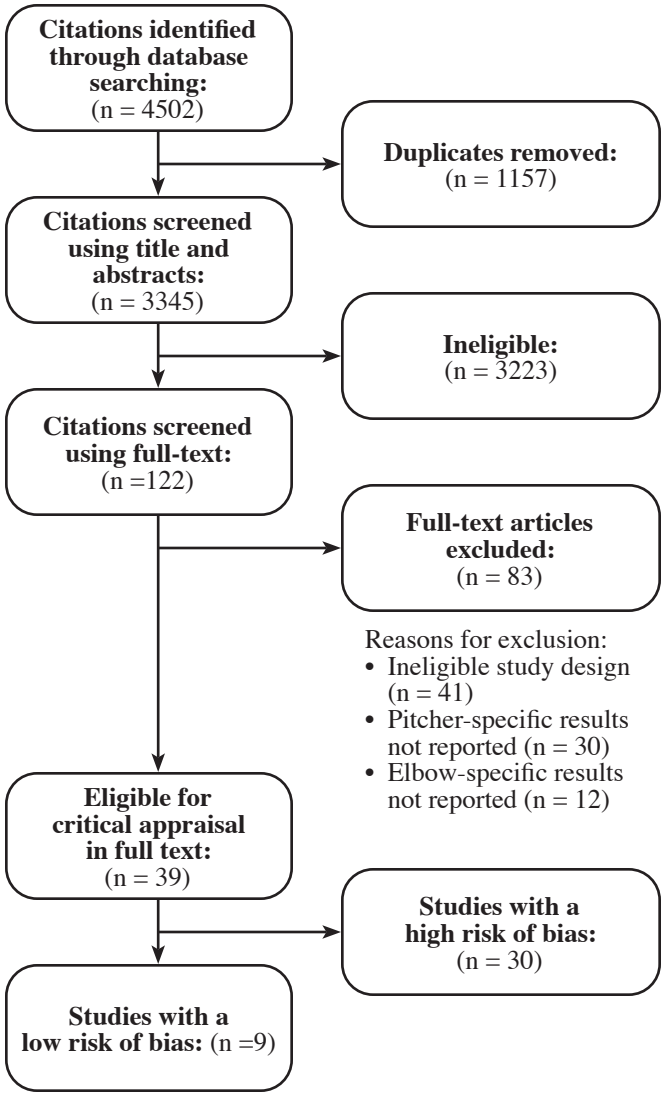

Figure 1.
PRISMA flowchart.

Article characteristics

Of the nine articles with a low risk of bias, six were cohort studies and three were case-control studies.[10,29–36] All six of the cohort studies reported on incidence.[10,29–33] The three case-control studies reported on risk factors.[34–36] Three cohort studies investigated professional baseball pitchers[29,31,32], two studied adolescent and high school pitchers (age 13-19 years)[10,33], and two studied youth (less than 13 years) pitchers[10,30]. Five articles reported on the incidence of time-loss associated with musculoskeletal

disorder of the elbow.[10,29,31–33] One article reported on the incidence of elbow physical complaints and disorders requiring medical attention.[30] Five articles followed players for one baseball season[10,29,31–33] and the other article followed players for one year[30].

Three low risk of bias case-control studies investigated risk factors in professional pitchers[34–36], and one in high school pitchers[33]. The studies of professional pitchers investigated risk factors for UCL tears requiring surgical reconstruction.[34–36] The study of high school pitchers studied risk factors for time-loss musculoskeletal disorders of the elbow.[33] These four articles investigated the following risk factors: pitch velocity[36], pitch selection[34], playing catcher as a secondary position[33], days between games pitched[35], standing height[35], horizontal release location[35], and the number of pitches per game[35].

Risk of bias

All low risk of bias cohort studies had a clear research question, their outcomes were clearly defined and all included clearly defined populations at risk (pitchers had no restrictions in throwing or baseball participation at the time of enrolment).[10,29–33] All cohort studies had a follow-up rate of at least 95%.[10,29–33] All case-control studies (3/3) clearly defined cases and controls and the exposure was measured in a standard, valid and reliable way.[34–36] The cases and controls were taken from comparable populations in 100% (3/3) of the case-control studies.[34–36] Potential confounders (age, height, weight, position, major league experience, innings pitched) were identified and controlled for in all case-control studies.[34–36]

Twenty-five cohort studies had a high risk of bias.[1–3,11,12,37–56] The limitations of these cohort studies included lack of blinding of outcome assessment (15/25)[2,11,12,37–43,45,53–56] and lack of evidence to demonstrate the outcome assessment was valid and reliable (15/25)[2,11,12,37,38,40,42–45,52–56]. Eight of the cohort studies had a high risk of bias because they failed to report whether the pitchers were injury-free at the onset of the study (8/25).[1,3,46–51] Five high-risk of bias case-control studies[6,57–60] had important limitations including lack of an appropriate control group (1/5)[57], pre-injury exposure data available for less than half of the eligible participants (1/5)[58], and lack of consideration for potential confounding variables (5/5)[6,57–60].

Incidence of musculoskeletal disorders of the elbow in baseball pitchers

Youth baseball pitchers

The incidence of musculoskeletal disorders of the elbow varies depending on case definition (Table 1). In youth baseball pitchers (between the ages of 6-12 years old), the incidence of musculoskeletal disorders of the elbow requiring medical attention was 2.2 disorders per 1000 athletic-exposures (95% CI: 1.5-3.2). This equates to 40.6% (95% CI: 29.8-52.4) of the pitchers sustaining an elbow disorder requiring medical attention per year.[30] The incidence of elbow pain in the same sample was 2.5 complaints per 1000 athletic-exposures (95% CI: 1.8-3.5).[30] An athletic-exposure was defined as one athlete participating in one practice or game during which a player was at risk of sustaining an injury. The incidence of time-loss elbow musculoskeletal disorders was 21.3% per baseball season (95% CI: 12.0-34.9) in pitchers younger than 13 years of age.[10] A time-loss injury was defined as an injury that was verified by the team's athletic trainer or research physical therapist and required the player to miss a minimum of one practice or game. As expected, musculoskeletal disorders of the elbow requiring medical attention are more common than those requiring time-loss in youth baseball pitchers.[10,30]

Adolescent and high school baseball pitchers

The reported incidence of time-loss musculoskeletal disorders of the elbow, per season, is lower in adolescents than in youth or professional baseball pitchers. Hibberd *et al*.[33] reported that 2.3% (95% CI: 1.2-4.4) of high school baseball pitchers (between the ages of 14-19 years) sustained a time-loss musculoskeletal disorder of the elbow over the course of a season. Shanley *et al*.[10] documented a higher incidence of 11.8% (95% CI: 6.1-21.5) of adolescent baseball pitchers (between the ages of 13-18 years) sustaining a time-loss musculoskeletal disorder of the elbow over a season.

Professional baseball pitchers

The reported incidence of elbow musculoskeletal disorders requiring time-loss in professional baseball pitchers ranges from 13.5% (95% CI: 9.5-18.9%) to 21.7% (95% CI: 15.5-29.6%).[29,31,32] The definitions used for time-loss musculoskeletal disorders of the elbow were: (1) any

Table 1.

Elbow injury incidence in baseball pitchers. Abbreviations: AE = athletic-exposure; CI = confidence interval.

Author(s), year	Study design	Subjects and setting	Follow-up period	Case definition	Incidence (95% CI)
Youth injuries					
Sakata et al., 2016[30]	Cohort study	69 junior baseball pitchers (ages 6-12 years) with no history of elbow pain	12 months	**Physical complaint (elbow pain):** • Elbow pain lasting greater than 2 weeks, elbow pain that caused them not to play in a game or practice, or recurrent elbow pain **Elbow injury requiring medical attention:** • Medial elbow pain during throwing with either an abnormal sonography finding or the presence of pain during a clinical assessment	**Elbow pain incidence density:** 2.5/1000 AEs (1.8-3.5/1000 AEs) **Elbow injury requiring medical attention incidence density:** 2.2/1000 AEs (1.5-3.2/1000 AEs) **Elbow injury requiring medical attention annual incidence:** 40.6% (29.8-52.4)
Shanley et al., 2015[10]	Cohort study	47 asymptomatic youth (8-12 years old)	One baseball season	**Time-loss elbow injury:** • An injury to any muscle, joint tendon, ligament, bone or nerve of the elbow requiring the pitcher to miss at least one game or practice	**Time-loss elbow injury incidence per season:** 21.3% (12.0-34.9)
High school and adolescent injuries					
Shanley et al., 2015[10]	Cohort study	68 adolescent (13-18 years old) pitchers	One baseball season	**Time-loss elbow injury:** • An injury to any muscle, joint tendon, ligament, bone or nerve of the elbow requiring the pitcher to miss at least one game or practice	**Time-loss elbow injury incidence per season** 11.8% (6.1-21.5)
Hibberd et al., 2018[33]	Cohort study	384 high school baseball pitchers (age 14-19 years)	One spring baseball season	**Time-loss elbow injury:** • An injury to the elbow that occurred as a result of baseball throwing that resulted in at least one missed athletic-exposure.	**Time-loss elbow injury incidence per season:** 2.3% (1.2-4.4)
Professional injuries					
Byram et al., 2010[29]	Cohort study	207 pitcher-seasons from 144 Major and Minor League Baseball pitchers	One season	**Time-loss elbow injury:** • An injury to the elbow that resulted in placement on the disabled list and/or missing at least one game **Non-operative time-loss elbow injury:** • An elbow injury that did not require surgery **Operative time-loss elbow injury:** • An elbow injury that did require surgery	**Time-loss elbow injury incidence per season:** 13.5% (9.5-18.9) **Non-operative time-loss elbow injury incidence per season:** 5.8% (3.4-9.9) **Operative time-loss elbow injury incidence per season:** 7.7% (4.8-12.2)
Camp et al., 2018[31]	Cohort study	129 pitcher-seasons from pitchers invited to Major League Baseball Spring Training for a single professional baseball organization	One baseball season	**Time-loss elbow injury:** • A musculoskeletal injury to the elbow that resulted in at least one day out of play	**Time-loss elbow injury incidence per season:** 21.7% (15.5-29.6)
Camp et al., 2017[32]	Cohort study	132 pitcher-seasons from 81 pitchers invited to Major League Baseball Spring Training for a single professional baseball organization	One baseball season	**Time-loss elbow injury:** • An injury to the elbow that resulted in at least one day out of play	**Time-loss elbow injury incidence per season:** 21.2% (15.1-29.0)

elbow condition resulting in the pitcher's placement onto the disabled list and/or missing at least one game because of the condition[29]; or (2) any elbow injury that resulted in at least one day out of play[31,32]. These articles included all pitchers invited to the Major League Baseball Spring Training for a single professional baseball organization, who were willing to participate in the preseason assessment, were not currently injured, and did not have a recent surgery which would limit their ability to fully participate in baseball-related activities without restrictions.[29,31,32]

Risk factors for musculoskeletal disorders of the elbow

High school baseball pitchers

Data from Hibberd *et al*.[33] indicate that playing catcher as a secondary position may have a higher incidence than those who do not play catcher as a secondary position (RR=3.14; 95% CI: 0.68-14.50; p=0.14). However, the precision of this estimate is low as there is a non-significant p-value and a wide 95% confidence interval.

Professional baseball pitchers

Pitch velocity

The evidence suggests that pitch velocity is positively associated with UCL tears requiring reconstructive surgery in professional baseball pitchers (Table 2). According to Whiteside *et al*.[35], the odds of undergoing UCL reconstruction surgery increased by 38% for every unit (meters/second) increase in mean pitch speed (OR=1.38; 95% CI: 1.10-1.73; p=0.005). Similarly, Prodromo *et al*.[36] identified that a greater average fastball velocity (OR=1.15; 95% CI: 1.06-1.24; p=0.001), slider velocity (OR=1.10; 95% CI: 1.02-1.20; p=0.02), curveball velocity (OR=1.11; 95% CI: 1.03-1.20; p=0.009), and changeup velocity (OR=1.09; 95% CI: 1.02-1.18; p=0.016) was associated with an increased odds of an UCL tear requiring surgical reconstruction in professional baseball pitchers.[36] However, an increase of one-mile per hour to the mean pitch velocity of the cut fastball (OR=1.01; 95% CI: 0.94-1.08; p=0.85) or split-fingered fastball (OR=1.13; 95% CI: 0.94-1.34; p=0.191) did not increase the odds of UCL tears requiring surgical repair in professional baseball pitchers.[36]

Pitch selection

The evidence suggests that throwing a greater percentage of fastballs is associated with an increased risk of an UCL tear requiring surgical reconstruction, while throwing a greater variety of unique pitch types may reduce the risk of sustaining an UCL tear requiring surgical reconstruction. Keller *et al*.[34] reported a 2% increase in the odds of UCL tears for every 1% increase in the percentage of fastballs thrown over the course of a season (OR=1.02; 95% CI: 1.00-1.03; p=0.035). However, a greater percentage of sliders (OR=0.98; 95% CI: 0.96-1.00; p=0.11), curveballs (OR=1.00; 95% CI: 0.97-1.03; p=0.88), and changeups (OR=1.03; 95% CI: 0.99-1.07; p=0.13) thrown were not associated with an increased risk of UCL injury. Whiteside *et al*.[35] reported that having a greater number of unique pitch types was associated with a decreased odds of UCL tears requiring surgical reconstruction (OR=0.67; 95% CI: 0.49-0.92; p=0.012). Unique pitch types can be defined as the number of different pitches that pitcher throws regularly. For example, a pitcher that throws a fastball, curveball and sinker would have three unique pitch types. After controlling for confounders, a pitcher's odds of undergoing UCL reconstruction surgery decreased by 33% for each unique pitch type that he possessed in his repertoire.[35]

Pitcher workload

Limited evidence suggests that a greater number of pitches thrown per game is associated with an increased risk of sustaining an UCL tear requiring surgical reconstruction. A greater amount of days between games pitched is associated with a decreased risk of sustaining an UCL tear requiring surgical reconstruction. Whiteside *et al*.[35] reported that the odds of undergoing UCL reconstruction surgery increased by 2% over the course of a season for every one-pitch increase to the mean number of pitches per game (OR=1.02; 95% CI = 1.01-1.03; p=0.003). Increasing the number of days between games pitched was associated with a reduction in UCL tears requiring surgical reconstruction in professional baseball pitchers.[35] After controlling for confounders, a pitcher's odds of undergoing UCL reconstruction surgery decreased by 31% (OR=0.69; 95% CI: 0.54-0.87; p=0.002) for each additional day between consecutive games pitched.[35]

Table 2.
Risk factors for elbow injuries in baseball pitchers. Abbreviations: OR = odds ratio; RR= relative risk; CI = confidence interval; mph = miles per hour.

Author(s), year	Risk factor(s) Considered	Study design	Cases and control	Risk factors
Keller et al., 2016[34]	Percentage of fastballs, sliders, curveballs & change-ups thrown	Case-Control Study	**Cases:** 83 Major League Baseball pitchers who had undergone primary UCL reconstruction between 2008 and 2015. **Controls:** 83 Major League Baseball pitchers matched for year, age, position, size, experience and innings pitched	**One percent increase in fastballs thrown:** OR=1.02; 95% CI=1.00-1.03; p=0.035 **One percent increase in sliders thrown:** OR=0.98; 95% CI=0.96-1.00; p=0.11 **One percent increase in curveballs thrown:** OR=1.00; 95% CI=0.97-1.03; p=0.88 **One percent increase in change-ups thrown:** OR=1.03; 95% CI=0.99-1.07; p=0.13
Prodromo et al., 2016[36]	Fastball, slider, cut fastball, curveball, changeup & split-fingered fastball velocity	Case-Control Study	**Cases:** 114 Major League Baseball pitchers who underwent UCL reconstruction between 2003-2015 and had more than 20 innings in the season before UCL reconstruction. **Controls:** All (3780) age-matched Major League Baseball controls in the same preoperative season who pitched more than 20 innings.	**Fastball velocity greater by 1-mph:** OR=1.15; 95% CI=1.06-1.24; p=0.001 **Slider velocity greater by 1-mph:** OR=1.10; 95% CI=1.02-1.20; p=0.02 **Cut fastball velocity greater by 1-mph:** OR=1.01; 95% CI=0.94-1.08; p=0.85 **Curveball velocity greater by 1-mph:** OR=1.11; 95% CI=1.03-1.20; p=0.009 **Changeup velocity greater by 1-mph:** OR=1.09; 95% CI=1.02-1.18; p=0.016 **Split-fingered fastball velocity greater by 1-mph:** OR=1.13; 95% CI=0.94-1.34; p=0.191
Whiteside et al., 2016[35]	Mean days between consecutive games, number of unique pitch types thrown, standing height, horizontal release location, mean pitch speed (m/s), mean pitches/game	Case-Control Study	**Cases:** 104 pitchers who had UCL reconstruction since 2010. **Controls:** 104 age and position-matched controls.	**One more day off between consecutive games pitched:** OR=0.69; 95% CI=0.54-0.87; p=0.002 **One more unique pitch type thrown:** OR=0.67; 95% CI=0.49-0.92; p=0.012 **1cm greater standing height:** OR=0.94; 95% CI=0.90-0.99; p=0.013 **Greater horizontal release location (release locations normalized to standing height):** OR=0.03; 95% CI=0.001-0.64; p=0.025 **1m/s greater mean pitch speed:** OR=1.38; 95% CI=1.10-1.73; p=0.005 **Increase of one pitch to mean pitches/game:** OR=1.02; 95% CI=1.01-1.03; p=0.003
Hibberd et al., 2018[33]	Playing catcher as a secondary position in high school baseball pitchers	Cohort study	**Pitcher/Catcher:** A player who primarily identifies as a pitcher but plays catcher as a secondary position. **Pitcher/Other:** A players who primarily identifies as a pitcher and does not play catcher as a secondary position	**Playing catcher as a secondary position:** RR=3.14; 95% CI=0.68-14.50; p=0.14

Anthropometric and biomechanical factors

We found limited evidence suggesting that being taller and having a greater horizontal release location are associated with decreased odds of sustaining an UCL tear requiring surgical reconstruction in professional baseball pitchers. Whiteside *et al*.[35] reported that for every unit (cm) increase in standing height, the odds of undergoing UCL reconstruction surgery decreased by 6% (OR=0.94; 95% CI: 0.90-0.99; p=0.013). They also reported that a greater horizontal release location (normalized to standing height) may be associated with a reduced odds of undergoing UCL reconstruction surgery (OR=0.03; 95% CI: 0.001-0.64; p=0.025).

Discussion

Our review included nine articles with a low risk of bias,

Table 3.
Summary of elbow injury incidence in baseball pitchers. [a] *Numbers in parentheses indicate 95% confidence interval.*

	Youth pitchers	Adolescents and high school pitchers	Professional pitchers
Physical complaints of the elbow	**Incidence Density:** 2.5 (1.8-3.5)[a] physical complaints per 1000 athletic-exposures[30]		
Musculoskeletal disorders of the elbow requiring medical attention	**Incidence:** 40.6% (29.8-52.4) of pitchers per year[30] **Incidence Density:** 2.2 (1.5-3.2) injuries per 1000 athletic-exposures[30]		
Time-loss musculoskeletal disorders of the elbow	**Incidence:** 21.3% (12.0-34.9) of pitchers per season[10]	**Incidence:** 2.3% (1.2-4.4) to 11.8% (6.1-21.5) of pitchers per season[10,33]	**Incidence:** 13.5% (9.5-18.9) to 21.7% (15.5-29.6) of pitchers per season[29,31,32]

six of which assessed the incidence of musculoskeletal disorders of the elbow in baseball pitchers, three that evaluated risk factors, and one article that assessed for both incidence and risk factors. We found that the incidence of time-loss musculoskeletal disorders of the elbow may be lower in adolescent and high school baseball pitchers (13-19 years), than in youth (less than 13 years) and professional baseball pitchers.[10,29,31–33]

We used a novel approach to synthesize the evidence by relying on musculoskeletal disorder severity: (1) physical complaint, (2) musculoskeletal disorder requiring medical attention, and (3) time-loss musculoskeletal disorders. This provides a novel approach for comparing incidence rates.[24] Using this classification allowed us to compare incidence within and between different types of musculoskeletal disorders of the elbow (Table 3). The available evidence suggests that musculoskeletal disorders of the elbow requiring medical attention are more common than time-loss musculoskeletal disorders of the elbow in youth baseball pitchers.[10,30] However, there is insufficient evidence to compare the incidence of physical complaints, musculoskeletal disorders requiring medical attention and time-loss musculoskeletal disorders of the elbow across youth, adolescent, high school and professional baseball pitchers. Future research should aim to investigate the incidence of physical complaints and musculoskeletal disorders of the elbow requiring medical attention in adolescent, high school and professional baseball pitchers.

We investigated the risk factors for elbow injuries in baseball pitchers of all levels of play. The available evidence demonstrates that the risk factors for UCL tears requiring surgical repair in professional baseball pitchers are multifactorial in nature.[34–36] Variables related to pitch velocity, pitch selection, pitcher workload, anthropometric data and pitching biomechanics appear to affect the rate of UCL tears in professional baseball pitchers.[34–36] The available evidence indicates that mean pitch velocity, number of unique pitch types thrown and number of days between consecutive games pitched may have the largest impact on the risk of professional baseball pitchers sustaining an UCL tear requiring surgical reconstruction.

The UCL is believed to tear as a result of the valgus stress being placed on the elbow joint during the pitching motion, resulting in a tissue load that exceeds tissue capacity.[61] Most of the available evidence supports this paradigm. A greater mean pitch velocity and a greater pitch velocity of the fastball, slider, curveball and changeup were associated with a greater risk of sustaining an UCL requiring surgical repair in professional baseball pitchers.[35,36] A greater pitch velocity is likely to place a greater valgus load on the elbow, thus increasing the strain on the UCL.[62–64] However, greater pitch velocity is often a desired performance metric that pitchers seek to attain, as a greater pitch velocity decreases the batter's decision time of whether to strike the ball, thus increasing the pitcher's chance at success.[65,66]

We found that certain pitch types may increase the risk of elbow injuries in baseball pitchers.[7] The pitch type that

has received the greatest amount of scrutiny is the curveball. This is demonstrated in previous guidelines produced by the USA Baseball Medical and Safety Advisory Committee which states that, youth pitchers should avoid throwing breaking pitches in order to reduce the risk of future overuse injuries.[17] However, Grantham *et al*.[7] reported no increased risk of elbow injury associated with the curveball. Escamilla *et al*.[67] reported that fastballs create the greatest amount of valgus stress on the medial elbow before ball release. The results of our systematic review support these findings. The evidence suggests that a greater percentage of fastballs thrown is associated with an increased risk of sustaining an UCL tear requiring surgical reconstruction in professional baseball pitchers, while the percentage of sliders, curveballs and changeups do not appear to have an effect on the risk of injury.[34] Despite the consistency of the results of our systematic review with previous studies for professional baseball pitchers, careful consideration of the level of evidence and best practices are necessary when considering design and implementation of pitching guidelines for all levels of play.

Having a greater repertoire of pitch types may be associated with a decreased risk of surgical reconstruction for a torn UCL in professional baseball pitchers.[35] Overuse injuries are thought to be the result of repetitive microtrauma to tissue.[68] It is hypothesized that throwing a variety of unique pitch types decreases the rate of UCL tears as a result of avoiding repetitive, uniform loading of the UCL due to the biomechanical difference of each pitch type.[35]

Our synthesis suggests that pitcher workload may be associated to the rate of UCL tears requiring surgical repair in professional baseball pitchers. Throwing a greater number of pitches per game and having fewer days between consecutive games pitched are associated with an increased risk of sustaining an UCL tear in professional baseball pitchers.[35] These risk factors highlight the importance of load management in professional baseball pitchers. However, a specific cut-off point beyond which a greater load will result in an increased risk of injury remains poorly defined.

Looking solely at load management and prescribing mandated pitch counts or minimum rest intervals for pitchers is likely an oversimplification of the multifactorial nature of UCL tears in professional baseball pitchers. Baseball experts often tout that pitching biomechanics variables (i.e. open lead foot angle, open foot position, insufficient or excessive shoulder rotation, excessive horizontal shoulder adduction during arm cocking, etc.) are a risk factors for elbow musculoskeletal disorders in baseball pitchers.[69] There is evidence suggesting a relationship between pitching biomechanics and stresses placed on the shoulder and elbow.[70,71] However, other than the association between greater normalized horizontal release location and decreased risk of sustaining an UCL tear, there is a lack of high quality epidemiological evidence demonstrating the relationship between pitching biomechanics and elbow injuries in baseball pitchers. Future epidemiological research is required to determine the relationship between pitching biomechanics and musculoskeletal disorders of the elbow in baseball pitchers.

Most of the low risk of bias articles assessed risk factors for UCL tears requiring surgical repair in professional baseball pitchers.[34–36] This leaves a gap in the literature for risk factors in pitchers at the youth, adolescent, high school and collegiate levels. These risk factors must be considered with caution, as there is no evidence demonstrating the identified risk factors are applicable for populations other than professional pitchers.

High quality cohort studies are urgently needed to understand the etiology of elbow disorders in baseball pitchers. Many studies that were identified through our search strategy were not included in the systematic review because they could not ensure that the pitchers did not have a musculoskeletal disorder of the elbow at the onset of the study. Cohort studies must focus on enrolling samples of pitchers at risk of developing a musculoskeletal disorder of the elbow (incident cases) and avoid the enrollment of pitchers who may already have a musculoskeletal disorder of the elbow (prevalent cases). This is necessary to prevent prevalence-incidence bias. Moreover, the independence of the risk factors must be tested through well-planned studies to control for confounding.

Some limitations exist for this review. We limited our search to English-language articles. Some articles have reported incidence density based on athletic-exposures. However, using athletic-exposure as a measure of exposure, requires the assumption that each athletic-exposure has the same potential for injury. This may not be true as time engaged in throwing, throwing effort or differences in throwing mechanics may alter the risk for injury. The

studies identified in this review that assess risk factors for musculoskeletal disorders of the elbow in baseball pitchers focus largely on UCL tears in professional baseball pitchers. This may leave a gap in the literature for youth, adolescent, high school and collegiate players that may sustain UCL tears or other musculoskeletal disorders of the elbow. There are also several strengths to the current review. We included studies that only assessed the incidence or risk factors for musculoskeletal disorders of the elbow in baseball pitchers. This allowed for us to thoroughly examine a concise and important topic in baseball. We were broad in our inclusion of multiple age ranges and level of play. Although the evidence is limited at this point it does allow for some comparison of the incidence of musculoskeletal disorders of the elbow in baseball pitchers across different age groups. This review also used a novel approach to synthesize the evidence by classifying the musculoskeletal disorders of the elbow based on disorder severity. This allowed for unique comparison of incidence of musculoskeletal disorders of the elbow of varying severity.

Conclusions

Elbow musculoskeletal disorders are common in baseball pitchers. The available evidence suggests that an increased pitch count, a greater percentage of fastballs thrown, a greater mean pitch velocity and greater fastball, slider, curveball and changeup velocity are associated with an increased risk of sustaining a tear of the UCL requiring surgical reconstruction in professional baseball pitchers. More days between games pitched, having a greater repertoire of unique pitch types, being of greater height and having greater normalized horizontal release location have been associated with a decreased risk of sustaining a tear of the UCL requiring surgical reconstruction in professional baseball pitchers. Overall, the epidemiological studies regarding elbow injuries in baseball pitchers are of low quality and future high-quality evidence is needed to confirm these findings before adequate guidelines and prevention strategies can be developed.

Key Points

What is already known:

- Baseball pitchers are at risk for musculoskeletal disorders of the elbow.
- Pitching biomechanics and overuse are hypothesized to be risk factors for these conditions in baseball pitchers.

What are the new findings:

- The etiology of musculoskeletal disorders of the elbow is multi-faceted and includes biomechanical, anthropometric and pitch selection variables.
- The overall quality of the evidence is weak and well-designed epidemiological studies are needed to inform the development of effective prevention strategies.

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Appendix 1.
PubMed search strategy.

1. Baseball*. ti,ab
2. Pitch*. ti,ab
3. Major league baseball. ti,ab
4. MLB. ti,ab
5. Hardball. ti,ab
6. Overhand athlete. ti,ab
7. Overhead athlete. ti,ab
8. Throw*. ti,ab
9. /Baseball
10. or/1-9
11. Injur*. ti,ab
12. Musculoskeletal injur*. ti,ab
13. Athletic injur*. ti,ab
14. Soft tissue injur*. ti,ab
15. Cumulative trauma disorders. ti,ab
16. Repetit*. ti,ab
17. Little league elbow. ti,ab
18. Elbow. ti,ab
19. Rotator cuff. ti,ab
20. Strain. ti,ab
21. Sprain. ti,ab
22. Tear. ti,ab
23. Disabled list. ti,ab
24. Disabil*. ti,ab
25. Absenteeism. ti,ab
26. Injured reserve. ti,ab
27. Upper extremity. ti,ab
28. Lower extremity. ti,ab
29. Shoulder. ti,ab
30. Elbow. ti,ab
31. Wrist. ti,ab
32. Hip. ti,ab
33. Arm. ti,ab
34. Tendon*. ti,ab
35. Ligament*. ti,ab
36. /Athletic Injuries
37. /Soft Tissue Injuries
38. /Tendon Injuries
39. /cumulative trauma disorders
40. /neck injuries
41. /ankle injuries
42. /foot injuries
43. /Back injuries
44. /wrist injuries
45. /leg injuries
46. /knee injuries
47. /hand injuries
48. /forearm injuries
49. /finger injuries
50. /arm injuries
51. /upper extremity
52. /lower extremity
53. /Absenteeism
54. Or/11-53
55. Inciden*. ti,ab
56. Epidemiolog*. ti,ab
57. Prevalen*. ti,ab
58. Risk factor*. ti,ab
59. Pitch count*. ti,ab
60. Athlete exposur* or Athletic exposur*. ti,ab
61. Work load. ti,ab
62. Curveball*. ti,ab
63. Range of motion. ti,ab
64. Age. ti,ab
65. Stretch*. ti,ab
66. Strength*. ti,ab
67. Etiolog*. ti,ab
68. Statistic*. ti,ab
69. Data. ti,ab
70. Informatics. ti,ab
71. Pattern*. ti,ab
72. Trend*. ti,ab
73. Rate or Rates. ti,ab
74. Number of Injur*. ti,ab
75. /Incidence
76. /Epidemiology
77. /Prevalence
78. /Epidemiologic studies
79. /Epidemiologic methods
80. /Epidemiologic factors
81. /Etiology
82. /causality (explode)
83. /Precipitating factors
84. /Protective factors
85. /Risk factors
86. Or/55-85
87. 84 and 85 and 86
88. Limit 87 to English

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Appraisal and summary of patellofemoral pain clinical practice guideline

Gaelan Connell, BHK, DC, MRSc[1,2]
Daphne To, BSc, DC[1,2]
Mariam Ashraf, BSc, DC[3]
Leslie Verville, BHSc, MHSc[1,2]

Objective: *The purpose of this commentary was to critically appraise the patellofemoral pain clinical practice guideline published by the Academy of Orthopaedic Physical Therapy in 2019 and to summarize their recommendations for chiropractic practice.*

Methods: *Quality and reporting of this guideline was assessed with the Appraisal of Guidelines for Research and Evaluation II (AGREE II) instrument. Three reviewers independently scored between 1-7 (strongly disagree-strongly agree) for 23 items organized into six quality domains.*

Results: *AGREE II quality domain scores ranged between 57%-98%, with overall quality of the recommendation rated 89%. The guideline contained evidence summaries and/or recommendations for three topics: impairment/function-based diagnosis; examination; and interventions.*

Objectif : *Ces commentaires visaient à évaluer le la ligne directrice relative à la prise en charge du syndrome fémoro-patellaire publiées par l'Academy of Orthopaedic Physical Therapy en 2019 et de résumer les recommandations aux chiropraticiens.*

Méthodologie : *La qualité de cette ligne directrice a été évaluée à l'aide de l'instrument Appraisal of Guidelines for Research and Evaluation II (AGREE II). Trois examinateurs, chacun de leur côté, ont attribué une cote comprise entre 1 et 7 (allant de fortement en désaccord à fortement d'accord) à 23 aspects répartis dans six domaines reliés à la qualité.*

Résultats : *Les cotes attribuées au domaine relié à la qualité AGREE II allaient de 57 à 98 % ; de façon globale, la cote de la qualité de la recommandation était de 89 %. La ligne directrice renfermait des résumés de preuves et/ou des recommandations portant sur trois points à savoir le déficit/le diagnostic fondé sur la fonction, l'examen et les interventions.*

[1] Faculty of Health Sciences, Ontario Tech University, Oshawa, Ontario, Canada
[2] Centre for Disability Prevention and Rehabilitation, Ontario Tech University and Canadian Memorial Chiropractic College, Toronto, Ontario, Canada
[3] Simcoe Place Health Clinic. Toronto, Ontario, Canada

Corresponding author:
Gaelan Connell, Ontario Tech University, 2000 Simcoe Street North, Oshawa, ON L1H 7K4
Tel: 604-862-5578
Email: gaelan.connell@uoit.ca

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Conclusion: *Based on its methodological quality, we recommend the use of this guideline for the examination, diagnosis, and management of patellofemoral pain in chiropractic practice. A summary of recommendations from this guideline is presented for use within the scope of chiropractic practice in Canada.*

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KEY WORDS: patellofemoral pain syndrome, chiropractic, guideline, summary, appraisal

Conclusion : *À la lumière de la qualité de la méthodologie, nous recommandons l'utilisation de cette ligne directrice pour pratiquer l'examen, établir un diagnostic et prendre en charge du syndrome fémoro-patellaire dans les cliniques chiropratiques. Un résumé des recommandations issues de cette ligne directrice est présenté à l'intention des chiropraticiens du Canada.*

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MOTS CLÉS : syndrome fémoro-patellaire, chiropratique, ligne directrice, résumé, évaluation

Introduction

Patellofemoral pain is a musculoskeletal-related condition that is characterized by diffuse and poorly defined pain in the anterior retropatellar and/or peripatellar regions.[1] Patellofemoral pain is often described as insidious and non-traumatic anterior knee pain arising from activities that load the joint which can include squatting, jumping, running, ascending or descending stairs.[2] Patellofemoral pain is also common in adolescents and active adults[3], with a reported annual prevalence of 28.9% in adolescents and 22.7% in the general population[2,4]. In chiropractic practices, 2.9% of the general population sought care for knee pain.[5] Chiropractors, like other healthcare providers, are able to provide evidence-based care for patients with patellofemoral pain by understanding the best available evidence.

Chiropractors are able to provide care for patients with patellofemoral pain by utilizing information from clinical practice guidelines (CPGs) which provide evidence-based recommendations to inform clinical practice. The guideline titled, "Patellofemoral pain: Clinical practice guidelines linked to the international classification of functioning, disability and health from the Academy of Orthopaedic Physical Therapy of the American Physical Therapy Association" (PFP-CPG) provided recommendations regarding examination, diagnosis, and management of patellofemoral pain in adolescents and adults.[1] The guideline developers searched the MEDLINE, Scopus, CINAHL, SPORTDiscus, and the Cochrane Library databases from 1960 to May 2018 retrieving 4703 articles. After screening for eligibility, 271 studies were included: 120 for diagnosis/classification, 56 for examination, and 95 for interventions. Criteria for inclusion included 1) systematic reviews, meta-analyses, experimental and quasi-experimental, cohort, case series, and cross-sectional studies, 2) functional anatomy or tests, measures, properties of instruments for measuring PFP or pain-related outcomes, and 3) risk, diagnostic characteristics, or interventions within the scope of physical therapists.

The Academy of Orthopaedic Physical Therapy appointed content experts to conduct a literature review and develop a CPG for patellofemoral pain. Content experts consisted primarily of physical therapists, one medical doctor, and one patient representative.[1] Content experts evaluated relevant research published before May 2018 and independently assigned a level of evidence and grade of quality for each article. The grading system was used to develop recommendations and followed criteria adapted from the Center for Evidence-Based Medicine, Oxford, UK, for diagnostic, prospective, and therapeutic studies.[6,7] The level of evidence was organized from 'I' (highest level – obtained from high quality studies such as randomized controlled trials) to 'V' (lowest level – expert opinion).[6,7] Based on the grading system, the strength of the evidence supporting each recommendation was graded on a scale from 'A' (highest- strong evidence) to 'F' (lowest- expert opinion).[6,7] The final grading of each recommendation was subjected to review from external stakeholders such as claims reviewers, medical coding experts, academic educators, clinical educators, physician specialists, and researchers. Feedback was considered by the CPG coordinator and editors and then applied to create a decision tree model for clinical decisions.

Maximum possible score = 7 (strongly agree) x 3 (items) x 3 (appraisers)

Minimum possible score = 1 (strongly agree) x 3 (items) x 3 (appraisers)

$$\text{Scaled domain score} = \frac{\text{Obtained score} - \text{Minimum possible score}}{\text{Maximum possible score} - \text{Minimum possible score}} \times 100$$

Figure 1.
AGREE II scaled domain score formula.[8]

Physical therapists were the primary target audience for this guideline; however, the recommendations are also relevant for chiropractic practice. Chiropractors have knowledge and expertise in musculoskeletal conditions, which allows them to play a role in the management of patellofemoral pain. The purpose of this commentary is to critically appraise the abovementioned CPG for the management of patellofemoral pain published by the Academy of Orthopaedic Physical Therapy in 2019.[1] Additionally, we aim to provide a summary of the recommendations from this guideline for use within the scope of chiropractic practice and other rehabilitation professions.

Methods

The Appraisal of Guidelines for Research and Evaluation II (AGREE II) instrument was used to assess the quality of the PFP-CPG.[1,8] The AGREE II instrument is a valid and reliable measure of quality of reporting and guideline development.[9,10] The AGREE II manual recommends that each guideline be assessed by at least 2 appraisers, and preferably 4.[9] Three independent reviewers who were trained by online module and practice appraisals, independently provided scoring between 1 (strongly disagree) to 7 (strongly agree) for 23 items organized into six quality domains (Scope and purpose, Stakeholder involvement, Rigour of development, Clarity of presentation, Applicability, and Editorial independence). After independent appraisal, the reviewers met to reach consensus through discussion. Reviewers considered each item independently for biases and determined the impact the bias might have on the overall quality of the guideline. Scaled domain scores were calculated according the AGREE II User Manual formula (Figure 1).[8] The combination of the scaled domain scores and the consensus discussion informed the overall quality rating of the guideline.

Results

AGREE II item scores are rated from 1 (strongly disagree) to 7 (strongly agree). Individual item scores and scaled domain scores were used to evaluate the overall quality of the guideline. AGREE II domain scores are presented in Table 1 and ranged between 57% (Applicability) to 98% (Clarity of presentation). An overall percentage of each domain was calculated using the AGREE II scoring formula.[8] However, the reviewers also considered each item independently for biases and determined the impact the bias might have on the overall quality of the guideline. The reviewers rated the overall quality of this guideline as 89% and recommended this guideline for use. The Applicability domain received a low score due to a lack

Table 1.
AGREE II scaled domain scores.
** A quality score was calculated for each domain according to the AGREE II formula and were reported as percentages.*

Domain	Scaled domain score (%)*
▶ Scope and purpose	83
▶ Stakeholder involvement	85
▶ Rigour of development	91
▶ Clarity of presentation	98
▶ Applicability	57
▶ Editorial independence	92
▶ Overall guideline assessment	89
▶ Overall guideline recommendation	Yes

of reporting on facilitators and barriers to guideline application and measuring the impact of guideline recommendations. All other domain scores were rated above 83% and the overall assessment by reviewers suggest that the guideline was well organized, easy to follow, and demonstrates a rigorous review of the available research.

Discussion

Recommendations

The target audience for this guideline was orthopedic physical therapists; therefore, it was important to ensure the guideline recommendations were relevant to chiropractors. The guideline quality was acceptable, as per our appraisal and does not need to be modified or adapted for use with the chiropractic population. The guideline recommendations which consist of assessment of risk factors, prognosis, diagnosis, examination, and interventions are mostly congruent with the scope of chiropractic practice in Canada. Recommendations relevant to chiropractic practice have been adopted and discussed below. These recommendations were also used to inform a clinical algorithm created by the authors of this commentary (Figure 2).

1. Impairment/Function-Based Diagnosis.

Based on level I-II evidence, longer duration of symptoms, higher baseline pain severity, and poorer function were identified as prognostic factors more likely associated with negative outcomes or unfavourable recovery. Risk factors may play a role in the development of patellofemoral pain. Women are more likely to develop patellofemoral pain than men and young female athletes participating in a single sport have a higher incidence of injury in comparison to those participating in multiple sports. Individuals with isometric knee extensor weakness have a higher incidence of patellofemoral pain.

Clinicians should use reproduction of retropatellar or peripatellar pain during squatting as a diagnostic test for patellofemoral pain, as well as performance or other functional activities that load the patellofemoral joint in a flexed position, such as stair climbing or descent (Grade A recommendation).

The diagnosis of patellofemoral pain should be made based on the following criteria: (1) presence of retropatellar or peripatellar pain; AND (2) reproduction of retropatellar or peripatellar pain with squatting, stair climbing, prolonged sitting, or other functional activities loading the patellofemoral joint in a flexed position; AND (3) exclusion of all other conditions that may cause anterior knee pain (Grade B recommendation). Additionally, clinicians may use the patellar tilt test with the presence of hypomobility to support the diagnosis of patellofemoral pain (Grade C recommendation).

Clinicians should consider differential diagnoses associated with serious medical conditions (red flags), other musculoskeletal conditions, and/or psychosocial factors (yellow flags) particularly when a patient's activity limitations or impairments of body function and structure are not consistent with those presented in this guideline or if symptoms are not resolving with the use of interventions presented in this guideline. If necessary, clinicians should refer patients to the appropriate health care provider and co-manage when appropriate. Most differential diagnoses are applicable to both adults and adolescents, such as tumors, infection, and fracture. However, clinicians should consider referral from slipped capital femoral epiphysis in adolescents as a possible cause of knee pain.

2. Examination

The guideline recommends the use of the Anterior Knee Pain Scale (AKPS), Knee injury and Osteoarthritis Outcome Score – Patellofemoral subscale (KOOS-PF), and the Visual Analogue Scale (VAS) for activity (also known as the EPQ) to measure pain and function based on evidence of validity, reliability, and responsiveness (Grade A recommendation). Clinical and field tests that reproduce pain and assess lower-limb movement coordination, such as squatting, step-down, and single-leg squat should be used to assess activity limitations (Grade B recommendation). Clinicians may assess body structure and function with measures of patellar provocation, patellar mobility, foot position, hip and thigh muscle strength, and muscle length (Grade C recommendation).

3. Interventions

Clinicians should prescribe exercise therapy with combined hip- and knee-targeted exercises to reduce pain and improve patient-reported outcomes and functional performance (Grade A recommendation). Hip-targeted exercise therapy should target the posterolateral hip musculature. Knee-targeted exercise therapy includes either

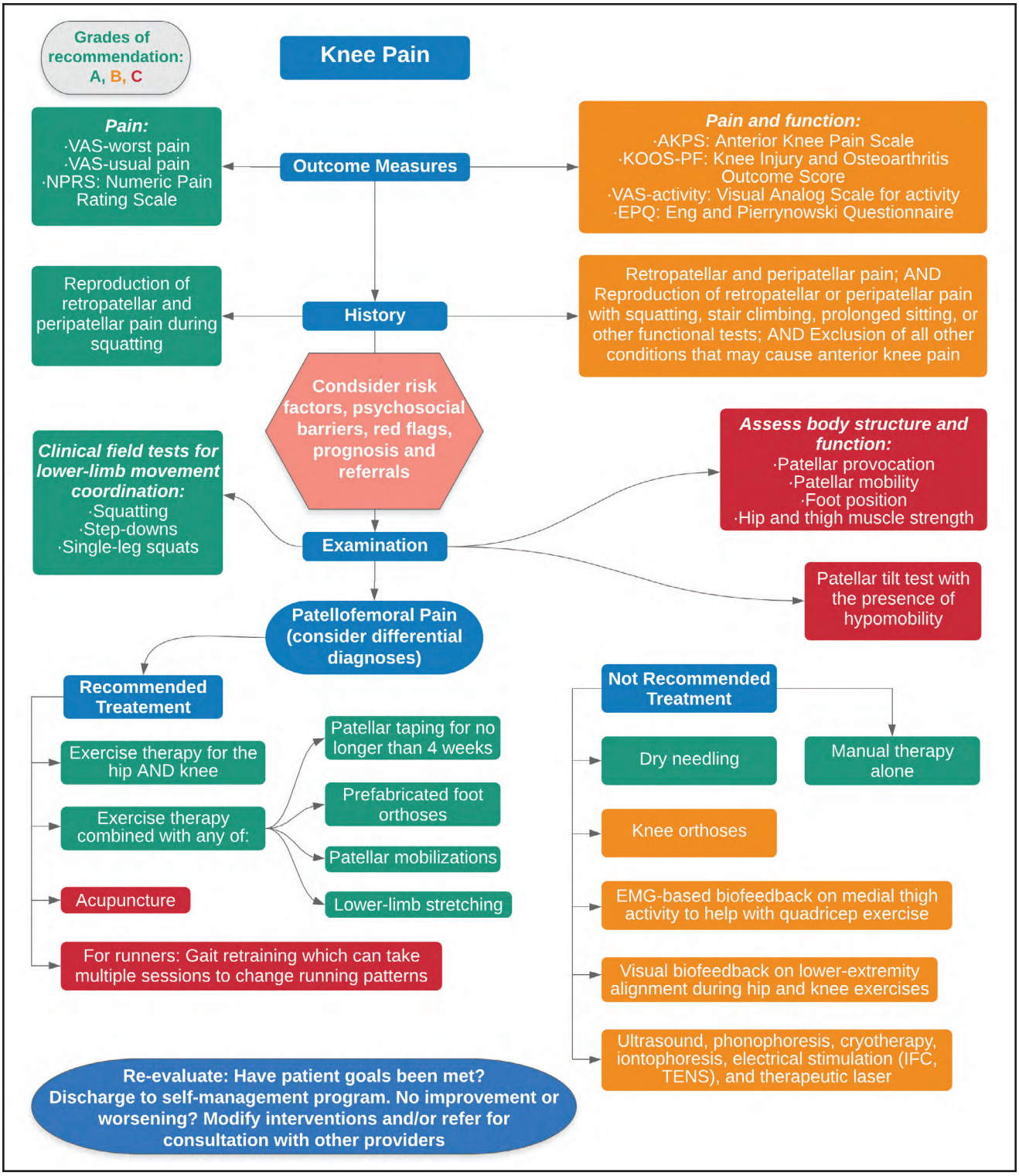

Figure 2.
Patellofemoral Pain Clinical Algorithm.

weight-bearing (resisted squats) or non–weight-bearing (resisted knee extension) exercise.

Clinicians should prescribe prefabricated foot orthoses combined with an exercise therapy program for those with greater than normal pronation to reduce pain in individuals with patellofemoral pain, but only in the short term (up to 6 weeks) (Grade A recommendation).

Clinicians should combine physical therapy interventions for the treatment of individuals with patellofemoral pain. Interventions to consider combining with exercise therapy include foot orthoses, patellar taping, patellar mobilizations, and lower-limb stretching (Grade A recommendation).

Clinicians may use tailored patellar taping in combination with exercise therapy to assist in immediate pain reduction, and to enhance outcomes of exercise therapy in the short term (4 weeks) (Grade B recommendation).

For runners with patellofemoral pain, clinicians may use gait retraining consisting of multiple sessions of cuing to adopt a forefoot-strike pattern (for rearfoot-strike runners), cuing to increase running cadence, or cuing to reduce peak hip adduction while running (Grade C recommendation).

Clinicians may use acupuncture to reduce pain; however, the superiority of acupuncture over placebo or sham treatments is currently unknown (Grade C recommendation).

The following interventions should not be used based on evidence of no effectiveness: dry needling (Grade A recommendation); manual therapy including lumbar, knee, or patellofemoral manipulation/mobilization, in isolation (Grade A recommendation); patellofemoral knee orthoses, including braces, sleeves, or straps (Grade B recommendation); EMG-based biofeedback on medial vastii activity to augment knee-targeted (quadriceps) exercise therapy (Grade B recommendation); visual biofeedback on lower extremity alignment during hip- and knee-targeted exercises (Grade B recommendation); and biophysical agents, including ultrasound, cryotherapy, phonophoresis, iontophoresis, electrical stimulation, and therapeutic laser (Grade B recommendation).

How chiropractors can help

With expertise in diagnosis, chiropractors are able to conduct a thorough examination in order to rule out possible medical conditions which may relate to a patient's anterior knee pain. Through recognizing serious pathology or psychosocial barriers, the appropriate referral to other healthcare providers can be facilitated. Additionally, this guideline offers evidence-based recommendations for the assessment of patellofemoral pain using outcome measures for pain and function, as well as examination procedures to assess for physical performance, impairment, and function. Patellofemoral pain has historically been a diagnosis of exclusion but recommendations for impairment/function-based diagnosis provide clear criteria that chiropractors can use in practice.[11] This guideline recommends treatment interventions based on the current best available evidence and supports a shift in treatment focus to active treatments such as exercise therapy, which are within the scope of practice and expertise of chiropractors.

Knowledge dissemination strategies will be implemented to share CPG recommendations with chiropractors and their patients. A patient handout on patellofemoral pain will be posted on the Canadian Chiropractic Guideline Initiative (CCGI) website and distributed via social media channels directed at Canadian Chiropractors. Chiropractors will also have access to a summary of this guideline on the CCGI website.

Limitations

We did not perform inter-examiner agreement testing or pilot testing before appraising the CPG. The guideline recommendations have been adopted due to the acceptability of AGREE II consensus scores. Therefore, we did not make significant changes to the recommendations as they were already relevant for chiropractic practice.

Conclusion

Patellofemoral pain is a musculoskeletal-related condition that presents to chiropractic offices. The guideline titled, "Patellofemoral pain: Clinical practice guidelines linked to the international classification of functioning, disability and health from the Academy of Orthopaedic Physical Therapy of the American Physical Therapy Association" provided recommendations for physical therapists.[1] Based on its methodological quality, we recommend the use of this guideline for the examination, diagnosis, and management of patellofemoral pain in chiropractic practice. A summary of recommendations from this guideline is presented for use amongst Canadian chiropractors.

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The 2015 U.S. Soccer Federation header ban and its effect on emergency room concussion rates in soccer players aged 10-13

Rahim Lalji, BHSc, MSc, DC[1]
Hayden Snider, BKin[2]
Noah Chow[3]
Scott Howitt, BA, MSc, DC, RKin, FRCCSS(C), FCCPOR[4]

Background: *In 2015, the U.S. Soccer Federation banned heading for players aged 10-13.*

Purpose/Question: *To assess the change in proportion of children aged 10-13 playing soccer in the US presenting to an Emergency Department (ED) with a concussion in relation to any other injury before and after the ban.*

Methods: *Analysis was restricted to soccer athletes between 10-13 years that reported to a National Electronic Injury Surveillance System (NEISS) participating hospital ED following injury in 2013-2014 and 2016-2017. Multivariable logistic regression was performed to assess the association between year of injury and concussion diagnosis in relation to other injury diagnosis after adjusting for age, sex, and ethnicity.*

Results: *Concussion in relation to other injuries*

Contexte : *En 2015, la U.S. Soccer Federation a interdit le coup de tête au ballon aux joueurs de 10 à 13 ans.*

Objectif/question : *Déterminer le changement de proportion de jeunes joueurs de soccer américains de 10 à 13 ans arrivant en salle des urgences avec une commotion cérébrale liée à d'autres types de blessures subies avant et après l'interdiction.*

Méthodologie : *L'analyse s'est limitée aux jeunes joueurs de soccer âgés de 10 à 13 ans, s'étant présentés à une salle des urgences d'un hôpital participant au registre National Electronic Injury Surveillance System (NEISS), après avoir subi une blessure entre 2013 et 2014 et entre 2016 et 2017. Une régression logistique multivariée a servi à évaluer le rapport entre l'année de la blessure et le diagnostic de la commotion cérébrale et un autre diagnostic de blessure après correction pour tenir compte de l'âge, du sexe et de l'origine ethnique.*

Résultats : *Le rapport entre commotion cérébrale et*

[1] Department of Chiropractic Medicine, Faculty of Medicine, University of Zurich and Balgrist University Hospital, Zurich, Switzerland
[2] School of Kinesiology and Health Science, York Univeristy, Toronto, Canada
[3] Department of Health Science, Wilfrid Laurier University, Waterloo, Canada
[4] Canadian Memorial Chiropractic College, Toronto, Canada

Corresponding author:
Rahim Lalji, Forchstrasse 340, Zurich, Switzerland
Tel: +41 78 240 05 08
E-mail: Rahim.lalji@uzh.ch

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showed a significant increase in 2016-2017 when compared to 2013-2014 after adjustment (OR= 1.286, 95%CI = 1.090-1.517).

Conclusions: *These results suggest that banning heading may not reduce concussion within this population. However, significant confounders, including increased reporting, were not controlled for.*

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KEY WORDS: concussion, epidemiology, injury prevention, mild traumatic brain injury, public health

autres blessures a considérablement augmenté en 2016-2017par rapport à ce qu'il était en 2013-2014 après correction (RR = 1,286, IC à 95 % = 1,090-1,517).

Conclusions : *Ces résultats laissent supposer que l'interdiction de coups de tête au ballon peut ne pas réduire le nombre de commotions cérébrales dans cette population. Cependant, il y a eu d'importantes variables confondantes, comme l'augmentation du nombre de cas signalés, pour lesquelles aucun contrôle n'a été inclus.*

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MOTS CLÉS : commotion cérébrale, épidémiologie, prévention des blessures, traumatisme crânien léger, santé publique

Introduction

Soccer is the most popular and fastest growing sport with over 265 million active players worldwide, 27 million of which reside in North America.[1] Soccer, like other sports, carries inherent injury risks due to its competitive nature and unpredictability. Common injuries include sprains, strains, fractures, abrasions, contusions and concussions. However, unlike other sports, soccer involves the act of heading which poses its own unique risks to the player. Heading occurs when players intentionally use their head for the purpose of controlling or directing the ball and may place athletes in vulnerable positions for head injuries. It is estimated that heading is responsible for 31% to 37% of youth soccer-related concussions.[2-4] Although substantial, these numbers pale in comparison to the mechanism of player-to-player contact which is estimated as the cause of 51.3% of soccer-related concussions in girls and 68.8% in boys.[5] In addition to concussion, the role of heading in the accumulation of sub-concussive blows to an athlete is also of concern. These impacts are described as being similar to those giving rise to a concussion, but demonstrate insufficient impact forces or accelerations to produce symptoms associated with mild traumatic brain injury (mTBI). Despite lower impact and acceleratory forces from sub-concussive blows, repeated exposure can elicit changes to the gray and white matter of the brain as well as manifest in reduced neurocognitive scores on testing which is particularly concerning in youth athletes.[6,7]

Concussion and sub-concussive blows in adolescent athletes are of concern as the brain is still developing.[8] When the adolescent brain is exposed to these biomechanical forces, it may be more susceptible to hypoxia, ischemia and traumatic axonal injury than adult counterparts.[7,9,10] In August 2014, a class action-lawsuit was filed in the United States District Court of California accusing FIFA, U.S. Soccer and the American Youth Soccer Organization of negligence in dealing with head injuries. The U.S. Soccer Federation responded in 2015 by placing a ban on all headers for athletes aged 10 and under. In addition, athletes aged 11-13 were only allowed to perform headers in practice. The 2015 header ban was also accompanied by an initiative to improve concussion education and the implementation of a more uniform concussion management program for over 3 million participants registered with the U.S. Youth Soccer Association.

The National Electronic Injury Surveillance System (NEISS) collects data on consumer product-related injuries occurring in the United States and produces nationwide estimates.[11] The NEISS has been used previously in epidemiological studies to show injury rates in ice hockey and muay thai kick boxing.[12-14] The purpose of this study is to analyze differences in concussion injury odds in children aged 10-13 in the United States playing soccer before and after the 2015 ban on headers using the NEISS database.

Methods

NEISS Overview

The NEISS is an American Consumer Product Safety Commission (CPSC) Database. For more than 45 years the CPSC has operated this statistically valid injury surveillance and follow-back system for the primary purpose to collect data on US consumer product-related injuries. The database collects information from approximately 100 NEISS participating hospitals for every Emergency Department (ED) visit involving an injury associated with a consumer product. The NEISS is based on a nationally representative probability sample of hospitals in the US and its territories.[11] In the year 2000, the CPSC expanded the NEISS to collect data on all injuries. NEISS data for the last 20 years is available online.[15] At the time of patient presentation, ED representatives assign a CPSC code to each patient that mirrors the products used or activity engaged in at time of injury. At the end of each day, a NEISS hospital coordinator reviews these cases, extracts pertinent clinical data and transcribes it into coded form.[15] We used this product-specific code in order to gather injury data in youth soccer for the calendar years of "2013-2014" and "2016-2017". These years were categorized as such, creating two separate year categories. The year 2015 was excluded in our analysis, as this was the year the U.S. Soccer Federation instituted the rule change banning headers.

Participants

Due to the specific age groups targeted with this rule change, we chose to only include athletes who were aged 10-13. Diagnosis of injury was obtained from the NEISS database as "concussion" and "all other injuries". All other injures included any injury sustained by an athlete which was not a concussion. Within the database this would include strain/sprain, fractures, dislocations, contusion, laceration and avulsions. Those who were injured without an explicit diagnosis of concussion were considered to not have a concussion and were coded as such. Sex was categorized and extracted as "male" and "female". Finally, patient ethnicity was coded "Not Specified", "Caucasian", "African American", "Asian", "American Indian" and "Native Hawaiian". Injuries were all soccer specific and those that occurred from a different sport were not extracted from the NEISS.

Table 1.
Participant characteristics with regards to sex, age and injury diagnosis collected from the NEISS.

Year 2013-2014	Total n (%)	Concussion diagnosis n (%)	Any other injury diagnosis n (%)
Sex			
Male	2150 (100%)	150 (7%)	2000 (93%)
Female	1520 (100%)	129 (8.5%)	1391 (91.5%)
Age			
10	672 (100%)	42 (6.25%)	630 (93.75%)
11	841 (100%)	64 (7.61%)	777 (92.39%)
12	1026 (100%)	75 (7.31%)	951 (92.69%)
13	1131 (100%)	98 (8.66%)	1033 (91.34%)
Year 2016-2017	**Total n (%)**	**Concussion diagnosis n (%)**	**Any other injury diagnosis n (%)**
Sex			
Male	2426 (100%)	200 (8.24%)	2226 (91.76%)
Female	1400 (100%)	152 (10.86%)	1248 (89.14%)
Age			
10	722 (100%)	52 (7.2%)	670 (92.8%)
11	863 (100%)	79 (9.15%)	784 (90.85%)
12	1054 (100%)	111 (10.53%)	943 (89.47%)
13	1187 (100%)	110 (9.27%)	1077 (90.73%)

Statistical analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) and alpha level was set at 0.05. Univariate analysis was performed and reported as raw numbers and percentages. Chi square test was performed to analyze categorical data at a bivariate level. Finally, multivariable logistic regression was used to assess the odds of presenting to an ED for a concussion for the years "2013-2014" compared to "2016-2017" after adjusting for age, sex and ethnicity.

Results

Concussion before and after the 2015 ban

The total number of injuries reported to a NEISS hospital was 7496 cases over the span of the four years analyzed (2013-2014/2016-2017). 49% of injury cases were reported in the years 2013 and 2014, while 51% of all cases were reported in 2016-2017. With regards to concussion, 7.6% of all injury cases resulted in a concussion diagnosis in the two years preceding the ban versus 9.2% of all injuries resulting in a concussion diagnosis in the two years

Table 2. *Frequencies, adjusted odds ratios and 95% confidence intervals of sex, age, ethnicity and year as associated with diagnosis of concussion in individuals aged 10-13 while playing soccer, based on the NEISS.*

Covariates	n (%)	Adjusted OR (95% CI)	p-value
Sex	7496 (100%)		
Male	4576 (61%)	Ref.	
Female	2920 (39%)	1.242 (1.053-1.497)	**0.011**
Age			
10	1394 (18.6%)	Ref.	
11	1704 (22.7%)	1.286 (.980-1.686)	0.069
12	2080 (27.8%)	1.364 (1.053-1.767)	**0.019**
13	2316 (30.9%)	1.376 (1.067-1.774)	**0.014**
Ethnicity			
Not Specified	3243 (42.3%)	Ref.	
White	3612 (48.2%)	1.387 (1.167-1.650)	**<.001**
Black	499 (6.6%)	.802 (.542-1.187)	0.27
Asian	127 (1.7%)	.624 (.272-1.433)	0.266
American			
Indian	8 (0.11%)	0	0.999
Native Hawaiian	7 (0.10%)	0	0.999
Year			
2013-2014	3670 (49%)	Ref.	
2016-2017	3826 (51%)	1.286 (1.09-1.517)	**0.003**

following the ban on headers. Regardless of diagnosis, reporting to NEISS participating ED's following soccer-related injury increased by 2% between 2013-2014 and 2016-2017 (Table 1). Concussion in relation to all other injuries showed a statistically significant increase between the years 2016-2017 compared to 2013-2014 (OR= 1.286, 95%CI = 1.090-1.517) when controlling for age, sex and ethnicity (Table 2).

Concussion in relation to age

Overall, a general trend was noted with increased concussion in comparison to all other injures as children got older. Concussion accounted for 6.25% of all injuries in the 10-year-old category in 2013-2014 and 7.20% of all injuries in the years 2016-2017. In 2013-2014, concussions resulted in approximately 8.66% of all injuries in the 13-year-old category, while in 2016-2017 concussion accounted for 9.27% of all injuries. Our bivariate analysis shows the highest percentage of concussions in the 12-year-old category. However, when controlling for sex, ethnicity and year, concussions were more likely to occur in the 13-year-old category when compared to the 10-year-old age bracket. The increase with age was statistically significant in relation to 10-year-olds to 12-year-olds (OR=1.364, 95%CI = 1.053-1.767) and 13-year-olds (OR = 1.376, 95%CI = 1.067-1.774). A positive, but non-significant relationship was seen in the 11-year-old bracket (OR =1.286, 95%CI = .980-1.686) (Table 2).

Concussion in relation to sex

During both 2013-2014 and 2016-2017 males sustained more concussions (350) versus females (281). However, when looking at raw percentages, females were more likely to sustain a concussion injury. In 2013-2014, 7% of all injuries were a diagnosed concussion in males. This number rose to 8.24% in 2016-2017. Eight and half percent of all injuries were concussions in 2013-2014 for females. This number rose to 10.86% of all injuries being concussions for females in 2016-2017 (Table 1). Concussion in relation to all other injuries increased after the ban in both sexes, but more so for females aged 10-13 presenting to a NEISS participating ED's. This relationship was found to be statistically significant, as females were more likely to have a concussion in relation to all other injuries when compared to males (OR = 1.242, 95%CI = 1.052-1.467) after adjustment (Table 2).

Discussion

This is the first study, to our knowledge, evaluating the 2015 US Soccer Federation ban on headers and its association with concussion in relation to any other injury for adolescents aged 10-13. Between 2013-2014 and 2016-2017 there was a statistically significant increase in the odds of concussion in relation to all other injuries amongst US adolescent soccer players aged 10 to 13 presenting to NEISS participating ED's. This relationship was maintained when controlling for covariates such as age, sex and ethnicity. It is estimated that between 1.1 and 1.9 million sport and recreation-related concussions occur annually in children ≤18 years in the US.[16] Of these, between 115,479 and 166,929 cases present to an ED.[16] Overall, trends of concussion reporting to ED's are increasing over time. A recent review of paediatric concussion in physicians' offices and ED's showed a 4.4-fold (95% CI = 4.37-4.45) increase in concussion rate per 100,000 from 2003 to 2013.[17] It has also been shown that following edu-

cational interventions, rates of concussion reporting are likely to increase. A seven year trend analysis in Ontario schools showed an increase in concussion reporting and identification following an educational intervention in children aged 4 to 18 years.[18] As such, it can be theorized that educational and policy changes in conjunction with the 2015 header ban may have influenced the reporting rates of concussion-like symptoms in athletes to parents, coaches and trainers. The authors believe this finding of increased concussions in the years following the ban on headers is likely to reflect an increased overall trend in reporting of concussions, increased education and higher overall awareness of concussion following litigation and increased media reporting. Alternatively, player-to-player contact remains the most common mechanism of injury for concussion in adolescent soccer.[5] Our findings may also be interpreted with the suggestion that banning heading may not necessarily significantly reduce contact in soccer. However, this relationship was beyond the scope of this study.

Our analysis shows sex to be significantly related with the diagnosis of concussion. Although males have more concussions overall due to the higher enrollment in youth soccer, when controlling for all other factors, females are shown to have higher odds of concussion. This is consistent with findings in other published epidemiological studies.[19-21] Biomechanical issues such as increased ligament laxity leading to higher whiplash forces, reduced deep neck flexor strength, and smaller head/neck mass ratio are theorized to make females more likely to sustain a concussion when compared to males.[22-25] Therefore, the findings in our study are consistent with the trend of published work in this area.

The findings also suggest that an increase in age is accompanied by a rise in concussions. This is congruent with research identifying that the period in which the adolescent growth spurt occurs (10 to 14 years) increases the risk of sport-related injury. It has been shown that changes in limb length, mass, body composition are major contributing factors to injury.[26,27] These changes in anthropometrics during the adolescent years result in a strength-flexibility asymmetry contributing to the lack of muscular control at a variety of body segments including the head and neck regions.[28] This imbalance between strength and mass at the head and neck segment specifically, might lead to higher cranial velocities during soccer, contributing to concussion risk. It is also plausible that increased body size and limb length changes encourage more combativeness in the sporting realm.

Limitations

The limitations to this study include selection bias due to the nature of the NEISS database. The NEISS database accounts for 100 hospitals and only captures a small amount of ED data in the United States. In addition, those patients who present to hospital ED's likely represent the worst cases of injury that occurred during soccer and smaller injuries are less likely to be recorded. Patients with soccer-related injuries may have decided to visit a private medical or rehabilitation clinic and thus would not have been captured. Athletes have also been shown to consistently under-report concussion symptoms in order to return to sport.[29] Those who did under-report their symptoms may not be included in our sample or may have been diagnosed with a different injury due to the clinical nature of the concussion diagnosis.[30] When extracting data from the NEISS for the specific covariate of ethnicity, a large portion of data was coded as "not specified". This presents as a limitation of our study and may change the nature of our findings if accounted for. The 2015 header ban applied to U.S. Soccer Federation activities only and did not relate to recreational games of soccer. Therefore, it is a possibility that some reported injuries may have occurred in individuals playing in recreational settings, where heading may have occurred. Finally, a rise in concussion awareness may lead to an increase in reporting and subsequent follow-up with ED's. This presents as a significant confounder. A variety of other confounders such as skill level of play, past history of concussion, medical insurance coverage, etc., were not controlled for in the analysis.

Conclusions

This paper found a significant increase in proportion of concussions in relation to any other injury after the 2015 U.S. Soccer Federation header ban (2016-2017) when compared to before the ban (2013-2014) after adjustment when analyzing injury data from the NEISS database. Although this study suggests that banning heading in soccer may not reduce concussion in adolescents aged 10-13 presenting to NEISS participating hospitals, we suspect our findings were influenced by increased reporting

due to improved concussion education and management policy implemented by the U.S. Soccer Federation. This study provides an objective analysis of the 2015 ban on headers and may be used to inform other policy and rule changes in adolescent soccer.

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Sports chiropractors in Australia: a cross-sectional survey

Alex Pucciarelli, MChiro, AES, AEP[1]
Nathan Randall, MChiro[1]
Matthew Hayward, MChiro[1]
John Triantis, MChiro[1]
William Owen, MChiro[1]
Michael Swain, MChiro, PhD[1]
Katie de Luca, BAppSci(Ex&SpSci), MChiro, PhD[1]

Background: *Whilst half of all Australian chiropractors report often treating athletes, there is insufficient evidence to characterise the sports chiropractor in Australia.*

Objective: *To perform a workforce survey of Sports Chiropractic Australia (SCA) members.*

Methods: *A 74-item web-based questionnaire collected information about practitioner and practice characteristics. Descriptive statistics summarised practitioner and patient characteristics, caseload and management approaches.*

Results: *SCA members were predominantly male (74%) with 11.3 (±8.4) years of clinical experience. Amateur or semi-professional sportspeople comprised 67% of SCA members' caseload. Athletes were most likely to present with a lower limb musculoskeletal condition (44%), followed by low back pain (34%). Nearly half (43%) of musculoskeletal conditions were*

Contexte : *Bien que la moitié des chiropraticiens australiens affirment soigner souvent des athlètes, on ne dispose pas de données suffisantes pour caractériser les chiropraticiens du sport australiens.*

Objectif : *Mener une enquête sur l'effectif auprès des membres de la Sports Chiropractic Australia (SCA).*

Méthodologie : *Un questionnaire en ligne comprenant 74 questions a servi à recueillir des données sur les caractéristiques du praticien et de sa clientèle. Des données statistiques descriptives ont résumé les caractéristiques du praticien et celles du patient, le nombre de cas et les méthodes thérapeutiques.*

Résultats : *Les membres de la SCA étaient majoritairement des hommes (74 %) possédant 11,3 (± 8,4) années d'expérience en clinique. Les sportifs amateurs et les sportifs semi-professionnels constituaient 67 % des membres de la SCA. Les athlètes présentaient le plus souvent un trouble musculosquelettique à un membre inférieur (44 %) et des lombalgies*

[1] Department of Chiropractic, Faculty of Science and Engineering, Macquarie University

Corresponding author:
Alex Pucciarelli, Department of Chiropractic, Faculty of Science and Engineering, Macquarie University, Sydney, Australia
E-mail: alex.pucciarelli93@gmail.com

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co-managed with another healthcare practitioner.

Conclusions: *SCA members provided care for people of all sporting abilities, ranging from recreational to elite athletes, but most typically at the non-elite level. SCA members almost exclusively treat musculoskeletal conditions and apply various modalities in the management of athletes and sportspeople.*

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KEY WORDS: chiropractic, cross-sectional survey, exercise, sports chiropractic, Sports Chiropractic Australia, sports medicine, survey

(34 %). Presque la moitié (43 %) des troubles musculosquelettiques étaient aussi traités par un autre professionnel de la santé.

Conclusions : Les *membres de la SCA traitent des gens ayant toutes sortes de capacités sportives, à partir de sportifs amateurs jusqu'à des athlètes d'élite, mais le plus souvent à des sportifs de niveau non compétitif. Les membres de la SCA traitent presque exclusivement des troubles musculosquelettiques et utilisent diverses modalités en traitant des athlètes et des sportifs.*

(JCCA. 2020;64(3) : 193-200)

MOTS CLÉS : chiropratique, enquête transversale, exercice physique, Sports Chiropractic Australia, médecine sportive, enquête

Introduction

Sporting injuries are a common cause of disability for individuals and create a substantial health burden in the community.[1] In Australia, an annual estimate of 1.65-2 billion dollars is spent on sports-related injuries, to which over 30,000 people sought hospital treatment in Victoria alone.[1-3] Sporting injuries are treated by a variety of healthcare practitioners including physiotherapists, chiropractors, sports physicians, osteopaths, exercise physiologists, massage therapists and sports trainers.[4] A survey of the chiropractic profession found 49.5% of Australian Chiropractors report often treating athletes, which potentially represents a large proportion of a chiropractor's clinical workload.[4]

In Canada, more than a quarter of chiropractors manage sporting injuries as a focal point of clinical practice.[5] Canadian chiropractors that treat sporting injuries incorporate rehabilitation and report a high number of referrals from medical doctors.[5] Elsewhere, chiropractic care for athletes has been documented in various sporting events using injury surveillance study designs.[6] However, there is insufficient research to generally characterise chiropractors who focus their interest on athletes or sportspeople.[6,7]

In the United States of America (USA) and Canada, sports chiropractic has been granted a sports specialisation stature via the American Chiropractic Board of Sports Physicians (ACBSP) and the Royal College of Chiropractic Sports Sciences (Canada) (RCCSS (C))[8], establishing a minimum standard for sports specialist chiropractors in USA and Canada [9,10]. Chiropractors in Australia who have a particular interest in treating sports people can undertake further education in post-graduate courses through the International Federation of Sports Chiropractic (FICS).[11] In Australia, Sports Chiropractic is a rapidly growing semi-formalised (not recognised by the regulator) branch of chiropractic for clinicians with an interest and expertise in treating athletes. The national special interest group, Sports Chiropractic Australia (SCA), reports that sports chiropractors commonly focus on the conservative management, rehabilitation and optimization of the neuro-musculoskeletal system of athletes in clinical practice.[11] Despite having training pathways (FICS qualification) and an organised national group (SCA), Australian chiropractors are yet to establish clinical practice standards, a code of practice, or gain regulatory body recognition (formalised specialisation) for sports chiropractic.[8] Additionally, there is insufficient research evidence that characterises the work of sports chiropractors in Australia.

Workforce studies aim to ensure that an industry has a supply of people with the appropriate skills, knowledge, and experience to meet the needs of the community. While several chiropractic workforce studies exist[4,12], there is limited research in the field of sports chiropractic.

Knowledge gaps exist in the literature around the utilisation of sports chiropractic and the outcomes of chiropractic treatment for athletes. This area is broad and includes a lack of understanding in the chiropractic management and prevention of sporting injuries, and the optimisation of sports performance for athletes. As a result, there is insufficient evidence to differentiate chiropractic care for the athlete specifically, which results in sports chiropractors currently lacking recognition and acceptance within the traditional sports medicine team.[4,8]

The survey's specific objectives are to describe the characteristics of sports chiropractors in Australia and to summarise the cases that present for care. In response to the research gaps, this project aims to perform a workforce survey of SCA members. Defining the profile (highlighting key roles and qualities) of sports chiropractors will raise awareness of sports chiropractors and help gain professional recognition in Australia.[13,14]

Methods

Ethical approval was granted from the Faculty of Science and Engineering Human Research Ethics Sub-Committee at Macquarie University on the 6th of July 2018 (Reference number: 5201800441).

Design and setting

We conducted a cross-sectional study of SCA members between the dates of the 20/08/2018 until the 24/09/2018. SCA members were invited, via two emails to participate in the study. The workforce survey was administered using an online survey formatted in Qualtrics software. This research consulted with national board members from SCA and the Australia Chiropractors Association as stakeholders, with permission granted to contact all active members through the SCA membership base.

Recruitment and sample

All eligible participants were current financial members of SCA and chiropractors currently registered with the Australian Health Practitioner Regulation Agency (AHPRA). Participants were excluded from the study if they were not SCA members, student members of SCA or if they were a financial member of SCA but not in clinical practice. The study sourced subjects through the SCA membership email database.

Workforce survey

The current study reports on 24 items relating to practitioner and patient characteristics including practitioner demographics (8 items), clinical work (5 items) and fieldwork (4 items) and their patients' athletic level (1 item) as well as most recent case characteristics (6 items). Remaining items on sports chiropractors' 'typical approach to care' and 'professional identity' will be presented in a future analysis. Five sports chiropractors with over 15 years of clinical experience levels piloted the workforce study, all of whom fit into the study's inclusion criteria. These five chiropractors affirmed the survey's face validity, but content validity was not assessed. A small number of corrections were made focusing on the duration of the survey, the wording of specific questions, and the overall number of questions. The final workforce survey had three sections and a total of 74 questions. The first four items of the survey obtained participant registration information for eligibility along with an online informed consent response. Section 1 asked about demographic characteristics of sports chiropractors such as age, sex, location of practice (state, regional, remote, rural), education/qualification/s, the population of athletes treated, co-management with other health professionals/referral (sending and/or receiving referrals and co-management), diagnostic imaging and community/volunteer work. Section 2 asked surface-level questions about case presentations (patient demographics, sporting history and common chief complaints/regions treated). Section 3 specifically asked about the last athlete the sports chiropractor treated (provisional diagnosis list, triage category, patient demographics, primary sport, level of athlete, treatment duration, examination procedure, preferred imaging, whether the patient required General Practitioner (GP) or specialist referral, passive and active (rehabilitation) care modalities and take-home advice). We have included a copy of our Sports Chiropractors Workforce Survey as supplementary material (Supplementary File 1).

Statistical methods

Data were initially collated, cleaned and inspected. Descriptive analyses for each item were reported as frequency distributions (counts and proportions) or summary statistics (means and standard deviations). All statistical analyses were conducted using The Statistical Package

for Social Sciences software (IBM SPSS Statistics for Windows, release 22.0. Armonk, NY: IBM Corp).

Results

A total of 73 participants, out of 213 eligible SCA members completed the survey (34% response rate and a 16% attrition rate), taking approximately 40 minutes on average. Characteristics of the sample of SCA members who completed the workforce survey are shown in Table 1. The average age of the participants was 35.9 ± 9.0 years of age. A total of 54 (74%) participants were male, and most sports chiropractors practised in New South Wales (34.2%). The average years of clinical experience were 11.3 ± 8.4 years. Over two-thirds of participants had a Masters level qualification and more than half (51.5%) graduated from Macquarie University in New South Wales, Australia.

With regards to post-graduate courses (Table 2), more

Table 1.
Sociodemographic characteristics of Sports Chiropractic Australia members who completed the workforce survey. ACT= Australian Capital Territory, NSW= New South Wales, NT = Northern Territory, QLD = Queensland, RMIT/PIT= Royal Melbourne Institute of Technology, SA= South Australia, TAS = Tasmania, VIC= Victoria, WA = Western Australia.

Sociodemographic characteristics	**(n=73)**
Age in years (mean ± sd)	35.9 ± 9.0
Gender (n (%))	
Male	54 (74%)
Female	19 (26%)
Clinical experience in years (mean ± sd)	11.3± 8.4
Location (n (%))	**(n=73)**
NSW	25 (34.2%)
VIC	22 (30.1%)
QLD	10 (13.7%)
WA	3 (4.1%)
SA	7 (9.6%)
TAS	2 (2.7%)
NT	1 (1.4%)
ACT	3 (4.1%)
Qualification (n (%))	**(n=73)**
Bachelors (or Double Bachelor's) degree	16 (22.2%)
Masters degree	53 (73.6%)
Doctoral degree	1 (1.4%)
Post-graduate Honours, certificate, diploma, degree	2 (2.8%)
Institution (n (%))	**(n=73)**
Macquarie University/ Sydney College of Chiropractic	35 (51.5%)
RMIT/PIT	26 (38.2%)
Murdoch University	7 (10.3%)
Qualification within Australia (n (%))	**(n=73)**
Yes	69 (94.5%)
No	4 (5.5%)

Table 2.
Post-graduate courses undertaken by Sports Chiropractic Australia members. ASCA= Australian Strength and Conditioning Association, ICCSP= The International Certified Chiropractic Sport Science Practitioner

Post-graduate course (n (%))	**(n=73)**
ICCSP Program	40 (54.8%)
Acupuncture / Dry needling course	44 (60.3%)
Rocktape/Kinesio Taping course	44 (60.3%)
Sports Medicine Australia sports trainer levels	34 (46.6%)
ASCA Strength and Conditioning course	23 (31.5%)
Selective Functional Movement Assessment	22 (30.1%)
Functional Movement Screen	17 (23.3%)
Functional Neuro-Orthopaedic Rehabilitation	13 (17.8%)
Functional and Kinetic Treatment with Rehabilitation course	12 (16.4%)
Dynamic Neuromuscular Stabilisation	10 (13.7%)
Functional Capacity Screen	2 (2.7%)

Table 3. *Clinical characteristics of Sports Chiropractic Australia members.*

Clinical characteristic	**(n=73)**
Patient care hours per week (mean ± sd (n))	30.8 ± 11.1 (72)
Patient visits per week (mean ± sd (n))	78.9 ± 44.3 (70)
Practice alongside other health professionals within the same practice location (n(%)	62 (86.1%) (72)
Types of practitioners working with within practice (n(%))	**(n=73)**
General Practitioner	4 (5.5%)
Medical Specialist	6 (8.2%)
Exercise Physiologist	13 (17.8%)
Psychologist/Counsellor	15 (20.5%)
Podiatrist	16 (21.9%)
Physiotherapist	20 (27.4%)
Another Chiropractor	27 (60.3%)
Massage Therapist	44 (60.3%)
Other	44 (37.0%)

than half of the study group (54.8%) completed the Internationally Certified Chiropractic Sports Practitioner (ICCSP) program through FICS. SCA members undertook a wide range of certifications, notably almost two thirds (60.3%) had a completed acupuncture/dry needling or a Rocktape/Kinesio Taping certification. The least common post-graduate courses reported were Functional and Kinetic Treatment with rehab (16.4%), Dynamic Neuromuscular Stabilisation (13.7%) and Functional Capacity Screen (2.7%). Clinical and fieldwork characteristics of SCA members are shown in Tables 3 and 4, respectively. SCA members worked 30.8 ± 11.1 patient care hours per week and had, on average, approximately 79 patient visits. A total of 62 (86.1%) sports chiropractors practised alongside another health care practitioner, with over 60% of these being a massage therapist or another chiropractor. Of SCA members, 5.5% worked alongside a GP, and approximately 8% worked with a medical specialist within their practice. SCA members spent an additional 3.8 ± 11.7 hours per week out of their chiropractic clinics, performing, on average, fieldwork to approximately 12 patients per week. In our study, half of Australian sports chiropractors travelled with athletes or sports teams (51%) and had provided sideline emergency care for athletes or sportspeople (54%). With regards to their role as a sports chiropractor over the last 12 months, 81% attended continuing professional development courses or conferences and 71% had volunteered at sports events in the last year. Over 57% had intra-professional relations (SCA); however, only 11% had inter-professional relations (i.e. a relationship with Sports Medicine Australia), and only 5% undertook higher degree research.

Table 4.
Fieldwork characteristics of Sports Chiropractic Australia members.

Field Work characteristics	
Fieldwork hours per week (mean ± sd (n))	3.8 ± 11.7 (34)
Fieldwork patient visits per week (mean ± sd (n))	11.7 ± 7.9 (43)
Travel with sports teams/athletes (n (%) (n=43))	22 (51.2%) (43)
Emergency assessment of athletes (n (%) (n=43))	23 (53.5%) (43)
Self-reported role as a sports chiropractor in the last 12 months (n (%))	**(n=73)**
Private sports chiropractic Practice	67 (91.8%)
Professional development (attending courses or conferences)	59 (80.8%)
Sports Chiropractic volunteer work	52 (71.2%)
Intra-professional organisations i.e Sports Chiropractic Australia	42 (57.5%)
Inter-profesional organisations i.e Sports Medicine Australia	8 (11.0%)
Undergraduate student clinical supervision	19 (26.0%)
University teaching or tutoring	6 (8.2%)
Undertook higher research degree	4 (5.5%)

Table 5 reports the frequency of care for various athletes and sportspeople. Approximately 9% of SCA members often provide treatment to elite athletes, 32 % often treat semi-professional athletes, 69% often treat amateur athletes, and 88% often treat weekend warriors. The characteristics of the most recent case presentation are reported in Table 6. A total of 27 (44.3%) cases were patients aged 25-44 years, with the majority (70.5%) of patients being male. The level of sporting competitiveness of patients ranged from the weekend warrior to an elite athlete, most frequently amateur to semi-professional. The most frequent region of the complaint was a lower limb muscu-

Table 5.
Frequency of care for different types of athletes/sportspeople by Sports Chiropractic Australia members in Australia (n=65).

Type of athlete/sports people (n(%))	**Never**	**Rarely**	**Sometimes**	**Often**
Weekend warrior	0 (0%)	1 (1.4%)	7 (10.8%)	57 (87.7%)
Amateur	0 (0%)	1 (1.4%)	19 (29.2%)	45 (69.2%)
Semi-professional	4 (6.2%)	11 (16.9%)	29 (44.6%)	21 (32.3%)
Elite	13 (20.3%)	24 (37.5)	21 (32.8%)	6 (9.4%)

Table 6.
A description of the most recent case presenting to Sports Chiropractic Australia members.

Most recent case characteristics	
Age of patient (n (%))	**(n=61)**
>6	0 (0)
7-12 years	2 (3.3%)
13-18 years	8 (13.1%)
19-24 years	16 (26.2%)
25-44 years	27 (44.3%)
45-65 years	8 (13.1%)
Gender (n (%))	
Male n (%)	43 (70.5%)
Female n (%)	18 (29.5%)
Level of sports participation (n (%))	
Weekend warrior	4 (6.7%)
Amateur	20 (33.3%)
Semi-professional	20 (33.3%)
Elite	16 (26.7%)
Region(s) of complaint (n (%))	
Neck pain axial	9 (12.3%)
Neck pain referred / radicular	2 (2.7%)
Thoracic pain	13 (17.8%)
Chest pain	1 (1.4%)
Low back pain – axial	25 (34.2%)
Low back pain – referred / radicular	7 (9.6%)
Lower limb musculoskeletal disorder (Hip, Knee, Ankle, Foot)	32 (43.8%)
Upper limb musculoskeletal disorder (Shoulder, elbow, wrist, hand)	21 (28.8%)
Postural disorders (lordosis, kyphosis, scoliosis)	2 (2.7%)
Headache disorders (cervicogenic, migraine, tension)	7 (9.6%)
Spinal health maintenance/management	12 (16.4%)
Non-musculoskeletal disorders	1 (1.4%)
Sporting/performance enhancement	18 (24.7%)
Co-management with another health practitioner (n (%))	
Yes	26 (42.6%)
No	35 (57.4%)
Modalities that were utilised for treatment (n (%))	
Soft-tissue, trigger point, massage	57 (78.1%)
Spinal manipulation/mobilisation	51 (69.9%)
Specific exercise therapy/rehabilitation	49 (67.1%)
Extremity manipulation/mobilisation	46 (63%)
Taping technique	23 (31.5%)
Dry needling/acupuncture	15 (20.5%)
Electro-modalities (Transcutaneous electrical nerve stimulation, laser, interferential, ultrasound, shock-wave)	10 (13.7%)
Heat/cryotherapy	10 (13.7%)
Orthotics (foot care)	2 (2.7%)

loskeletal disorder (43.8%), followed by axial low back pain (34.2%), and an upper limb musculoskeletal disorder (28.8%). A total of 26 of the 61 cases (42.6%) were co-managed with another allied health practitioner, while the majority of cases (57.4%) were managed by sports chiropractic care alone. The most common intervention modalities used inpatient care were soft-tissue, trigger point, and massage therapy (78.1%), spinal manipulation/mobilisation (69.9%), specific exercise therapy and rehabilitation (67.1%) and extremity manipulation/mobilisation (63%).

Discussion

This cross-sectional survey reports the practitioner and practice characteristics of SCA members, a special interest group of the Australian Chiropractor's Association. The predominant profile from the study sample of the Australian sports chiropractor was male, from New South Wales and had an average of 11 years of clinical experience. Just over half of the respondents had completed the Internationally Certified Chiropractic Sport Science Practitioner (ICCSP) program with just less than half completing the Sports Medicine Australia sports trainer courses. Nearly all Australian sports chiropractors engaged within post-tertiary educational courses such as dry needling and taping, which suggests they incorporate additional modalities in their clinical toolbox. Previous studies on sports chiropractic have found that chiropractors apply multi-modal treatments in their care of athletes[8], and the findings in our study supported this. The most commonly used interventions in the treatment of athletes were soft-tissue therapy, spinal manipulation/mobilisation and specific exercise therapy/rehabilitation. Nearly half of SCA members co-managed their most recent patient (case) with another health professional, potentially reflecting the practice of Australian sports chiropractors to work in multidisciplinary primary care teams. Multidisciplinary care has long been supported as an integral pathway to the improvement of patient outcomes, particularly those that are complex.[2]

One in 10 Australian sports chiropractors self-reported often treating elite athletes, with a further one-third self-reporting sometimes treating elite athletes. This study suggests that elite athletes commonly sought treatment from SCA chiropractors, and that elite athletes are common in the sports chiropractic setting. Commen-

taries and anecdotal reports[12] have previously speculated chiropractic care to offering performance enhancement benefits to elite athletes. Given that Australian sports chiropractors report treating high-level athletes, the benefits and harms of care must be clearly understood. Future research is warranted, both quantitative (the effectiveness of chiropractic on sports performance, management and injury prevention) and qualitative (the theoretical frameworks of why elite athletes seek treatment by sports chiropractors). We do not know the context of the treatment of elite athletes in our study; that is, whether this is as part of, or external to, the provision of care from their sports medicine team. Importantly, future research must determine the acceptance of sports chiropractors into sports medicine teams and their delineated role from existing team members. Unfortunately, in Australia chiropractors are still lacking formal specialisation or further accreditation for a protected title "Sports Chiropractor". A recent tiered institute of chiropractic education by the Australian Chiropractors Association promotes sports chiropractic specialisation, however, whether this provides integration into sports medicine is yet to be seen.

We found Australian sports chiropractors worked with sports and recreational teams on top of their usual clinical load. The majority of respondents volunteered professionally to provide care, with half of the respondents reporting travelling with sports teams/athletes in an official medical role. In addition to caring for sporting teams/athletes, Australian sports chiropractors provided emergency assessment of athletes, suggesting they often serve as the first point of contact for athletes. In amateur and community sport settings chiropractors appear to provide on-field sports injury triage with escalation to off-field injury management, as well as clinic-based care. The interest of sports medicine stakeholders is the role of sports chiropractors in the sports medicine team.

In an attempt to profile the clinical case management of Australian sports chiropractors, respondents were asked to retrospectively describe their most recent sports chiropractic case (that is the treatment of an athlete or sports person). These athletes sought care for both axial and peripheral musculoskeletal presentations, with the most cases being lower limb musculoskeletal disorders, axial low back pain and upper limb musculoskeletal disorders. A 2012 systematic review on manipulative therapy for lower limb extremity conditions found 'fair' (short-term) and 'limited' (long-term) evidence of effectiveness for ankle inversion sprains, and fair (short-term) evidence of the effectiveness of manipulative therapy for plantar fasciitis.[15] Similarly, fair evidence supports manipulative therapy for upper limb extremity conditions.[16] In the current study, one-third of Australian sports chiropractic respondents reported providing treatment for sporting/performance enhancement in their most recent case; however, the research evidence to support this supposition (i.e. enhance sports performance through chiropractic care) is unknown. Australian sports chiropractors need to develop a research agenda to understand better the effects of care on extremity injuries, including outcomes beyond pain and disability, for example in the prevention of injury (prehabilitation), time to return-to-play after injury, and in enhancing sporting performance.

Several limitations need to be considered when interpreting the findings of this cross-sectional survey. One-third (73) of invited SCA members answered the survey, and after attrition of 16%, only 61 respondents completed all questions. The length and duration of the survey may have impacted the attrition rate, with the survey taking respondents an average of nearly 40 minutes to complete. The data collected is based on self-reporting and is therefore potentially susceptible to practitioner recall bias and possibly an over or under-estimation of the reported outcomes. User-defined missing values were treated as missing and all statistical methods were based on all cases with valid data, with denominators being reported in the Results tables. In this study, there was a higher proportion of male versus female sports chiropractors (74.3% to 25.7%), which is not representative of the general Australian chiropractic profession.[4,17] It is unclear if our study sample is equal to the expected sex ratio among sports chiropractors. Our case audits were retrospectively captured, and future study should focus on collecting information about sports chiropractors' practice characteristics prospectively, ideally via a practice-based research network. Using a consecutive-series design, where the base unit of measure is the patient encounter, would provide a more robust estimate for care-seeking and practise characteristics. In addition, this approach would ensure a more comprehensive assessment of sports chiropractic. A practice-based model could further be used to assess the treatment effects of care on patients in pre-post observational study designs in the future (i.e. effectiveness of care).

Conclusions

In our study, Australian sports chiropractors were more likely to be male, from NSW and have an average of 11 years of clinical experience. Approximately two-thirds of Australian sports chiropractors who responded to this survey indicated they treat athletes, which were generally comprised of non-elite levels. Respondents also work alongside another health care practitioner in a clinical setting, or a multidisciplinary team. This study had a low response rate, and further research is needed to clarify the findings. Our findings assist the chiropractic profession in delineating the role of sports chiropractors and the nature of the athlete population that seeks care.

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Construct validity and reliability of the Concussion Knowledge Assessment Tool (CKAT)

Mitchell Savic, BHSc(Hons), DC, FRCCSS(C)[1]
Mohsen Kazemi, DC, FCCPOR(C), FRCCSS(C), MSc, PhD, RN[2]
Alexander Lee, BSc(Hons), DC, FRCCSS(C)[3]
David Starmer, BSc(Hons), DC, MHS[4]
Sheilah Hogg-Johnson, BMath(Hons), MMath, PhD[2]

Objective: *To evaluate the test-retest reliability and construct validity of the concussion knowledge assessment tool (CKAT) as a measure of knowledge of concussion and its management among chiropractic subgroups and to compare these properties for two scoring strategies for the CKAT.*

Methods: *Three chiropractic subgroups (first year students, interns and sports chiropractors) completed the CKAT via SurveyMonkey with as second administration two to six weeks later for a subset of respondents. Scatter plots and Intraclass Correlation Coefficients (ICC) were used for test-retest reliability. A priori hypotheses regarding the relationship of CKAT scores across known subgroups, and with concussion knowledge self-rankings were established prior to data collection. Distributions of CKAT scores were compared across the subgroups*

Objectif : *Évaluer la fiabilité du test-retest et interpréter la validité du* Concussion Knowledge Assessment Tool (CKAT*)) servant à évaluer les connaissances sur la commotion cérébrale et sa prise en charge par des sous-groupes de chiropraticiens et comparer ces propriétés pour deux stratégies de cotation du CKAT.*

Méthodologie : *On a demandé à trois sous-groupes de chiropraticiens (étudiants de première année, internes et chiropracticiens du sport) de remplir le questionnaire CKAT par SurveyMonkey et de deux à six semaines plus tard, on l'a utilisé une deuxième fois auprès d'un sous-ensemble de répondants. Des diagrammes de dispersion et des coefficients de corrélation intraclasse (CCI) ont été utilisés pour évaluer la fiabilité du test-retest. Des hypothèses a priori sur le rapport des scores CKAT dans les sous-groupes connus et les auto-évaluations des connaissances sur la commotion cérébrale ont été établis avant la collecte des données. On a comparé les*

[1] Velocity Sports Medicine & Rehabilitation
[2] Department of Research and Innovation, Canadian Memorial Chiropractic College
[3] Clinical Education, Canadian Memorial Chiropractic College
[4] Undergraduate Education, Canadian Memorial Chiropractic College

Corresponding author:
Mitchell Savic, 167 Lakeshore Road West, Mississauga, Ontario
Tel: 289-338-7277
Email: drmitchsavic@gmail.com

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using boxplots and ANOVA for known groups validity, and correlation of CKAT scores with concussion knowledge self-ranking was examined.

Results: *Test-retest ICC for the revised scoring was 0.68 (95%CI 0.51-0.80). First year students had a mean revised CKAT (out of 49) of 36.9 (SD= 4.7), interns 39.9 (SD=3.0) and sports chiropractors 41.8 (SD=3.2) which are significantly different ($F_{2,125}$=17.54; p<0.0001).*

Conclusions: *The CKAT distinguished between chiropractic subgroups expected to have different levels of knowledge, supporting construct validity, however, it did not achieve adequate test-retest reliability.*

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KEY WORDS: assessment, concussion, knowledge, management, tool

répartitions des scores CKAT entre les sous-groupes à l'aide de diagrammes de dispersion et ANOVA pour la validité des groupes connus et la corrélation des scores CKAT et on a examiné les auto-évaluations des connaissances sur la commotion cérébrale.

Résultats : Les CCI du t*est-retest pour le score révisé était de 0,68 (IC à 95 % : 0,51-0,8). Pour Les étudiants de première année, le score révisé moyen CKAT (sur 49) était de 36,9 (ÉT = 4,7), pour les internes de 39,9 (ÉT = 3) et pour les chiropraticiens du sport de 41,8 (ÉT =3,2) ce qui constitue d'importantes différences ($F_{2,125}$=17,54; p < 0,0001).*

Conclusions : *Le score CKAT variait entre les sous-groupes de chiropraticiens qui sont censés avoir de différents degrés de connaissances, ce qui prouve la validité de l'interprétation. Cependant, le degré de fiabilité du test-retest n'est pas suffisant.*

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MOTS CLÉS : évaluation, commotion cérébrale, connaissances, prise en charge, outil

Introduction

There has been increasing interest and focus on sport-related concussion (SRC) in the scientific literature and popular media in recent years. SRC is an immediate and transient display of traumatic brain injury (TBI) symptomatology as defined by the 2017 Concussion in Sport Group (CISG).[1] Symptoms are variable, and can be somatic, cognitive, and/or emotional in nature and may include: headaches, feeling like in a fog, lability, loss of consciousness, amnesia, neurological deficit, gait unsteadiness, irritability, slowed reaction times, and drowsiness.[1] Concussion has a favorable natural history with 80 to 90% of concussions resolving on their own within seven to 10 days.[2] Factors associated with slower recovery from concussion symptoms include: increased severity of initial symptoms, pre-existing and/or subacute development of migraine headaches or depression, particularly in young adults, adolescents and children.[1]

The literature regarding concussion education for athletes has grown at a much faster pace than the literature on instructing healthcare practitioners about concussion management.[3] This is especially of concern for those practitioners who work in sports health care settings and primary contact practices that frequently come into contact with the condition.[3] As a result, concussion management can be challenging for health care practitioners, and assessing health care practitioners' knowledge of concussion and its management is of interest.

Boggild and Tator[4] developed a concussion knowledge assessment tool (CKAT) for clinicians based on a literature review (including the 2008 Zurich consensus statement on concussion in sport[5]), expert review, and pilot testing. They then used the tool to assess concussion knowledge in graduating medical students and neurology/neurosurgery residents.[4] Since that initial publication, the CKAT has been administered to other healthcare practitioner groups to assess their knowledge of concussion and its management, including physician trainees[3,4,6], chiropractors[7], chiropractic trainees[7], and sports chiropractors[8]. Although the distribution of CKAT scores across these different samples were comparable, all of these studies concluded that more education is required to fill know-

ledge gaps, which would likely require changes in the education curricula of these respective professions.

However, to our knowledge, the measurement properties of the CKAT, such as test-retest reliability and construct validity, have not been evaluated. Test-retest reliability is the degree to which a test score is able to be repeated on a second administration given the trait being measured has not changed.[9] Construct validity is the extent to which a test measures what it claims to be measuring, capturing the construct of interest. In other words, for the CKAT, construct validity is the degree to which it measures the knowledge of concussion and its management.[9] As such, the aim of this study is to investigate the test-retest reliability and construct validity of the CKAT among chiropractic trainees and practitioners. We also set out to investigate an alternative scoring method (as described in the methods) for the CKAT to determine whether it would have better measurement properties than the originally proposed scoring method. The original scoring has a nine-point scoring scale which possibly limits its resolution making it more difficult to discriminate between groups with different levels of knowledge. We hypothesized a priori that if the CKAT (with either scoring) is a valid tool to assess concussion knowledge and management, then it should be able to distinguish between groups of healthcare providers at different stages of training, it should correlate moderately with a self-ranking of concussion knowledge, and it would demonstrate adequate test-retest reliability.

Methods

Study design

Validity and reliability study with survey administration and short-term follow-up and re-administration for a subset of respondents.

Participants, recruitment and survey administration

A convenience sample of three groups of participants were targeted for the study, first-year chiropractic students (first year students), fourth-year chiropractic interns (interns) (both from the Canadian Memorial Chiropractic College (CMCC)) and Fellows from the Royal College of Chiropractic Sports Sciences Canada (RCCSS(C) (sports chiropractors). First year students and interns were recruited from CMCC via class and/or clinic announcements, and word-of-mouth in July and August of 2017. Students were given a SurveyMonkey[10] link on a piece of paper either after a laboratory session, at the beginning of class, or during clinical rounds and were asked to complete the survey without the help of any external sources. Paper copies of the survey were made available for sports chiropractors at an RCCSS(C) annual general meeting and conference in Toronto, ON in November 2017. Additionally, email addresses for a complete list of sports chiropractors were obtained from the RCCSS(C) (n=117) and these sports chiropractors were invited to complete the survey via an emailed SurveyMonkey[10] link in December of 2017. All participants from each of the three groups who completed the survey were emailed two to six weeks after initial submission with a SurveyMonkey[10] link directing them to an identical copy of the survey for a re-test. There are no standard rules for determining the time interval between repeated measures for test-retest reliability. However, a common time frame of two weeks has been suggested in the literature.[9] A time interval of two to six weeks between measures was used here, with the belief that this was long enough to avoid recall of the first administration, and short enough for changes in knowledge of concussion and its management to be unlikely. There was no blinding. Analysts weren't blinded to the responses, nor were the responders blinded to the purpose of the study.

Measures

The 26-item CKAT survey, originally created by Boggild and Tator[4] and modified for chiropractors by Kazemi *et al*.[7,8], was entered into SurveyMonkey[10]. The original survey consisted of three sections: 1) questions about demographics, participation in sport, and history of concussion, 2) questions about knowledge of concussion and its management (the CKAT), and 3) questions about learning needs regarding concussion. The modified version of the CKAT implemented in this study is presented in Appendix 1.

Modifications to the original survey by Kazemi *et al*.[7,8] altered language used in questions that was specifically aimed at physicians to wording more appropriate for chiropractic respondents. For instance, question 2 was changed from "What medical school…" to "What chiropractic college…". Three further modifications were implemented for the current study. For question 15 in part 2 "What is the appropriate management of concussion?

Select all that apply", the response option "Every concussed individual should see a physician", was changed to "Every concussed individual should see a healthcare professional". For question 16, "What are some "red flags" that may predict the potential for more prolonged symptoms and may influence your investigation and management of concussion? Select all that apply", the response option "age" was changed to "younger age" to remove ambiguity. The last modification was made to the version administered to the sports chiropractors, with the addition of an open-ended question asking whether there are changes they would recommend to the assessment tool, as a result of newer research.

The primary measure from the survey of interest in this study comes from the questions in section 2 measuring knowledge of concussion and its management – the CKAT. Boggild and Tator[4] proposed a scoring scheme for this tool with a range of scores from 0 to 9 with each of questions 9 through 17 of the survey contributing one possible point to the overall score. Questions 12, 15, 16, and 17 are compound questions requiring the respondent to indicate all response options that apply and not indicate any options that do not apply. For instance, for question 17, "*What are the long-term consequences of repetitive concussive injury? Select all that apply*", there are ten possible responses offered, with eight being correct choices and two being incorrect choices. To get one point for these questions in the original scoring, the respondent must have selected all the appropriate responses, *and not selected* the inappropriate responses. For the current study, we considered an alternative scoring method that allowed for one possible point for each of the compound question responses – either correctly endorsed, or correctly not endorsed. This scoring gives a potential range of scores from 0 to 49. We entertained this option as we thought these scores might be more dispersed and therefore have higher reliability and better discrimination. Kazemi *et al*.[8] also considered an alternative scoring method utilizing the individual response options.

Other measures from the survey used in this study (see Appendix 1, 'Modified Survey with CKAT') included question 21, asking the respondent to self-rank their knowledge of concussions on a 1 to 10 scale anchored by Inadequate (1) and Completely Adequate (10).

Analysis

Descriptive statistics (counts and percentages for categorical variables, means and SD for continuous variables) were used to describe the participants.

Reliability

Test-retest reliability was assessed using scatterplots of retest versus test scores and intraclass correlation coefficients with 95% CI, specifically ICC(2,1) based on the taxonomy of Shrout and Fleiss.[11] Adequate test-retest reliability would be indicated by an ICC of 0.70 or greater.[12]

Validity

Construct validity is typically approached by posing hypotheses of how a measure should behave if it is a valid measure of the construct under study.[9] We hypothesized that knowledge of concussion and its management should be highest among sports chiropractors who not only gain extra practical training throughout their two-year sports sciences residency, but they also frequently manage athletic injuries including SRC. We also hypothesized that interns in their fourth-year of education would have less knowledge than sports chiropractors, but would have some content related to concussion studied in years 1 through 3, followed by first-year chiropractic students, expected to have the lowest levels of knowledge.[3] This approach is referred to as known groups validity or discriminative validity.[9] We examined the distributions of scores across these three groups using boxplots to assess overlap of distribution, computing means and 95% CI for each subgroup and comparing mean subgroup levels of knowledge using one-way Analysis of Variance (ANOVA). Furthermore, for construct validity, we hypothesized that the CKAT scores should correlate at least moderately (r~0.5) with the participants' self-ranking of concussion knowledge, and this was investigated using scatterplots and Pearson correlation coefficients (r) with 95% CI.

Statistical software

The graphical analysis for this study was generated using R[13] and the R package "psych"[14] with remaining analysis 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.)

Table 1.
Study participants.

	First year students n=46	**Interns** n=45	**Sports chiropractors** n=37	**Total** n=128
Gender *n (%)*				
Female	26 (56.5%)	22 (48.9%)	9 (24.3%)	57 (44.5%)
Male	20 (43.5%)	23 (51.1%)	28 (75.7%)	71 (55.5%)
CMCC student/graduate	46 (100%)	45 (100%)	30 (81.1%)	121 (94.5%)
Experienced concussion *n (%)*	17 (37.0%)	23 (51.1%)	15 (40.5%)	55 (43.0%)
Completed paper copy *n (%)*	N/A	N/A	17 (45.9%)	
Retest completed *n (%)*	15 (32.6%)	21 (46.7%)	22 (59.5%)	58 (45.3%)
Self-Rank Concussion Knowledge 1-10 *Mean (SD)*	5.0 (2.0)	5.5 (1.5)	7.4 (1.6)	5.9 (2.0)
Time taken minutes *Mean (SD)*	8.5 (4.7)	13.4 (10.2)	11.4 (13.0)	11.1 (9.9)

Sample size

The study protocol planned for at least 30 subjects per group (1st year, 4th year, sports chiropractors) for the original testing with retests completed by as many of each group as possible, targeting at least 50 retests overall distributed across the three groups. Streiner and Norman[15] suggest that studies of test-retest reliability can be adequately conducted with 50 subjects. With at least 30 subjects per group for known groups validity, the sample size would be sufficient to detect between groups effect sizes of around 0.70[16] with type 1 error α=0.05 and power 1-β=0.80. Effect sizes reported for comparisons made by Boggild and Tator[4] and Kazemi *et al*.[7,8] were considerably larger than 0.70."

Ethics

The protocol for this study was reviewed and approved by the Research Ethics Board of the Canadian Memorial Chiropractic College (CMCC) (REB# 172008).

Results

Table 1 provides descriptive statistics of the participants in the study by study group. Overall there were 128 participants completing the survey at least once, with 46 first year students (out of approximately 200 first year students), 45 interns (out of approximately 175 interns) and 37 sports chiropractors (out of 117) corresponding to 23%, 26% and 32% response rates respectively. Seventeen (46%) of the sports chiropractors completed paper copies of the survey at an annual conference hosted by the RCCSS in Toronto, Ontario. Fifty-six percent of the sample was male, although distribution by gender was fairly even for the two student groups, with the sports chiropractors being predominantly male. All of the students were affiliated with CMCC, while 81% of the sports chiropractors were CMCC graduates. Retests were completed by 33%, 47% and 60% of the first-year students, interns and sports chiropractors respectively. Retests occurred on average 25 days after the test (SD=6.9), with a minimum gap of 16 days and a maximum gap of 37 days. On average, mean time to complete the survey as recorded by SurveyMonkey was 11 minutes.

Reliability

Test-retest findings are presented in Figures 1(a) (original CKAT scoring) and 1(b) (revised CKAT scoring).

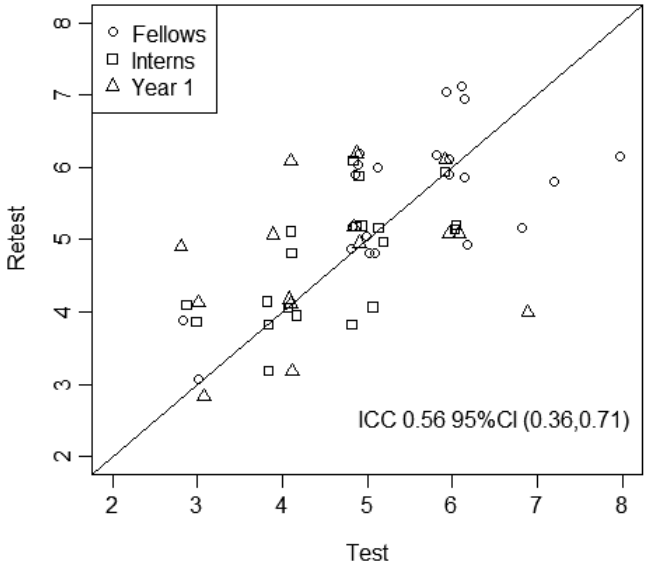

Figure 1(a).
Test-retest reliability with original scoring, scatterplot of retest versus test, with line retest=test superimposed, and intraclass correlation coefficient with 95% confidence interval.

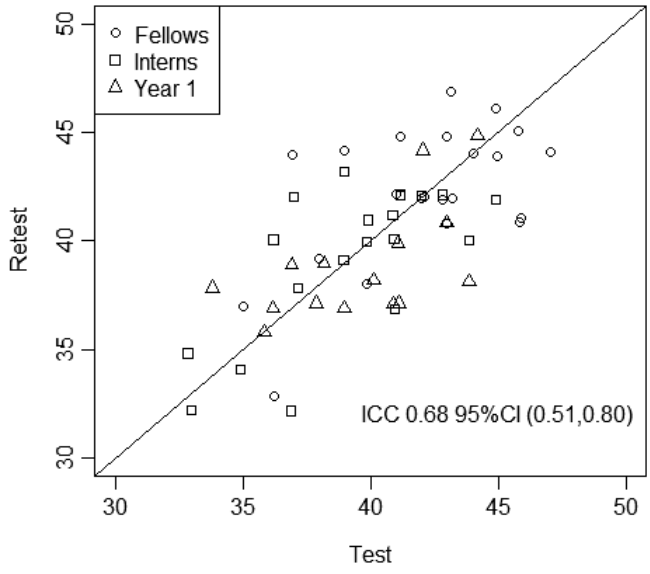

Figure 1(b).
Test-retest reliability with modified scoring, scatterplot of retest versus test, with line retest=test superimposed, and intraclass correlation coefficient with 95% confidence interval.

Because there are a discrete number of scores that the CKAT can take on (0 to 9 for original scoring and 0 to 49 for revised scoring), the scatter plots were produced using the "jitter" function in R to add a small amount of noise to each coordinate to avoid multiple plotting points overlapping each other. There is some scatter in both plots – that is, they are loosely clustered around the line y=x, and the intra-class correlation coefficients (ICC(2,1)) for test-retest reliability are 0.56 (95% CI 0.36-0.71) and 0.68 (95% CI 0.51-0.80) for the original and revised scoring respectively.

Validity

Table 2 shows descriptive statistics by group for the

Table 2. *Comparing distribution of CKAT scores across known groups.*

	First year students n=46	**Interns** n=45	**Sports chiropractors** n=37	**ANOVA comparing means across groups**
CKAT original scoring (possible range 0-9)				
Mean (95%CI)	3.98 (3.59, 4.37)	4.53 (4.26, 4.81)	5.49 (5.11, 5.86)	$F_{2,125}$ =18.44
SD	1.31	0.92	1.12	P<0.0001
CKAT revised scoring (possible range 0-49)				
Mean (95%CI)	36.9 (35.5, 38.3)	39.9 (39.0, 40.8)	41.6 (40.6, 42.7)	$F_{2,125}$ =17.54
SD	4.7	3.0	3.2	P<0.0001

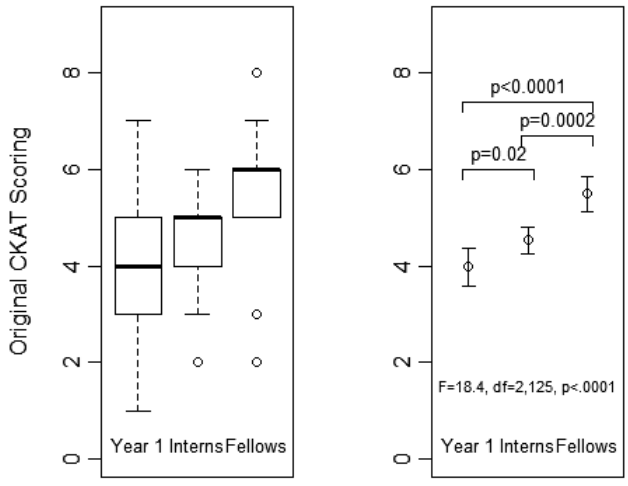

Figure 2(a).
Comparing distribution of CKAT across known groups using original scoring. The left-hand plot depicts boxplots for comparison of entire distribution of scores across the three groups. The right-hand plot depicts group means with 95% confidence intervals, and also shows the overall ANOVA F-test, and p-values for each pairwise comparison contrast.

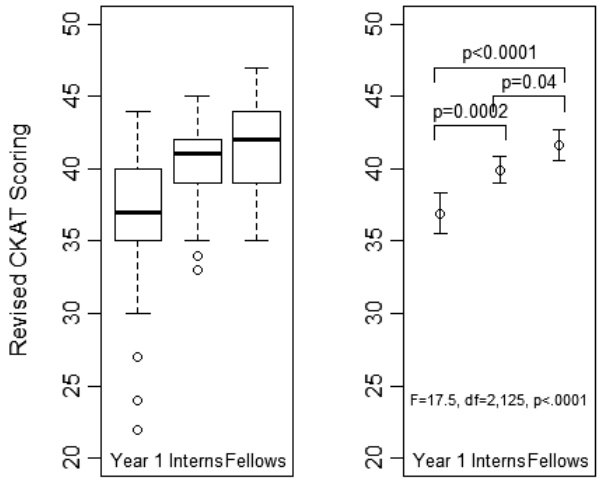

Figure 2(b).
Comparing Distribution of CKAT Across Known Groups – Revised Scoring. The left-hand plot depicts boxplots for comparison of entire distribution of scores across the three groups. The right-hand plot depicts group means with 95% confidence intervals, and also shows the overall ANOVA F-test, and p-values for each pairwise comparison contrast.

CKAT scores using both the original scoring method and the revised scoring method along with the test statistics from ANOVA. Figures 2(a) and 2(b) present graphical representations of the distributions of CKAT scores. For the original scoring of the CKAT (top rows of Table 2, Figure 2(a)), there is a gradient with mean scores increasing from 3.98 to 4.53 to 5.49 across first year students, interns and sports chiropractors. These means are significantly different with $F_{2,125}$ =18.44 and p<0.0001, as were the means for each pairwise comparison of groups, p-values shown in the right-hand plot of Figure 2(a). These differences in means correspond to effect sizes of 0.49, 1.34 and 0.85 which are medium (0.49) and large (1.34, 0.85) using Cohen's classification[16]. In the boxplots (left-hand plot), there is some overlap of distribution between first year students and interns, although the majority of interns scored above the first-year student median score. There is almost no overlap in scores between the sports chiropractors and both the first-year students and interns. With the revised scoring, there is less overlap in distribution as seen in the boxplots, between the first year and fourth year students, but more overlap in distribution between the fourth-year students and the sports chiropractors. Mean scores again show a gradient from 36.9 to 39.9 to 41.6 for first year, fourth year and sports chiropractors respectively and these means are significantly different with ANOVA test results of $F_{2,125}$ =17.54 and p<0.0001, as are the means for each pairwise comparison of groups, p-values shown in the right-hand plot of Figure 2(b). These differences in means correspond to effect sizes of 0.80, 1.25 and 0.45 which are large (0.80, 1.25) and close to medium (0.45) using Cohen's classification[16]. Figures 3(a) and 3(b) show scatterplots (again using the jitter function) of the two versions of CKAT scoring against the participants' self-ranking of concussion knowledge. There was a moderately positive correlation between self-ranking of concussion knowledge and CKAT scores when using both the original and revised scoring respectively (Pearson Correlation Coefficients) (r = 0.54; 95% CI = 0.40, 0.65) and (r = 0.48; 95% CI = 0.33, 0.60) respectively. Self-

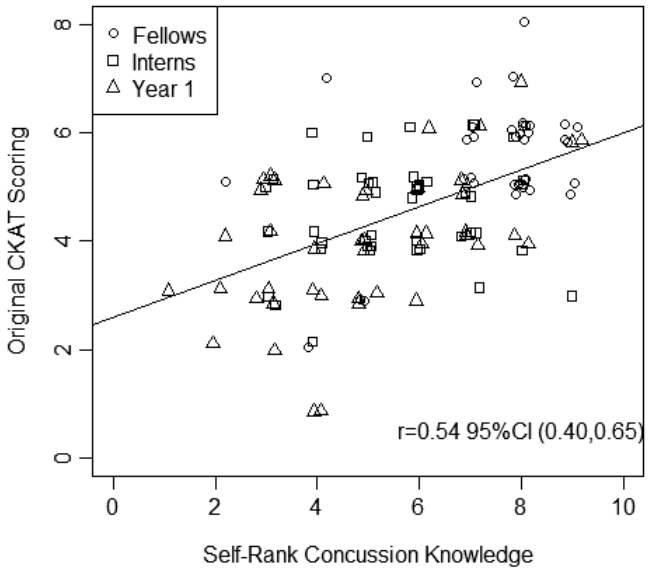

Figure 3(a).
Comparing CKAT scores using the original scoring and self-ranking of concussion knowledge using scatter plot and Pearson correlation coefficient with 95% confidence interval. The best fitting regression line is superimposed on the plot.

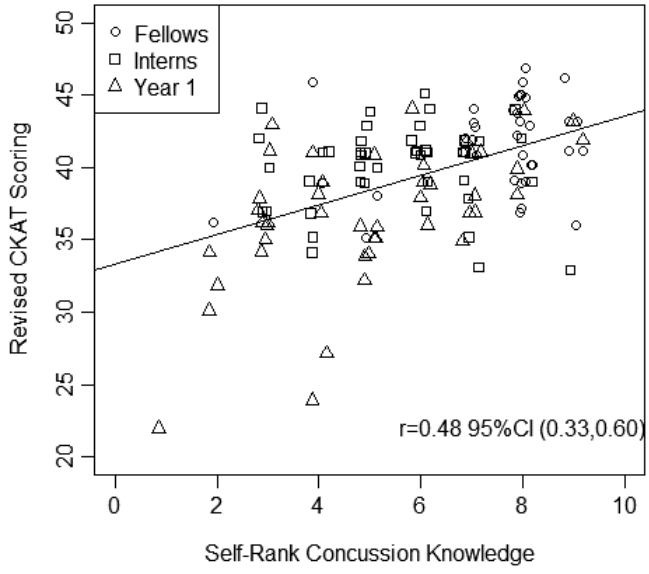

Figure 3(b).
Comparing CKAT scores using the revised scoring and self-ranking of concussion knowledge using scatter plot and Pearson correlation coefficient with 95% confidence interval. The best fitting regression line is superimposed on the plot.

ranked concussion knowledge on average increased with increasing training with means of 5.0, 5.5 and 7.4 for first year, fourth year and sports chiropractors respectively.

Discussion

We conducted a study to examine the psychometric properties of the CKAT, a tool developed to measure clinician knowledge of concussion and its management, and to compare two approaches to its scoring. The results show that both scoring versions of the CKAT were able to distinguish between the three groups of participants as hypothesized. There were moderate correlations of both versions with self-ranking as hypothesized a priori. Test-retest reliability was poor for the original scoring and fair for the revised scoring. Neither version achieved the criteria of 0.70 commonly considered adequate[12] although the revised scoring version came closer. Based on these findings, primarily the differences in test-retest reliability, the revised scoring of the CKAT performs more favorably.

We hypothesized a modest correlation (r~0.5) between the CKAT scores and the self-ranking of concussion knowledge if the CKAT is a valid measure of concussion knowledge and management and found support for that hypothesis with correlations of r=0.54 and r=0.48 for the two scoring approaches. These are similar to correlations previously reported by Boggild and Tator[4] (r=0.44), and Kazemi *et al*.[7] (r=0.40), but not similar to the correlation of r=0.07 reported by Mann *et al*.[6]. It is unclear why the latter study had findings so different from the others, and the authors do not discuss this in their paper.

Comparability of our findings with other similar studies in the literature lends further support for the known groups validity component of the findings, with the ordering of scores (using the original scoring method) aligning with levels of education and specialty training. First-year chiropractic students examined in this study, and medical students[4] have the lowest reported mean scores (4.0-4.2 respectively). Chiropractic interns examined both in this study and also in a different subset of respondents in

Kazemi *et al*.[6], chiropractic residents[6], and family medicine residents[5] reported mid-range mean scores (4.5, 5.2, 5.3, 5.2 respectively). Lastly, in those with specialty training including sports chiropractors examined both in this study and in a different subset of respondents in Kazemi *et al*.[7], along with neurology and neurosurgery residents[4] obtained the highest overall mean scores (5.5, 5.6, 5.8 respectively). When comparing the most novice (first year chiropractic students) to the most trained (sports chiropractors) in our data set, we saw very large differences in CKAT scores using both scoring methods, with Cohen's effect sizes of 1.25 and 1.34. These effect sizes are larger than the effect size corresponding to the comparison of medical school students to neurology and neurosurgery residents which was 1.06, and much larger than the effect size (0.70) we used in our sample size planning.

Limitations

There are some limitations to this study. Concussion education curriculums can differ among educational programs/institutions between healthcare professions, and so the CKAT's psychometric properties may be different in other groups of healthcare professionals. Secondly, the CKAT was developed from the 2008 consensus statement released following a meeting in Zurich[5], and since then subsequent consensus statements in Zurich 2012[2] and Berlin 2016[1] have been released. Although it does not appear that significant alterations to the CKAT questions are warranted based on the subsequent consensus statements, it would be a worthwhile exercise to scrutinize each question individually for content and face validity. Doing so may improve the psychometric properties of the test, which will provide a better representation of concussion knowledge in those tested. This study has demonstrated methods used to assess the validity and reliability of the CKAT, and as such, future CKAT versions can also have their psychometric properties assessed using the same approach. This is particularly important as newer guidelines are released.

We also could not prevent respondents from looking for answers in between test and retest. We aimed for a range of two to six weeks between trials to minimize recall of previous answers and limit the likelihood of change in concussion knowledge between administrations. Although the study's consent form stressed that our interest was in the investigation of the CKAT as a measurement tool rather than individual respondents' scores, there is the possibility that some respondents may have felt that their knowledge was being evaluated, and it is possible that some individuals researched questions in between administrations. If a respondent is to study the content of the test in between test trials and change their responses, it would inevitably lead to an underestimation of true test retest reliability, biasing the results. Validity would not be affected by this since it is only based on the first test.

CKAT mean scores may not be representative of the populations from which our samples were recruited with response rates ranging from 23% to 32%, as perhaps only those with experience or interest in concussion diagnosis and management chose to participate. It is also inherent within every subgroup that there may be some variability in knowledge which could introduce bias. For example, some first year student respondents may have obtained concussion knowledge prior to their education at CMCC which may inflate the mean test score, which would not be representative of that group. Also, some of the sports chiropractor respondents are separated by decades of clinical experience which may also bias CKAT scores within that group. Lastly, it is not known whether respondents are able to accurately self-rank their level of concussion knowledge. In other words, respondents may over or underestimate their self-rank of knowledge which may not correlate as hypothesized with their CKAT score. Previous studies utilizing the tool have compared respondent self-rank to the CKAT score with an unwritten assumption that they should positively correlate, whereas we have stated this as an a priori hypothesis as another way to demonstrate construct validity.

Strengths

Target sample sizes were achieved which allowed for an adequate study sample size and power. The hypotheses for construct validity were established prior to collecting any data. We examined the psychometric properties using two different scoring methods. We are the first to assess test-retest reliability of this instrument.

Future considerations

We are able to measure concussion knowledge with more confidence now that the psychometric properties of the CKAT have been analyzed with favorable outcomes for validity, but not so favourable for reliability. Moving for-

ward, we highly recommend that each question of the CKAT be examined individually, especially in light of newer guidelines, in an attempt to improve the psychometric properties, particularly reliability. Identifying whether a statistical difference in mean scores between groups actually represents a clinically meaningful difference in actual knowledge also needs to be addressed. The validity and reliability findings from this study are limited to Canadian Doctors of Chiropractic and chiropractic students largely trained at CMCC, so establishing the psychometric properties in other populations would also be of importance as concussions are being managed by several different sport healthcare professions. Lastly, there seems to be a learning gap between concussion guidelines and practitioner/trainee knowledge which should be addressed through institutional curricula.

Conclusions

This study provided evidence to support construct validity of the CKAT by distinguishing chiropractic subgroups as hypothesized, and by moderately correlating with concussion knowledge self-rating. However, the CKAT was not able to achieve adequate test-retest reliability (0.70) using either scoring method, even though the revised scoring came close (0.68). In light of this and given there have been updates to the 2008 Zurich consensus statement on concussion in sport, we recommend a re-examination of the CKAT, item by item, to identify where improvements could be made to improve the psychometric properties of the instrument.

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Appendix 1.
Modified survey with CKAT (used for this study).

Part 1: ID questions and Sports and Recreation background:

1. What is your gender?
2. Which chiropractic college are you currently attending? If you have currently completed your chiropractic undergraduate degree, which college did you receive this at?
3. What residency program and year are you in? (question only in survey to residents)
4. Have you done any of the following in the past 2 years? Mark all that apply.
   Thirty-one options of sports and activities given, including the option "other"
5. Last week, how many times did you participate in sports or physical activity?
   Options for 1 time to 7 times given
6. About how much time did you spend on each occasion?
   Options: 1 to 15 minutes, 16 to 30 minutes, 31 to 60 minutes, More than one hour
7. In the past, have you ever suffered a concussion? You may have been "knocked out", knocked unconscious, confused, or had your "bell rung". You may have felt lightheaded, not known where you were, etc.
   Options: Yes – once, Yes – 1-5 times, Yes – more than 5 times, No
8. If you answered yes to the previous question, how did your concussion(s) occur? Please select all that apply.
   Options: Work related, Motor Vehicle Crash, Sport or recreational activity, Fall, Other

Part 2 Knowledge questions about concussions **(Answers that were considered correct are bolded)**:

9. What is the definition of concussion? Select the best answer.
   a. Loss of consciousness for <5 mins after an impact to the head
   b. A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces
   c. A structural brain injury caused by mild traumatic force that transiently decreases cerebral blood flow
10. Is a concussion a brain injury? Select the best answer.
    a. No, as there is no abnormality seen on standard structural neuroimaging
    b. No, as symptoms are only psychological in nature
    c. Yes, as there is a functional disturbance that cannot be seen on standard neuroimaging
    d. Yes, as there is structural abnormality seen on standard neuroimaging
11. Which one of the following is true?
    a. A period of unconsciousness is necessary for the diagnosis of a concussion
    b. Over 2/3 of all concussions involve loss of consciousness (LOC)
    c. 1/3 to 2/3 of all concussions involve loss of consciousness (LOC)
    d. Less than 1/3 of all concussions involve loss of consciousness (LOC)
12. Which of the following is a sign or symptom of a concussion? Select all that apply.
    Options: **Headache**, Hemiparesis, **Dizziness, Confusion**, Fixed dilated pupil, **Nausea and/or Vomiting, Vertigo, Amnesia, Tinnitus, Emotional or personality changes**, Papilledema, Intention tremor, **Fatigue, Temporary loss of consciousness**, Prolonged coma

13. How many symptoms of a concussion are required to diagnose a concussion?
    Options: **One or more symptoms**, three or more symptoms, five or more symptoms

14. Which of the following is true regarding the mechanism of concussion?
    a. Direct physical contact to the head is necessary to sustain a concussion
    b. Localized damage to the brainstem is the cause a concussion
    c. Localized damage to the prefrontal cortex is the cause of a concussion
    d. Localized damage to the hippocampus is the cause of a concussion
    e. A whiplash effect to the brain caused by an impact to any part of the body may cause a concussion

15. What is the appropriate management of concussion? Select all that apply
    a. Every concussed individual should see a healthcare professional
    b. A concussed player can return to play in the same game or practice if examined by a healthcare professional
    c. A stepwise increase in exercise and activity if symptomatic
    d. Physical rest is always recommended after a concussion
    e. Mental rest is always recommended after a concussion
    f. Signs and symptoms should be monitored for increasing severity
    g. Full neurological exam at initial assessment is recommended
    h. The standard mini mental status exam at initial assessment as an adequate cognitive test for concussion
    i. MRI of the brain is mandatory
    j. CT of the brain is mandatory

16. What are some "red flags" that may predict the potential for more prolonged symptoms and may influence your investigation and management of concussion? Select all that apply:
    a. Nose bleed
    b. Prolonged loss of consciousness
    c. Number and duration of symptoms
    d. Younger Age
    e. Repeated concussions occurring with progressively less impact force
    f. Slower recovery after each successive concussion
    g. Repeated concussions over time
    h. Concussions close together in time
    i. Being hit on the left side of the head

17. What are the long term consequences of repetitive concussive injury? Select all that apply.
    a. Dementia
    b. Depression
    c. Headaches
    d. Increased risk of hemorrhagic stroke
    e. Death or disability with second concussion before recovery from a first concussion
    f. Increased risk of schizophrenia
    g. Prolonged fatigue
    h. Impairment of concentration and memory
    i. Parkinsonism
    j. Chronic traumatic encephalopathy

Part 3 Learning needs about concussions:

18. In your undergraduate chiropractic education, how did you learn about concussions? Select all that apply.
    Options: Lecture, PBL (problem based learning), Seminar, Interest Group, Shadowing/Observership, Other, Never, I can't remember

19. In your residency to date, how did you learn about concussions? Select all that apply.
    Options: Clinical experience, Self-study, Lecture, Never, I can't remember, Other

20. To date, have you seen a patient with:
    – concussion in the acute phase? Yes, No, I don't know (select one)
    – post-concussive syndrome? Yes, No, I don't know (select one)

21. How would you self-rank your knowledge about concussions?

Inadequate									Completely adequate
1	2	3	4	5	6	7	8	9	10

22. What resource would you most likely use to find information about concussions?
    Options: Google, Wikipedia, Up-to-date, Textbook, Pubmed, an agency website, Thinkfirst.ca, other

23 Are concussions something you want to learn more about as part of your medical curriculum?

Not at all									Very much
1	2	3	4	5	6	7	8	9	10

24. What is your preferred format for healthcare professional learning material?
    Options: Pamphlet, letter, seminar or workshop, lecture, informational email

25. What challenges, if any, do you think healthcare professionals face when diagnosing and managing a concussion?

26. This concussion assessment tool was created from knowledge extracted from the 2008 Zurich Consensus Statement on Concussion. Given that there have been recent advances in concussion research since 2008, are there any changes you recommend to the assessment tool, as a result of newer research? (question asked to sports fellows only)

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Multi-modal management of sport and non-sport related concussion by chiropractic sports specialists: a case series

Darrin Germann, BSc (Hons.), DC[1]
Cameron Marshall, BA (Hons.), DC, FRCCSS(C)[2]
Mohsen Kazemi, RN, DC, FRCCSS(C), FCCPOR(C), MSc, PhD[1]

This case series describes the multi-modal treatment plans delivered by two chiropractic sports specialists for the management of post-concussive symptoms (PCS). Three concussion cases are presented each with different mechanisms of injury (two sport-related and one non-sport-related) and each within a different stage of recovery (acute, sub-acute, and chronic). Treatment plans included patient education, sub-symptom threshold exercise, soft-tissue therapy, spinal manipulation, and cervical spine as well as visual/vestibular rehabilitation exercises. This series highlights three important observations: (1) the efficacy of individualized, multi-modal treatment plans based on suggested clinical profiles for patients with PCS of

Cette série de cas sert à présenter les plans multimodaux utilisés par deux spécialistes de la chiropratique sportive pour traiter des symptômes postcommotionnels (SPC). Trois cas de commotion cérébrale pour chaque type de mécanisme de lésion (deux cas de blessure liée au sport et un cas de blessure non liée au sport), chacun avec un stade différent (aigu, subaigu et chronique). Les plans de traitement englobaient l'information au patient, la réduction du seuil nociceptif par des exercices, le traitement des tissus mous, des manipulations vertébrales, des manipulations cervicales et des exercices de rééducation visuelle et/ou vestibulaire. Cette série de cas met en relief trois importantes observations, à savoir : 1)l'efficacité des plans multimodaux personnalisés élaborés selon les profils cliniques suggérés de patients présentant des SPC de divers stades sont efficaces; 2) la segmentation de la littérature sur la commotion cérébrale selon le

[1] Canadian Memorial Chiropractic College
[2] Complete Concussion Management Inc.

Corresponding author:
Darrin Germann, BSc (Hons.), DC, Sports Sciences Resident, Canadian Memorial Chiropractic College,
6100 Leslie Street, Toronto, ON M2H 3J1
Tel: 905-435-6074
e-mail: dgermann@cmcc.ca

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The involved patients provided consent for case publication.

various stages; (2) that the delineation of concussion literature based on mechanism of injury (i.e. sport- vs. non-sport-related) may be unnecessary; and (3) these cases provide encouraging evidence to support the inclusion of manual therapists with advanced knowledge of concussion treatment, such as chiropractors, as part of the interdisciplinary healthcare team when managing patients with PCS.

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KEY WORDS: concussion, concussion treatment, mild traumatic brain injury, multi-modal care, post-concussion syndrome, sport-related concussion, chiropractic

mécanisme de la blessure (commotion liée au sport et commotion non liée au sport) pourrait s'avérer superflue; et 3) ces cas fournissent des preuves encourageantes qu'il est pertinent d'inclure un thérapeute manuel possédant des connaissances poussées en matière de traitement des commotions cérébrales, comme le chiropraticien, à l'équipe interdisciplinaire de soins de santé prenant soin du patient ayant des SPC.

(JCCA. 2020;64(3) : 214-226)

MOTS CLÉS : commotion cérébrale, traitement de la commotion cérébrale, lésion cérébrale traumatique bénigne, traitement multimodal, syndrome postcommotionnel, commotion cérébrale liée au sport, chiropratique

Introduction

Concussion is a form of mild traumatic brain injury (mTBI) which can occur as a result of a motor vehicle accident, workplace related injury, a fall, or through participation in both contact and non-contact sport.[1,2] The Canadian Institute for Health Information (CIHI) reported that over a one-year period (2016-2017) non-sport related concussion (non-SRC) accounted for the majority (74%) of all brain injuries presenting to emergency departments in Ontario and Alberta, with sport-related concussions (SRCs) therefore only being responsible for the remaining 26%.[2] With that in mind, the CIHI also reported that the number of emergency department visits for SRC has increased by almost 28% over the last five years.[2]

Although the current trend in concussion literature is to separate SRC and non-SRC as individual entities, the only real distinction between the two conditions is the context in which the concussion is acquired. Given this seemingly arbitrary division between SRC and non-SRC, this paper will use the terminology 'concussion / mTBI' to refer to both SRC and non-SRC.

Numerous definitions of concussion / mTBI have been proposed, which remains a significant limitation in the existing literature. However, according to the most recent Consensus Statement on Concussion in Sport, concussion is defined as the onset of short-lived impairments of neurological function following a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.[3] The associated non-specific symptoms of both SRC and non-SRC may be of cognitive, visual, vestibular, physiological, or cervical spine origin.[4-7] The typical recovery time for adults is within 10 to 14 days, and up to four weeks in adolescents.[3] Unfortunately, a significant number of patients (23-47%) [8-10] will experience symptoms persisting longer than this time frame, and are subsequently diagnosed with persistent post-concussion symptoms (PPCS). The definition of PPCS is also inconsistent, but according to the most recent position statement released by the American Medical Society for Sports Medicine, it refers to the persistence of symptoms beyond the expected recovery time frame (greater than two weeks in adults, and four weeks in children) and does not necessarily represent ongoing concussive injury to the brain.[11] Other organizations, like the Ontario Neurotrauma Foundation (ONF), define PPCS as those still experiencing symptoms for greater than three months.[1]

There are a number of possible causes for post-concussion symptoms. There is evidence supporting theories such as brain blood flow abnormalities, metabolic/inflammatory contributors, visual and vestibular disorders, cervical spine dysfunctions, and even psychological causes.[1,3,7,11,12]

Despite this uncertainty, there is a consistent recommendation that individuals with PCS resulting from both SRC and non-SRC be managed by an interdisciplinary healthcare team with advanced concussion training through an impairment-based, multi-modal plan of management.[1,3,11] The purpose of this case series is to describe the efficacy of individualized multi-modal treatment plans delivered by chiropractic sport specialists for the management of acute, sub-acute, and chronic post-concussion symptoms originating from both sport and non-sport-related mechanisms of injury.

Case study 1

A 15-year-old elite female taekwondo athlete presented to the sports chiropractor with complaints of headache, dizziness, and neck pain of two days in duration. Symptoms began after she lost balance during an attacking kick and fell on her right shoulder while striking her head on the ground. The patient reported hearing a loud 'crack' sound in her neck at the moment of head impact and proceeded to lose consciousness for several seconds. She was immediately assessed by a certified emergency first responder for the taekwondo event who, at the time, reported her Glasgow Coma Scale as being 15/15. The sideline assessment also revealed cervical spine tenderness and the patient reported bilateral upper limb paresthesias with some objectively noted weakness in her fingers and toes. The emergency first responder proceeded to immobilize the athlete's cervical spine and contacted Emergency Medical Services. After being transported to the hospital by ambulance, cervical spine radiographs were taken and ultimately read as unremarkable. The attending emergency medical doctor diagnosed the athlete with a concussion and discharged the patient that evening.

At the two-day follow-up, further questioning by the chiropractor revealed that the patient was still experiencing a constant throbbing sensation in her head with occipital headaches rated 7-8/10 in intensity. These occipital headaches were aggravated primarily by noise and were not associated with any photophobia or aura. The patient was, however, reporting continued neck pain, nausea, and dizziness upon waking in the mornings. Her neck pain was located along the lower midline of her cervical spine, was rated at an intensity of 7/10, and was aggravated with cervical ranges of motion in all directions but particularly in right cervical rotation. The athlete was not reporting any referred pain into the upper extremities but was experiencing intermittent tingling in her fingers and toes bilaterally which occasionally lasted up to five-minutes before slowly resolving. A Neck Disability Index (NDI) was administered and was scored as 21/45 which is considered to be the upper limit of the 'moderate disability' category (five points excluded from the total because the patient did not drive). Additionally, the patient completed a Post-Concussion-Symptom Scale (PCSS) as part of the Sport Concussion Assessment Tool 3rd Edition (SCAT3) assessment which was scored as 125/132 (higher score equates to greater reported symptom severity). The SCAT5 was not yet released at the time of the patient presentation in this case. However, minimal changes were made to the symptom scale portion of the SCAT between the third and fifth editions.

Physical examination did not reveal any evidence of bruising, swelling, or deformities in the patient's upper body or head. Her active and passive cervical ranges of motion were restricted by 50% in all directions eliciting lower cervical spine pain in all directions, but most significantly with right cervical rotation. Resisted cervical spine ranges of motion caused right-sided cervical spine pain during right rotation, right lateral flexion, and extension. A cranial nerve exam (I-XII) along with a neurological assessment of the upper and lower limb deep tendon reflexes (C5-7, L4-S1) and motor and sensory systems (C5-T1, L2-S1) were within normal limits. Assessment of cerebellar function consisting of the Romberg test, rapid alternating movements, graphesthesia, and point-to-point tests were also performed and were within normal limits. Upper and lower nerve tension tests were negative. Orthopedic tests such as Jackson's, Spurling's, Kernig's, and the Slump test were unremarkable. Hypertonicity and tenderness were noted in the right upper trapezius, suboccipital muscles, levator scapulae, and rhomboid with her headache symptoms being reproduced during palpation of the right upper trapezius, suboccipital muscles, and challenging the right C1-2 facet joint. Further joint restrictions were found from C5-7 on the right, C2-3 on the left, along with T3-5 and the third and fourth costotransverse joints bilaterally.

The patient was diagnosed with: (1) a SRC; (2) grade-II Whiplash Associated Disorder (WAD II) with associated cervical and upper thoracic / costotransverse joint dysfunctions; and (3) cervicogenic headaches. The inter-

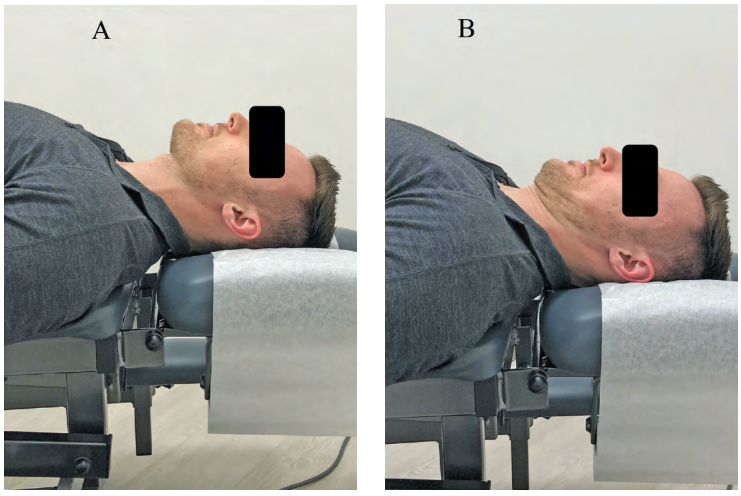

Figure 1.
Deep neck flexor strengthening exercises. (A) Patient lies supine in a relaxed position. (B) Patient performs a chin-tuck through active cervical retraction.

Figure 2.
(A) Single leg & (B) tandem stance exercises. The patient performs three sets of 20 second holds beginning with their eyes open and progressing to eyes closed.

mittent tingling reported in the upper and lower limbs was suspected to be a result of possible transient spinal shock (cervical cord neuropraxia), given that the patient's symptoms had been progressively resolving during the 48-hour period following her injury. Differential diagnoses included a central cervical disc herniation, or a bilateral brachial plexus injury (i.e. 'burner/stinger'). She was treated for a total of 16 sessions over eight-weeks (three sessions per week for four-weeks, then one session per week for four-weeks). Over the course of her care, her treatment included a combination of spinal manipulation, Vibromax Therapeutics Soft Tissue Therapy® (VMTX), interferential current therapy (IFC), heat, and needle acupuncture (Du-20, LI-4). A graded return-to-play (RTP) protocol as described in the 5th Consensus Statement on Concussion in Sport [3], along with home-based neck stretches and cervico-vestibular rehabilitation exercises such as single leg and tandem stance were prescribed.

The patient was initially advised to undergo a period of relative rest at home for one-week where she was allowed to engage in activities that did not aggravate her symptoms. The numbness / tingling in her fingers and toes completely resolved within the following 24 hours, and she reported that the concomitant chiropractic treatments were decreasing the intensity of her headache and neck pain. Following this one-week period the patient returned to school but was unable to tolerate the noise of the classroom environment, and had difficulty working on her computer for greater than one-hour without aggravation of her headaches. The patient was advised to continue to participate in school-related activities only within symptom tolerance and to perform short, daily walking sessions. At this point in time she was able to walk for 20-minutes before experiencing headaches.

10-days post-injury, the patient was prescribed a deep neck flexor exercise and single / tandem stance balancing exercises (three sets held for 20-seconds each) (Figures 1 and 2 respectively). At two-weeks post-injury, the patient was attending school full-time and was able to walk for 30-minutes without aggravating her headache symptoms. She reported one incident of noise-related headache exacerbation after watching a training session at her taekwondo school, but then did not experience any headache symptoms for a 48-hour period while still adhering to her exercise program. At this point in time, the chiropractor recommended that the patient begin jogging 10 minutes per day in conjunction with her current exercise program. Within a short time, the patient was able to spectate during

a full day of competition and jog for 20 consecutive minutes without eliciting a headache, at which point non-contact taekwondo kicking drills were recommended.

At the six-week mark the patient reported 80% improvement in her symptoms and a repeat NDI was scored as 7/50. Cervical spine ranges of motion were now full but mildly painful at all end ranges and palpation of her right suboccipital muscles and C1-2 joint challenging still slightly reproduced her headaches. As a result, the patient was treated with continued spinal manipulation and VMTX therapy once per week for an additional two-weeks after which these symptoms resolved. The patient was subsequently cleared to go back to full activity and was advised to return to the clinic if her headache or dizziness symptoms returned. A final follow-up appointment was performed three-months post-injury where the patient reported she had successfully returned to normal daily activities but was no longer competing in taekwondo due to unrelated personal reasons. Unfortunately, no final SCAT3 was performed at this time.

Case study 2

A 14-year-old elite female taekwondo athlete presented to a sports chiropractor with complaints of headaches, neck pain, and feelings of disorientation and dizziness after receiving a kick to the left jaw during her training nine-days earlier. She denied any loss of consciousness and did not report any nausea or vomiting at the time of the injury or in the following days. She did not seek out treatment initially, but rather managed her symptoms by resting at home for two days. The patient returned to school two days after the injury and reported aggravation of her headache and neck pain symptoms, with further aggravation of these symptoms following a light taekwondo training session (non-contact) now eight days after the injury.

Her neck pain was located in the sub-occipital region and was rated at 7/10 in intensity and characterised as 'stiff and tight'. The patient denied any radicular or referred symptoms into the upper limbs but noted that her neck pain was aggravated with both left and right cervical rotation. The chiropractor administered an NDI which was graded as 20/45 indicating a 'moderate' level of impairment due to her neck pain (five points excluded from the total because the patient did not drive). The patient indicated that her headaches were located in the temporal and frontal regions of her head, and that she experienced sharper headaches rated at 7-8/10 in intensity intermittently throughout the day. These periods of sharper headaches were accompanied by instances of photophobia, but she denied any nausea, vomiting, or presence of an aura in the hours preceding the sharp pains. The patient also reported bouts of dizziness when transitioning from a seated to standing position. A SCAT3 was also administered during the initial assessment with the patient recording 22/132 on the PCSS component of the test battery (Table 1). A baseline SCAT3 had been completed three-months prior to the injury where the patient recorded a PCSS score of 1/132. Similar to Case 1, the SCAT5 was not yet released at the time of the patient presentation in this case. However, minimal changes were made to the symptom scale portion of the SCAT between the third and fifth editions.

Table 1.
Summary of SCAT3 scoring for case study 2.
Max – Maximum; Sec – Seconds;
M-BESS – Modified Balance Error Scoring System

Test Domain	**Score**		
	3-months pre-injury (baseline)	**9-days post-injury**	**1-month post-injury**
Number of symptoms (max: 22)	1	7	7
Symptom severity score (max: 132)	1	22	13
Orientation (max: 5)	5	5	5
Immediate memory (max: 15)	15	14	15
Concentration (out of 5)	2	3	2
Delayed recall (out of 5)	4	5	5
M-BESS (total errors)	0	3	1
Tandem Gait (sec)	0	16	14
Coordination (max: 1)	1	1	1

On the physical examination the patient's blood pressure was measured as 106 / 72 with a heart rate of 60 beats per minute. Her active and passive cervical ranges of motion were limited by 25% in bilateral lateral flexion and extension which reproduced her suboccipital neck pain. Her temporal and frontal headaches were recreated during palpation of her suboccipital musculature, right C0-1 and left C1-2 vertebral segments. Further hypertonicity and tenderness were noted in the upper trapezius, levator scapulae, rhomboid, and thoracic longissimus muscles bilaterally. An assessment of the temporomandibular joint was unremarkable and did not reveal any dental injuries, nor did it recreate the patient's headache symptoms. A cranial nerve exam (I-XII), and a neurological assessment of the upper limb deep tendon reflexes (C_{5-7}) and motor and sensory systems (C_5-T_1) were within normal limits.

The patient was diagnosed with: (1) a SRC; and a (2) grade-II Whiplash Associated Disorder (WAD II) with associated cervicogenic headaches. She was treated by the chiropractor eight-times over five-weeks (three sessions per week for one-week, then two sessions per week for one-week, followed by one session per week for three-weeks). Over the course of her care, the multimodal plan of management included spinal manipulation, VMTX soft-tissue therapy, IFC, heat, needle acupuncture (Du-20, LI-4), a graded RTP protocol, and a home-based cervico-vestibular rehabilitation program similar to that described in Case Study 1 (Figures 1 and 2). Additionally, because the athlete's mother reported that the athlete had been craving more 'sweets' since the time of her concussion, a 'brain recovery diet' high in unrefined carbohydrates (i.e. real fruit juices, brown rice, pasta) was encouraged to try and counteract the possible blood-brain-barrier dysfunction and reduced intra-cerebral glucose levels that have been associated with concussion.[13]

After the first two treatments the patient reported improvements in the intensity and frequency of her headaches, however certain daily activities such as reading and climbing stairs continued to be mildly aggravating for her. After the third visit, the patient's headaches were no longer occurring daily and only lasting one-to-five minutes despite being back in school. The chiropractor then proceeded to prescribe deep neck flexor strengthening exercises (Figure 1) along with daily walking to symptom tolerance. The patient was re-assessed after three-weeks of treatment (one-month post-injury). She no longer reported having headaches, and that reading and climbing stairs, amongst other daily activities, no longer aggravated her symptoms. A repeat NDI revealed a reduced score of 4/45 ('no impairment'), and a reduced PCSS of 13/132 (Table 1). All cervical ranges of motion were now full and pain free and palpation of cervical and upper thoracic musculature no longer recreated her headache symptoms. The patient was then cleared to return to full activity / training with the exception of full contact taekwondo sparring. Following an additional two treatment sessions over a two-week period, the athlete reported 11 consecutive days without reoccurrence of her headache symptoms. At this point the athlete was cleared for full RTP and was discharged with the recommendation to follow-up for re-assessment should her symptoms return. At the time of her last follow-up (now six-weeks post-injury), the athlete was symptom-free and had successfully returned to full-contact taekwondo. No additional outcome measures were completed at the six-week mark.[11]

Case study 3

A 27-year-old female presented to the sports chiropractor with a six-year history of PPCS. Her symptoms initially began six years ago after she fell and subsequently struck the left parietal and temporal region of her head on a step. The patient reported experiencing an immediate headache, nausea, balance issues with blurred vision, along with mental confusion and feeling like she was 'in a fog'. She did not report the occurrence of any red flags such as evidence of cranial fracture, progressively worsening headache, deteriorating mental state, or progressive neurological symptoms such as motor or sensory deficits. The patient also did not report any antero-or-retrograde amnesia.

After seeking immediate care for the initial injury at a local hospital and having all diagnostic imaging studies (computed tomography and magnetic resonance imaging) return negative results for cranial fracture or moderate-to-severe traumatic brain injury, the attending physician placed her on prescribed bed rest for a period of approximately four-weeks. With little improvement in her symptoms over this rest period, she sought further care from a sports medicine physician. Once again, she was placed on bed rest, advised to withdraw from school activities, and instructed to spend time in a dark room to prevent further exacerbation of her symptoms.

Table 2.
Initial Post-Concussion Symptom Scale (PCSS) scores for case study 3.

Symptom	Score	Symptom	Score
Headache	3/6	Pressure in Head	3/6
Neck Pain	0/6	Nausea or Vomiting	2/6
Dizziness	3/6	Blurred Vision	6/6
Balance Problems	2/6	Sensitivity to Light	2/6
Sensitivity to Noise	5/6	Feeling Slowed Down	4/6
Fogginess	5/6	Don't Feel Right	5/6
Difficulty Concentrating	3/6	Difficulty Remembering	1/6
Fatigue or Low Energy	4/6	Confusion	3/6
Drowsiness	0/6	Trouble Falling Asleep	2/6
More Emotional	4/6	Irritability	4/6
Sadness	4/6	Nervous or Anxious	3/6
Totally Symptom Severity		68/132	
Total Symptoms		20/22	

She remained on bed rest for a period of eight-months. Gradually her symptoms improved enough to resume her schooling, however she never achieved complete recovery. The patient experienced several additional minor head impacts which repeatedly exacerbated her symptoms over the following six years. With each exacerbation of her symptoms, the patient was prescribed further bed rest by her medical doctor. Upon presenting to the chiropractor, the patient had been prescribed a cumulative total of 11-months bed rest since the initial injury.

During the initial assessment with the chiropractor, the patient reported ongoing headaches primarily in the left temporal/parietal region, along with intermittent frontal headaches felt bilaterally. These headaches were accompanied by dizziness and blurred vision. She experienced continued phonophobia, difficulty concentrating, fatigue and low energy, along with irritability and sadness. A complete copy of her PCSS can be seen in Table 2. The patient ultimately scored 68/132 on the PCSS, experiencing a total of 20 out of the 22 symptoms assessed. The patient denied ever being diagnosed with any behavioural disorders or learning disabilities, and has no previous history of headaches, anxiety, depression or sleep disorders – conditions commonly thought to increase the likelihood of developing PPCS [3,11].

A neurological exam consisting of a cranial nerve (I-XII) screen, pronator drift and cerebellar testing, upper limb deep tendon reflexes (C5-C7), dermatomal sensory testing (C5-T1), and motor function (C5-T1) were all within normal limits. Upon conclusion of this initial assessment, the patient was diagnosed with PPCS of unknown origin. The patient was provided with the diagnosis, educated on the plan of management and expected clinical course of PPCS, cleared for full days of work/school with modifications, and was restricted from exercise until a graded exercise tolerance test could be performed. Similar to Case Study 2, this patient was also provided with a 'brain recovery diet' consisting of three balanced meals. More specifically, the patient was encouraged to avoid refined sugars/carbohydrates (i.e. white bread or pasta) and select natural sources of carbohydrate instead, to select quality sources of protein (i.e. lean cuts of grass fed, free-range meats), to include quality fats (i.e. products high in omega-3 fatty acids), and select foods

rich with natural antioxidants. Contrary to Case Study 2, this diet was designed to temporarily reduce the patient's caloric intake – a concept which will be further examined in the Discussion section of this paper.

The patient returned one-week later to conduct a Buffalo Concussion Treadmill Test (BCTT). The BCTT protocol was completed as originally described by Leddy *et al*. (2013).[14] The patient's BCTT results are shown in Table 3. The patient was able to complete the entire test, which was stopped at the 14-minute mark due to the patient reaching her age-predicted maximum heart rate of 193 bpm. After passing her graded exercise testing, the patient was then encouraged to participate in light aerobic sub-symptom threshold exercise where there was no or little risk of head contact (i.e. treadmill walking or stationary biking).

Two days after the graded exercise testing, the patient returned to the chiropractor reporting that she completed a 20 to 25 minute walk the previous day, and that the intensity of her headache was reduced. The total symptom severity score on the PCSS dropped 55 points to 13/132, and the total number of symptoms dropped by 11 points to 9/22. The chiropractor then performed a Vestibular / Ocular Motor Screening (VOMS) test as well as a cervical spine examination consisting of cervical spine ranges of motion, joint motion palpation, and an assessment of the cervical spine soft tissues. The complete VOMS testing protocol along with a discussion of its' internal consistency and validity is described by Mucha *et al*. (2014).[15]

The patient reported symptom provocation of ≥ 2 points (a positive result) during both the horizontal and vertical vestibulo-ocular reflex (VOR) components of the

Table 3.

Buffalo Concussion Treadmill Test (BCTT) results with recorded walking time (minutes), treadmill incline (%), heart rate (bpm), any reported change in symptoms, and rational for terminating the test.

Time (minutes)	Treadmill Incline (%)	Heart Rate (bpm)	Reported Change in Symptoms
0:00	0	90	—
1:00	1	106	—
2:00	2	106	—
3:00	3	115	—
4:00	4	125	—
5:00	5	133	—
6:00	6	139	—
7:00	7	149	—
8:00	8	158	—
9:00	9	168	—
10:00	10	174	—
11:00	11	177	—
12:00	12	185	—
13:00	13	188	—
14:00	14	192	Test stopped due to patient reaching max heart rate
15:00	Cool Down		
16:00	Test Complete		

VOMS test (Table 4). During the VOR procedure, the patient fixates on a central point while moving his/her head in repetitive left and right rotation and then flexion and extension.[15] This procedure tests the function of the VOR and one's ability to stabilize his or her gaze during dynamic head movements.[15] The horizontal and vertical VOR movements were then prescribed as gaze-stability exercises to be performed daily to symptom tolerance (Figure 3). Although accommodation and convergence scores were also flagged during the VOMS test, this was thought to be caused by previously existing circumstances as the patient was wearing prescription glasses for these deficits. The cervical spine examination revealed tenderness upon palpation of primarily the left deep neck flexor muscle group, along with the left sternocleidomastoid (SCM) and suboccipital muscles – both of which referred pain to the left frontal region of the patient's forehead. Motion palpation revealed joint restriction at the C0-C1 and C2-C4 levels, with manual provocation of the C2-C3 levels recreating the patient's bi-temporal and frontal headaches. Joint restrictions were also found in the mid-thoracic (T3-T5) region and the associated costotransverse joints.

The chiropractor treated the above clinical findings at a frequency of one session per week over four-weeks with an average of five days between visits. A combination of myofascial release therapy and acupuncture was used to

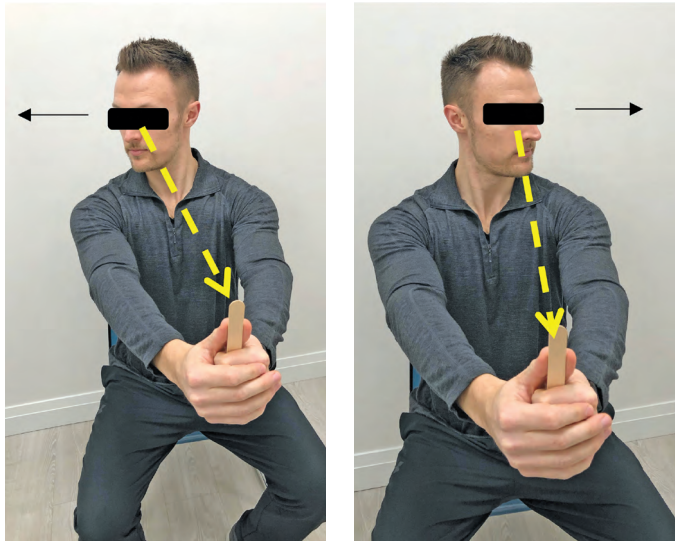

Figure 3.
Gaze stability exercises. The patient is asked to rotate his/her head horizontally while keeping the eyes focused (yellow arrow) on the target held roughly three feet in front of him/her. The head is rotated 20 degrees to each side and a metronome is used to ensure the speed of rotation is maintained at 180 beats/minute (one beat in each direction). The same procedure is used during the vertical gaze stability exercise, except the patient flexes and extends their head 20 degrees in each direction.

Table 4.
Vestibular / Ocular Motor Screening (VOMS) test results for case study 3.

Test Component	Headache (0-10)	Dizziness (0-10)	Nausea (0-10)	Fogginess (0-10)	Distance (cm)	Detected Abnormality?
Baseline Symptoms	**3**	**0**	**1**	**1**	**—**	**—**
Smooth Pursuits	2	0	1	1	—	No
Saccades -Horizontal	2	0	1	1	—	No
Saccades -Vertical	2	1	1	1	—	No
VOR – Horizontal	3	2	0	2	—	Yes
VOR – Vertical	4	3	1	2	—	Yes
Visual Motion Sensitivity Test	2	2	1	1	—	No
Accommodation – Left	2	1	1	1	13	Yes
Accommodation – Right	2	1	1	1	11	Yes
Convergence	2	2	1	2	8	Yes

treat the affected soft tissues, and spinal manipulation for the restricted joint segments. The patient reported immediate improvements in her symptoms following the first treatment. At the time of the patient's final visit, her symptom severity score had reduced to 4/132, and total symptom number to only 3/22. The three remaining symptoms of neck pain, pressure in the head, and blurred vision were only scored between one-and-two on a scale of six (most severe). Over the following two-weeks, the patient described that the frequency and intensity of her headaches and blurry vision had reduced significantly, going some days with no symptoms at all. To date, the patient remains in contact with the treating chiropractor receiving care for unrelated complaints and continues to report complete resolution of her concussion symptoms.

Discussion

The featured cases describe the experiences of three young females who suffered a concussion / mTBI each with a different mechanism of injury (SRC vs. non-SRC) and each with a different duration of symptoms (acute, sub-acute, and chronic). All three patients were eventually managed by chiropractic sports specialists using an individualized, multi-modal therapy program that included manual therapy, sub-symptom-threshold aerobic exercise, cervical and visual/vestibular rehabilitation, and dietary modifications (Cases 2 and 3).

One important comparison to make among the featured cases is the approach to prescribed rest by the various clinicians involved. The patient in Case Study 3, the only one to develop persistent and chronic symptoms, was primarily managed via prescribed rest by the first three healthcare practitioners she accessed. Prescribed rest until the point of symptom resolution is one of the most commonly used treatments in concussed patients.[11,16,17] However, the recommendation for physical and cognitive rest following a concussion is based mainly on dated expert opinion / consensus.[3,16] A recent systematic review found that the "best available evidence from clinical studies does not support the efficacy of prescribing complete rest for more than a few days" [16], and the most recent position statement by the American Medical Society for Sports Medicine seconds this argument.[11] As a result, the scientific community has begun to more thoroughly investigate the impact of individualized multi-modal treatments both acutely following a concussion, and in situations of PPCS.[6,7,12,18-21]

The concept of 'clinical profiles' or 'domains' of concussion presentation has become a more popular approach when designing multi-modal treatment plans.[11] Encouraging the discussion of these profiles was one of the main purposes of this case series. The proposed sub-types are based on the underlying deficits thought to be responsible for the patient's post-concussion symptoms, and may be: (1) physiologic, (2) vestibular/oculomotor, (3) cervicogenic, or (4) biopsychosocial in nature.[7,11] Additionally, it has been suggested that patients with PCS likely fall into multiple domains, and as such, should undergo a thorough evaluation for each profile before their treatment is decided.[7,11] This describes the treatment approach that was used by the chiropractic sports specialists in each of the three cases in this series.

The physiologic clinical domain primarily refers to those whose symptoms are exacerbated by aerobic exercise. It has been reported that some concussed individuals experience autonomic dysfunction following injury, leading to significant alterations in cerebral blood flow (CBF) and cardiac rhythm.[7,11,12] One study noted that in female athletes with persistent symptoms similar to those experienced by the patient in Case 3, "CBF increased out of proportion to exercise intensity when compared with non-concussed athletes exercising at the same intensities".[12] Further, it was found that this increased CBF was associated with the development of headaches and dizziness in those patients.[12] The BCTT is said to be one of the most well studied graded exercise tests that can be used to establish sub-symptom exercise thresholds, and is ideal for use in patients with PCS.[11] Additionally, sub-symptom aerobic exercise based on the results of the BCTT has been found to be safe and improve symptom resolution particularly in those patients with PPCS.[11,12] Hence, the BCTT was used to try and identify exercise thresholds in the PPCS case described above (Case Study 3). In this particular instance, the BCTT did not reveal any signs of persistent physiologic exercise intolerance, as the patient was able to reach her age-predicted maximum heart rate (193 bpm) without symptom exacerbation (Table 4). This is not uncommon, since it is thought that approximately two-thirds of concussed patients do not fall into the physiologic clinical profile.[12]

On the other hand, many PCS symptoms are more commonly thought to be a result of some combination of the visual, vestibular, or cervicogenic domains.[12] The

aforementioned domains can be clinically assessed in a number of ways. The three cases discussed in this series included a combination of cranial nerve testing, the balance component of the SCAT3 evaluation (a test that is unchanged in the updated SCAT5 version), a cervical spine assessment, and the VOMS test to assess for the contributions of the visual and vestibular systems toward the patients' symptoms. The VOMS test has demonstrated good sensitivity for identifying patients with concussive symptoms originating from visual or vestibular impairments.[11,15] Additionally, targeted vestibular rehabilitation therapy based on the significant findings from the VOMS test have been shown to improve symptom resolution in individuals with complaints of unbalance or dizziness, and may be more beneficial than continued physical and cognitive rest in this patient population.[4,22] The patient in Case Study 3 demonstrated positive test results during both the horizontal and vertical VOR components of the VOMS test. She was given gaze-stability exercises where the patient is required to fix her eyes on stable target while moving her head in repetitive horizontal and then vertical motions (Figure 3).[5] Gaze-stability training is prescribed based on an 'expose-recover' model where patients perform the given exercises to the point of symptom provocation, then rest, and repeat the exercise again.[5] Patients then progressively increase the volume of training as their capacity to do so improves.[5] The vestibulo-ocular systems in the patients from Case Studies 1 and 2 were trained via more traditional balance exercises, single leg and tandem stance, and were guided through a series of progressions to further challenge their balance and spatial awareness (i.e. eyes open / closed, stable/unstable surface, and accessory movements of the upper limbs).

The remaining clinical profile relevant to all three cases was the involvement of the patients' cervical spine. Each of the patients in Cases 1 through 3 presented with numerous cervical joint restrictions and hypertonic muscles, some of which recreated their chief complaints when provoked. The American Medical Society for Sports Medicine concluded that there is preliminary evidence that addressing cervical spine dysfunctions through targeted physical therapy programs can lead to improved outcomes in patients with PCS.[11] The effectiveness of spinal manipulation for post-concussion headaches specifically is limited, however cervical manipulation has proven to be beneficial in the management of common headache disorders including migraines and cervicogenic headaches.[23] Given the clinical findings in all three cases, spinal manipulation was deemed appropriate and appeared to provide benefit to the patient as part of a multi-modal treatment plan. Further research investigating the efficacy of spinal manipulation specifically for the management of neck pain and headaches in PCS patients is warranted.

One final component to the management of Case Studies 2 and 3 was the inclusion of a 'brain recovery diet'. There is a paucity of literature on specific nutritional / dietary interventions for the prevention and treatment of mTBI in humans, with the majority of research focusing on the role of nutrition in cognitive function of elderly and for the management of moderate to severe TBI. It is understood that following a concussion / mTBI there is a cascade of immunological, excitotoxic, and neuroinflammatory events leading to oxidative stress and cell death.[13,24] This on-going neuroinflammatory and excitotoxic state has been suggested as a possible contributor to the continuing symptoms in those who develop PPCS.[24] Recent evidence suggests that natural anti-inflammatory agents such as omega-3 essential fatty acids, vitamin D_3, and curcumin may offer benefit in immunoexcitotoxicity-associated neurodegenerative disorders by suppressing microglial activation and the ensuing excitotoxic / inflammatory cascade that follows.[24-26] Diets high in refined sugars and processed meats are thought to be pro-inflammatory.[27] Therefore, both of the brain recovery diets provided to the patients in Cases 2 and 3 encouraged the selection of unrefined carbohydrates and non-processed meats. Lastly, the patient in Case Study 3 was encouraged to only consume three balanced meals per day, as there is preliminary data from both animal and human models (primarily the elderly) to suggest that short-term caloric restriction (30-40% reduction) may exert neuroprotective effects following concussion / mTBI.[28,29,30] Another key feature of the neurometabolic cascade discussed above is the 'energy crisis' created within the brain due to the uncoupling of CBF and glucose metabolism early on following injury. This uncoupling describes a state of reduced CBF (and therefore the delivery of glucose/ energy) combined with the temporary state of hyperglycolysis within the brain, which creates a mismatch in the supply and demand for glucose.[31] It was thought that the cravings for glucose / 'sweets' reported by the patient in Case Study 2 during the first few days post-injury could

be related to such an 'energy crisis'. Thus, the athlete was encouraged to increase her intake of unrefined carbohydrate to try and mediate this energy mismatch and facilitate normal cerebral functioning acutely post-injury. The dietary modifications implemented in Cases 2 and 3 provide potentially promising but preliminary evidence of beneficial effects in patients with concussion / mTBI. However, further research on the efficacy of dietary interventions for concussion / mTBI and PPCS in young athletic populations is warranted. More specifically, it would be prudent to determine whether or not different nutritional recommendations should be made depending on the patient's age or phase of recovery (i.e. acute, sub-acute, or chronic), and whether or not pre-injury dietary habits may play a role in concussion recovery.

Limitations

This case series has a number of limitations. First, is the absence of original diagnostic imaging and laboratory reports for Case 3. During this time the patient relocated and changed family physicians and was not able to obtain copies of these investigations. These diagnostic reports would aid in describing the breadth of evaluations the patient in Case 3 had undergone and would emphasize the difficulty experienced in previous attempts at managing this case. Second, results from a baseline PCSS score in Cases 1 and 3, and a final follow-up PCSS score in Case 2 would provide reference upon which one could better judge the extent of the patients' recovery. Although the patient in Case 3 reported the continuation of three low-level symptoms at the point of discharge, it has been noted that both healthy controls and those with other co-morbidities report the presence of various non-specific symptoms that are also commonly experienced by those with PCS.[32] Therefore, one is unable to determine whether or not the patient would have reported these symptoms on a baseline PCSS even before her injury. Such a situation is well demonstrated by the baseline PCSS results of the patient in Case 2. Third, the use of a multi-modal treatment plan creates a challenge when trying to determine which intervention is providing therapeutic benefit to the patient. Fourth, although the recovery outcomes were positive in each of the three cases in this series, it should be noted that there are inherent limitations in the generalizability of case series results to other concussed patients. Fifth, the concept of 'clinical profiles / domains' is still an emerging theory, and it is uncertain at what time during recovery these clinical profiles become important with respect to treatment outcomes.[11] Additional research on the use of impairment-based, multi-modal treatment plans, along with the timing for which such a plan should be implemented is needed.

Summary

Concussion / mTBI can occur as a result of motor vehicle accidents, slip-and-falls, and through participation in professional or recreational sport. Emerging research suggests that patients diagnosed with PCS, regardless of the mechanism of injury, can be characterized by one or more clinical profiles based on their clinical assessment. These clinical profiles can then guide the development of individualized, multi-modal treatment plans that can significantly improve patients' symptoms. There is limited evidence describing the role that chiropractic sport specialists may play in the interdisciplinary management of concussion outside of sport. This case series describes three individualized multi-modal treatment plans delivered by sports chiropractors that included sub-symptomatic threshold exercise, vestibulo-ocular rehabilitation, spinal manipulation, soft-tissue therapy, and dietary modification during the management of both sport and non-sport related concussion. The positive results from this case series further contribute to the evolving literature supporting the role of chiropractors in the primary management of concussive symptoms of various origin and duration.

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Continuous moderate intensity versus discontinuous high intensity treadmill running on anterior cruciate ligament laxity and hamstrings flexibility in eumenorrheic women

Michael J. Landram[1]
Mary K. Halligan[2]

Objective: *To differentiate running intensity and menstrual phase effects on knee stability before and after exercise*.

Methods: *Ten eumenorrheic aerobically trained females were recruited to determine effects of a randomized crossover design of exercise intensity (85%HRR vs 42.5%HRR) on anterior cruciate ligament laxity (AP_{LAX}) and hamstrings flexibility (HF). A KT-2000 arthrometer measured AP_{LAX} and a 90-90 supine knee extension (MKE) and sit-and-reach test (SRD) measured HF in follicular (FP) and luteal (LP) menstrual cycle phases*.

Results: *Significant difference pre-exercise was observed for both 90N and 120N AP_{LAX} in LP compared to FP. Exercise increased AP_{LAX} at 90N and 120N in*

Objectif : *Distinguer les effets de l'intensité de la course sur tapis roulant et de ceux de la phase du cycle menstruel sur la stabilité du genou avant et après l'exercice*.

Méthodologie : *On a recruté dix femmes ayant des règles normales, faisant de l'exercice aérobie, pour établir les effets d'un modèle croisé d'intensité de l'exercice physique (85 % HRR contre 42,5 % HRR) sur la laxité du ligament croisé antérieur (AP_{LAX}) et la souplesse des ischio-jambiers (SI). On a utilisé un arthromètre KT-2000 pour mesurer l'AP_{LAX} et l'extension en supination du genou à 90-90 (MKE) et on a utilisé le test de flexion du tronc pour mesurer la SI durant les phases folliculaire (PF) et lutéale (PL) du cycle menstruel*.

Résultats : *On a observé une différence significative avant l'exercice physique pour 90° et 120° AP_{LAX} durant la PL par rapport à la PF. L'exercice physique a fait*

[1] Department of Exercise Science and Sport, The University of Scranton
[2] Department of Physical Therapy, The University of Scranton

Corresponding author:
Michael J. Landram, Department of Exercise Science and Sport, The University of Scranton,
237 Jefferson Ave., 18510, Scranton, PA, United States.
E-mail:michael.landram@scranton.edu

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both FP and LP with LP exhibiting larger changes than FP. MKE and SRD increased significantly following exercise but were not different across menstrual phases or between exercise intensities.

Conclusion: *AP_{LAX} taken together with increased HF post-exercise demonstrates a less stable knee joint in the LP before and following exercise.*

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KEY WORDS: aerobic exercise, anterior cruciate ligament, joint range of motion, menstrual cycle, hormone

augmenter l'AP_{LAX} à 90° et à 120° autant dans la PF que dans la PL, les variations étant plus importantes dans la PL que dans la PF. MKE et SRD augmentaient de façon significative après l'exercice physique mais n'étaient pas différents durant les phases du cycle menstruel ou entre les intensités de l'exercice physique.

Conclusion : *L'AP_{LAX} en association avec la hausse de la SI post-exercice prouve une moins grande stabilité du genou durant la PL avant et après l'exercice physique.*

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MOTS CLÉS : exercice aérobie, ligament croisé antérieur, amplitude du mouvement de l'articulation, cycle menstruel, hormone

Introduction

Anterior cruciate ligament (ACL) tears have been demonstrated to be approximately three times more likely in populations of female athletes compared to male athletes.[1] However, the underlying causes of ACL tears remain unclear.[2] Sport-related collision with other players accounts for about 30% of cases with the remaining 70% being non-collision.[3] In non-collision ACL injuries inherent anatomical differences in tibia and thigh length, pelvis width, and femoral notch width have been examined as contributing factors.[2,3] Additionally, hormone mediated changes to connective tissues, hamstrings flexibility (HF), and anterior-posterior knee laxity (AP_{LAX}) have all been cited as risk factors.[3]

Clinical evidence in females indicates that for every 1.3 mm increase in AP_{LAX} the risk of injury increases fourfold[4] and high AP_{LAX} (+1 SD) showed 2.7 times greater risk for ACL tear over a four year study period[5]. Among athletes who have sustained non-collision ACL injury, there was a higher level of HF compared with controls.[6,7] The higher level of HF is thought to reduce the passive protection of the ACL by the hamstrings during actions such as deceleration and landing.[6] It has long been thought that the hamstrings act as a load regulator on the ACL during anterior tibial displacement.[7] Using a cadaver knee model, More *et al*.[8] simulated squatting using an Oxford rig and demonstrated that by adding tension to the hamstrings there was a significant decrease in anterior tibial translation, and therefore ACL load, during the squat movement. They concluded that the hamstrings and the ACL work synergistically for anterior displacement knee stability.

AP_{LAX} can be quantified as the stretch of the ACL at a particular force which is applied to promote anterior tibial translation.[3] Therefore along with HF, which influences anterior tibial translation, AP_{LAX} provides a good measure of anterior knee stability.[8,9] AP_{LAX} and HF are of particular interest because not only do they vary between females, but also within a single female throughout the menstrual cycle.[9-11] Observational studies indicated that ACL tears are more common during the luteal phase (LP) and following ovulation[12,13], and knee stability may be one explanation for this correlation.

The influence of exercise on knee stability is of interest since the majority of non-collision ACL injuries occur during sport preparation or competition.[3] Not all forms of exercise appear to change AP_{LAX}. Neither cycling[14] nor powerlifting[15], produced a significant increase in AP_{LAX}, but discontinuous activities such as basketball[15], soccer[16], and shuttle runs[11], and continuous aerobic exercise such as a 10 kilometer run[15], triathlon, and a 20-minute run[17] do. While these studies utilized a mixed-sex or male only population, taken together, they indicate that running causes observable increases to AP_{LAX}. However, these studies [11,15-17] did not compare any type of work-matched exercise. In a continuous aerobic exercise study, Nawata

et al.[17] compared somewhat similar intensities at strikingly different volumes. They compared males undertaking a 20-minute treadmill run (7km/hr) to those competing in a long-distance aerobic event (variable speed during the 135 km bike and 42 km run) and concluded that AP_{LAX} increased by about 30% following either condition. Whereas discontinuous exercise, such as a 90-minute soccer specific practice increased AP_{LAX}[16]; however, was not compared to continuous running. Comparisons between discontinuous running and continuous running have yielded mixed results.[11,15] Shuttle runs of various intensities, when compared to a continuous treadmill run in males, resulted in significant AP_{LAX} increases in the discontinuous running group.[11] Whereas a 90 minute vigorous basketball practice that included shuttle-runs was not dissimilar from a 10 km road run.[15] Few studies describe exercise activities such as warm-ups, cool downs, and the degree of multi-directional running. Further, none of these studies that incorporated female participants controlled for menstrual cycle phase.

Few studies examining knee laxity extensively tracked or controlled for menstrual cycle phases for the female participants and many used mixed-sex groups, further complicating interpretation.[18] Although the data on how laxity varies in the menstrual cycle have been contradictory in the most recent systematic reviews, most observational studies agree there is increased laxity around ovulation and during the LP[18,19], making high estrogen levels a likely underlying cause of increased female ALC injury rates[3,18]. Some possible explanations for cycle-dependent laxity changes involve estrogen receptors localized on the ACL[10,20] and body temperature changes[21]. The increase of estrogen levels before ovulation and during LP may change the tensile strength of the ACL by decreasing procollagen synthesis thereby making it more susceptible to injury.[3] The female menstrual cycle presents a complicated set of variables to control, which is the most cited reason for the lack of a clear consensus on cyclic laxity variation. Recent studies have used differing approaches for determining menstrual cycle.[18] Some investigations assumed stages solely based on reported days since menses, which is inconsistent even among females with regular 28 day cycles, others have measured hormones such as estrogen or progesterone to directly compare hormone concentrations at different cyclic stages.[22]

Currently, there are no studies that have compared the effects of work-matched moderate and high intensity aerobic exercise on HF and AP_{LAX} in females while also measuring hormone concentrations across cycle phases. Therefore, the purpose of this study is to determine whether moderate intensity continuous versus high intensity discontinuous treadmill running has an influence on AP_{LAX} and HF in eumenorrheic women across LP and follicular phases (FP).

Methods

Subjects

Ten eumenorrheic women were recruited from a university population through flyers, online message boards, and word of mouth to participate in this study. No participant had in the past or were currently taking any form of oral contraceptive or hormonal therapy. Participants with prior knee injury, a body mass index ≥30 kg m^2, or known cardiovascular or pulmonary disease were excluded from the study. Participants were aerobically trained, undertaking ≥3 days and ≥150 min/week of aerobic exercise at a combination of moderate (~5-6 METS) to high (~10-11 METS) intensities, VO_{2peak} above the median for age (>37.8 ml kg^{-1} min^{-1}).[23] The experimental procedures were explained to all participants and informed consent was obtained before testing as submitted to and approved by the Institutional Review Board which are in accordance with the Helsinki Declaration.

Study design

Study participants reported to the lab on six separate occasions (Figure 1). The first (V_1) was baseline testing to determine anthropometric and body composition values and peak aerobic capacity. Following this, the participants went through a four-week period where they tracked menstrual cycle and body temperature through a mobile application to determine ovulation. After the control period ended, participants returned to the lab to repeat baseline testing (V_2) to determine changes to anthropometrics or fitness over the four weeks between V_1 and V_2. After the first full menstrual cycle was tracked, the phase (either LP or FP) was identified based on when menstruation and ovulation occurred. Using daily temperature readings, experimenters identified the post-ovulation temperature spike marking the beginning of the LP.[3] Participants con-

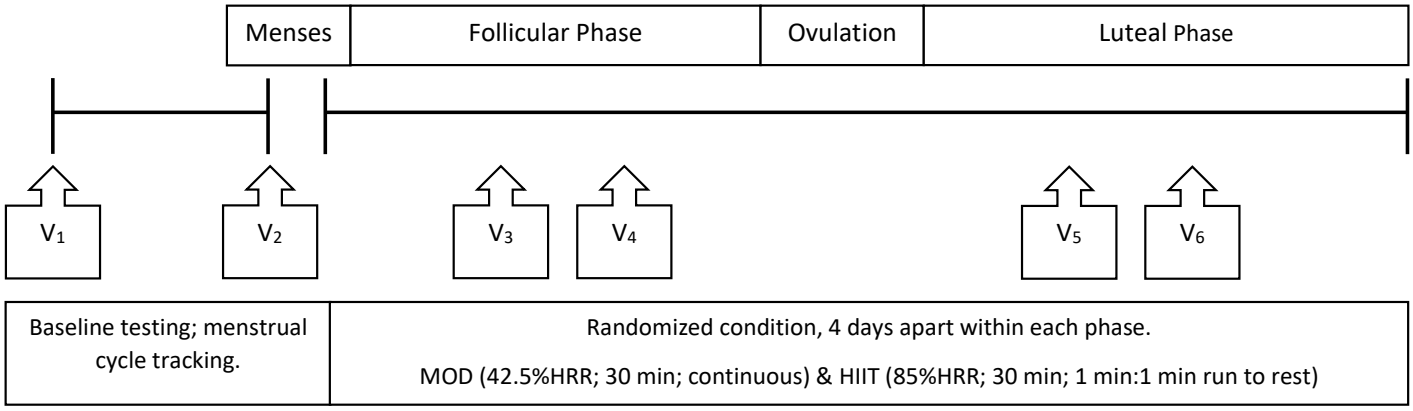

Figure 1.
Schedule of visits.

tinued tracking their menstrual cycle while they completed the experimental phase of the protocol.

Beginning the experimental phase, participants were randomized to one of two exercise conditions using a spreadsheet randomization function (Excel 2016, Microsoft Corp., CA, USA). Conditions were either a high (HITT; 85%HRR; 30 min; 1 min:1 min run to rest) or a moderate (MOD; 42.5%HRR; 30 min; continuous run) intensity protocol before crossing over to the other condition four days later within the same phase (V_3 & V_4, respectively). During the next menstrual cycle phase, participants were randomized to one of the two exercise conditions again before completing the other four days later (V_5 & V_6, respectively).

Upon arrival to the lab on experimental days, participants sat in a quiet room while a researcher confirmed cycle phase data. A sterile conical vial was given to the participant for unstimulated saliva collection which was immediately frozen for future estrogen concentration analysis. Following this, participants underwent AP_{LAX} and HF testing. Testing was performed by the same trained investigator who was blinded to the menstrual phase of the participants. Participants then completed the assigned exercise protocol for the visit. Within five minutes of exercise completion, participants underwent another round of AP_{LAX} and HF testing.

Anthropometric and body composition assessment

Height was measured using a stadiometer (402LB, Health-o-meter, Toledo, OH, USA) and recorded to the nearest 0.5cm. The Prodigy densitometer (GE Healthcare, Madison, WI) was used to assess percent body fat through dual-energy X-ray absorptiometry and was recorded to 0.1%.

Peak aerobic capacity

Aerobic capacity was assessed using the standardized Bruce treadmill protocol.[23] A test was considered successful if three of the following four criteria were met: (1) a plateau (ΔVO_2 < 2 mL/min at VO_{2peak} and the closest neighboring data point) in VO_2, (2) maximal respiratory exchange ratio (RER) > 1.1, and (3) sustained peak heart rate within 10 b/min of the age-predicted maximum (220 – age) for > 1 minute (4) a rating of perceived exertion ≥17. Heart rate was recorded continuously during the protocol and a minimum of four minutes into recovery using a Polar Heart Rate Monitor (Polar Electro Inc., Woodbury, NY, USA). Expired gases were analyzed using a Care Fusion Vmax Encore (Vyaire Medical, Yorba Linda, CA, USA) breath-by-breath metabolic system and was smoothed as 10 second averages.

Menstrual cycle tracking

During the four week period between V_1 and V_2, subjects

were provided thermometers to track their daily basal body temperature and menstrual cycle using a mobile ovulation tracking application (Fertility Friend, Tamtris Web Services Inc.). They would record their daily values in the application and then respond to weekly update requests from researchers regarding cycle stages.

Saliva collection

Recommendations for improving uniformity of acquisition and analysis of saliva were followed.[24] Briefly, participants were given a sterile 15 milliliter conical tube (Corning, Inc.; Corning, NY) and instructed to passively drool into it for five minutes. Once that time had elapsed, participants capped the tube and gave it to the investigator. Saliva tubes were immediately frozen at -20ºc until analysis. Samples were acquired between 7:00-8:00 am for all participants.

Hormone analysis

Analysis of salivary estrogen concentration was completed within 90 days of collection via commercially available enzyme-linked immunosorbent assay (ELISA) kit (Eagle Biosciences, sensitivity: 0.5 pg/ml). Samples were done in triplicate according to the manufacturer's instructions. Intra-assay coefficient of variation was 3.6%.

Anterior cruciate ligament laxity

AP_{LAX} was measured using a KT 2000 arthrometer (MEDmetric Corp., San Diego, CA). Per device instructions, participants laid supine on a test table with feet positioned in the provided U-shaped foot rest to prevent rotation. A platform was placed under the knee to keep the flexion angle of 25° consistent for the duration of the trials and across participants. Participants were instructed to relax while pulling force was applied and the device's gauge displayed the anterior displacement of the tibia on the femoral condyles (mm). Tones emitted from the device marked 90N and 120N and an investigator recorded the displacement measurement at each. The same trained researcher performed three trials on the right (arbitrarily chosen) leg (Figure 2).

Hamstrings flexibility

Flexibility of the right (arbitrarily chosen) hamstrings was measured before and after each exercise intervention using the following two tests. First, for the 90-90 knee extension test (MKE), the lateral malleolus, lateral epicondyle of the femur, and greater trochanter of the right leg were located and marked with a felt tipped pen for goniometric measurement. Each participant was positioned supine with the right hip and knee flexed to 90º, confirmed with a goniometer. One researcher then held the thigh in place while the participant attempted maximal active knee extension and a second researcher measured the amount of extension with a goniometer. The end point of knee extension (degrees) was recorded as the participants' maximum active knee extension (Figure 3).

Additionally, a sit-and-reach test (SRD) was performed while the participant was not wearing shoes. The participant sat on the ground with the soles of her feet against a standard sit-and-reach box with a top-mounted ruler. With hands overlapped, palms down, and middle fingers even, the participant stretched forward sliding their hands along the box ruler as far as possible. The fingertip position on

Figure 2.
Example of pulling on the KT-2000 handle to create anterior tibial displacement, tones are emitted at 90N and 120N. As the device moves in relation to the patellar pad, the dial indicates the displacement in mm.

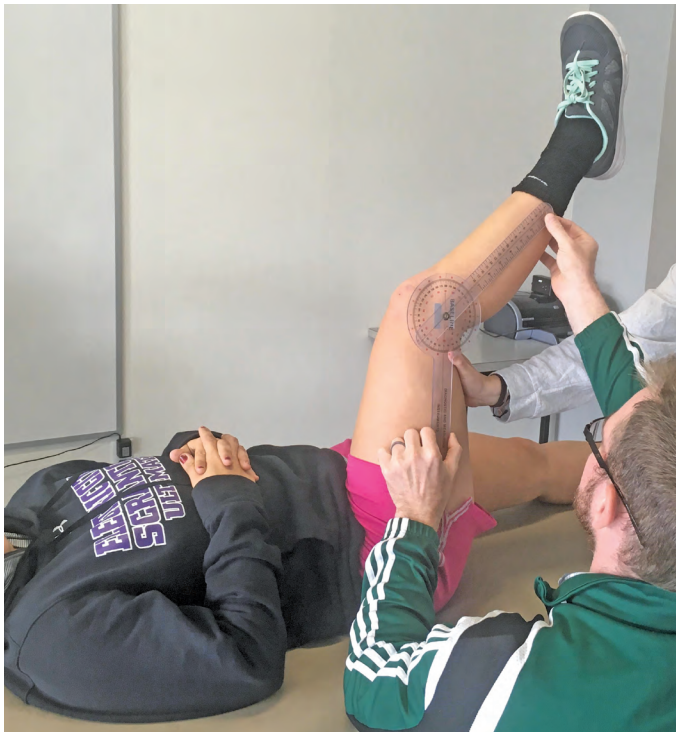

Figure 3.
Demonstrating as one researcher maintains the thigh at a measured 90º while the other measures the participant's maximal active knee extension with a goniometer.

the ruler at maximal stretch was recorded as the sit-and-reach distance (cm).

Statistical analysis

Data were analyzed using paired t-tests and a 2 x 2 x 2 [phase x intensity x exercise (pre vs post)] within-participants MANOVA with repeated measures carried out with a least significant difference correction. If significant interactions were detected, a univariate ANOVA was conducted to determine significant changes in the dependent variables. Further analyses were performed using ANCOVA to isolate the individual effects of exercise, menstrual cycle phase, and baseline when values were held constant. *A priori* significance was set at $\alpha \leq 0.05$, and data are reported as mean ± SEM.

Results

There were no significant differences in any demographic characteristic between V_1 and V_2. Results were then collapsed into an average (Table 1).

There was a significantly higher concentration of estradiol in the LP than there was in the FP [p=0.046] with no significant differences within each phase; therefore, the two testing days within the LP (80.27 ± 8.59 pg/mL) were consistent in estradiol concentration as were the two within FP (68.84 ± 6.97 pg/mL).

Pre-exercise AP_{LAX} was significantly greater during LP than FP at 90N [p=0.019] and 120N [p=0.014]. Regardless of phase, both intensities induced a significant AP_{LAX} increase in 90N [p=0.032] and 120N [p=0.022], but not differently between intensities. When controlling for pre-exercise values and exercise intensity, AP_{LAX} in LP was greater than FP at both 90N [p=0.020] and 120N [p=0.011] following exercise.

There was a significant increase in MKE [p<0.001] and SRD [p<0.001] from the pre-exercise to the post-exercise condition after controlling for the effects of menstrual phase and exercise intensity (Table 2).

Discussion

Non-collision exercise and menstrual cycle phase as causes of increased AP_{LAX} and HF are of interest because they are commonly cited ACL-tear risk factors.[4-6] Two elements of knee stability that we examined were HF and AP_{LAX} under continuous moderate intensity and discontinuous high intensity treadmill running across both LP and FP. The primary findings of this study were that a baseline difference of AP_{LAX} was evident for both 90N and 120N with the LP displaying greater laxity before exercise. Exercise also increased AP_{LAX} at 90N and 120N in both FP and LP with LP exhibiting larger changes com-

Table 1.
Subject descriptive data (n=10).

Variable	Mean±SD.
Age (years)	20.82±2.72
Height (cm)	164.16±5.31
Weight (kg)	60.81±9.89
Body fat (%)	32.46±5.32

Table 2 .

Flexibility and Laxity. [a] LP significantly greater than FP pre exercise (p<0.05); [b] LP significantly greater than FP post exercise controlling for intensity or baseline AP_{LAX} (p<0.05); [c] Pre-post exercise increase (p<0.05) regardless of cycle phase; [d] Pre-post exercise increase (p<0.001) controlling for intensity and cycle phase. All data mean±SEM. MOD, moderate continuous; HIIT, high discontinuous; LP, luteal phase; FP, follicular phase; AP_{LAX}, Anterior-posterior laxity; MKE, maximum active 90-90 knee extension; SRD, sit-and-reach score.

	MOD		HIIT	
	LP	**FP**	**LP**	**FP**
AP_{LAX} 90N (mm, pre/post)	0.77±0.08[a]/1.09±0.13[bc]	0.60±0.03/0.78±0.04[c]	0.72±0.08[a]/1.11±0.09[bc]	0.66±0.07/0.85±0.08[c]
AP_{LAX} 120N (mm, pre/post)	1.06±0.11[a]/1.32±0.17[bc]	0.88±0.04/1.09±0.12[c]	1.03±0.12[a]/1.43±0.11[bc]	0.98±0.07/1.26±0.12[c]
MKE (Degrees, pre/post)	148.60±7.08/153.8±7.36[d]	145.55±6.92/151.55±6.19[d]	144.44±8.78/153±7.37[d]	143.25±5.96/149.55±7.04[d]
SRD (cm, pre/post)	19.61±2.96/21.67±2.77[d]	20.30±3.17/21.76±2.89[d]	20.34±2.97/21.82±2.91[d]	17.97±3.08/20.03±3.23[d]

pared to FP. Both MKE and SRD increased significantly following exercise, but not differently across menstrual cycle phases or exercise intensities.

The increase in HF with exercise may be related to the biomechanics of the hamstring muscles during repetitive linear aerobic exercise. As observed in flexibility training, dynamic stretching, in which the muscle is cyclically taken through its range of motion (ROM), has been found to increase skeletal muscle flexibility to a greater degree than static stretching.[26] During running, the hamstrings are taken through about 60% of their ROM[27,28] and it is possible this movement acts similarly to dynamic stretching, which may explain the similar increases to ROM regardless of exercise intensity. Schache *et al*.[27] were able to find a difference in the magnitude of hamstrings stretch at different intensities in a study comparing short-term, high intensity 110 m sprints at speeds ranging from 7 to 20 mph. At a higher speed, the stride length increase caused the hamstrings muscle to lengthen more. It is possible that if we increased the difference between our intensities, or used relative running speeds as opposed to %HRR, the change in magnitude of the stretch-per-stride would cause a differential effect on the increase in HF.

In a similar way, the increase of AP_{LAX} with exercise may have to do with the loading of the ACL itself. Both running and walking produce anterior/posterior translation of the knee joint[29] and therefore ACL loading. Markolf *et al*.[30] used cadaveric knees to quantify the loads on the ACL through the knee's range of motion and found that anterior tibial loads at full extension and hyperextension produced the highest force on the ACL. Therefore, during our exercise interventions, where the lead leg was near fully extended, the ACL may have undergone "creep," in which laxity of a ligament increases with cyclic loading.[31] Besier *et al*.[32] found that during cutting and side-stepping movements, the ACL experiences even more load than it does during linear running; therefore, these types of exercise may produce a larger change due to loading in different planes. Moreover, the knee may not be stable in all planes of motion in all people.[33] ACL tears are often accompanied by injury to other ligaments such as the medial collateral ligament and anterolateral ligament that are essential to planting a foot and rotating while cutting which modifies the forces the knee must resist.[2,33,34] While the ACL provides knee stability near full extension during cutting and tibial rotation, it appears that other structures like the anterolateral ligament take on a greater stabilizing role as the knee flexes.[35] The inclusion of varied running patterns may explain the differential findings in field studies that evaluate live play and drilling which may challenge knee stability differently than linear running.[16] Future studies may want to restrict movements so that the role of the ACL can be isolated from other ligaments that may be providing stability to the knee joint.

Running-based exercise undertaken as a warm-up and in competition has shown effects on ACL laxity,[11,15-17] but

few studies have clearly identified the durations and intensities undertaken by study participants. Although previous comparisons were not work-controlled, Nawata *et al*.[17] hypothesized that above a certain intensity threshold, AP_{LAX} will not increase differentially. Our results agree that it is possible there is a maximum laxity that each individual ACL will reach with exercise based on the structural characteristics of the ACL at the time. Some participants in our study had MOD conditions where the treadmill speed was below the absolute intensity of the Nawata *et al*.[17] study which suggests that there may be a minimum that is lower than previously appreciated. More work-controlled studies should be conducted in order to explore this possibility for both males and females. In females, our study found that laxity may have had a different maximum depending on the menstrual cycle phase. Other studies that have added baseline ACL laxity tests during ovulation have agreed that ACL laxity has a significant increase at ovulation and likely in the LP after.[18,19] We saw non-significant variation in baseline AP_{LAX} within phases which agrees with some of the better controlled examples.[21,36-38] This suggests researchers should at least note menses and the ovulation temperature spike to estimate phase.

This is the first female only, work-equated treadmill study to test whether exercise intensity affects AP_{LAX} across the phases of the menstrual cycle. We found significant differences in percent AP_{LAX} increase between LP and FP. While the mean percent change in AP_{LAX} with exercise was 25.53% at 90N with variability between subjects and trials, when we split the data into phases and co-varied for intensity and baseline laxity, the adjusted mean percent change at 90N for the LP was 56.2% while FP was 12.2%. The menstrual phase did significantly affect the baseline and exercise induced increase in AP_{LAX}, with higher values before and after exercise in LP. This indicates AP_{LAX} is likely constrained by a certain increase resulting from exercise, but the influence of LP expands that constraint.

Our study had several strengths. Overall, our methods of predicting the phase of the menstrual cycle were confirmed with our quantification of salivary estradiol. Therefore, as we analyzed changes among the two phases, we can confirm that it is truly a LP vs. FP comparison. However, the hormones of the menstrual cycle change even within a phase, so this study does not aim to isolate the effects of the hormones, but rather to analyze the overall effect of a particular phase. The present study employed a cross-over design with a four day break between conditions to avoid connective tissue and muscular changes that might have arisen if we had attempted to test different exercise intensities more frequently.[25] Finally, the recruitment of participants that had never taken any form of oral contraceptive or hormonal therapy was a strength. These therapies can inhibit estrogen surges which may alter the ACL tissue's responsiveness to changes in the hormone[39] which may reduce ACL tear risk for users by nearly 20%.[18]

The use of a treadmill had a positive outcome on our ability to tightly control running speeds to ensure %HRR goals were being met. However, dissimilarities between treadmill and normal running were a limitation. Participants had to straddle the treadmill belt to begin and end exercise which might have created jarring acceleration and an absence of deceleration at the beginning and end of the exercise bouts. We were limited by the lack of an uphill running condition. Uphill running appears to be of interest as the greater degree of involvement from the hamstrings[7] may have implications for AP_{LAX}. Knee ligament laxity has been shown to increase in the first 15 minutes of moderate exercise[33] and an increased engagement and fatigue of the hamstrings may decrease the passive protection the hamstrings provide the ACL.[6] Our study only investigated posterior to anterior directional laxity of the ACL, which occurs in the sagittal plane. However, often during ACL rupture other ligaments such as the medial collateral ligament and anterolateral ligament are compromised.[2,33,34] Future studies should incorporate measures to quantify laxity changes in the frontal plane and knee rotation to better understand risks to injury.

Conclusion

This is the first study to examine equated aerobic exercise workloads in eumenorrheic women across hormone-confirmed menstrual cycle phases. We describe a significant change in baseline AP_{LAX} between phases and both AP_{LAX} and HF measures that increase with exercise, regardless of condition. Our findings suggest that engaging in exercise during the LP results in the greatest perturbation to knee stability. The degree to which this change in knee stability increases the chances of knee injury remains to be explored.

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Rare subtype of multiple myeloma presenting as sacroiliac joint pain in an avid golfer: a case report

Melissa Belchos, BSc(Hons), DC[1]
Varsha Kumar, BSc(Hons), DC, DACBR, FCCR(C)[1]
Carol Ann Weis, MSc, DC[2,3]

Objective: *Kappa (κ) light chain multiple myeloma can be disguised as low back pain (LBP), and as such may present to a primary contact provider such as a chiropractor. The rarity and non-specific nature of the clinical presentation of this condition typically lead to a delayed diagnosis.*

Case presentation: *A 53-year old male avid golfer presented to a chiropractor with a chief complaint of LBP. He was diagnosed with sacroiliac joint dysfunction. His pain was initially improving with chiropractic management. The character of his pain changed, and the chiropractor referred for further imaging. He was subsequently diagnosed with κ light chain multiple myeloma.*

Summary: *This case presentation highlights that spinal malignancy is a possible cause of LBP. It reminds the clinician to investigate signs and symptoms that*

Objectif : *Un myélome multiple à chaîne légère (kappa) (κ) peut se cacher derrière des lombalgies qu'un fournisseur de soins primaires, comme un chiropraticien, peut ne pas reconnaître. En raison de la rareté et de la nature imprécise des symptômes cliniques, ce type de myélome est souvent diagnostiqué tardivement.*

Exposé du cas : *Un fervent golfeur de 53 ans s'est présenté dans une clinique de chiropratique en se plaignant de lombalgies. Le chiropraticien a diagnostiqué une trouble de l'articulation sacro-iliaque. Au début, le traitement de chiropraxie a soulagé la douleur. Mais comme sa nature évoluait, le chiropraticien a recommandé un examen par imagerie, qui a révélé un myélome multiple à chaîne légère k.*

Résumé : *Les tumeurs de la colonne vertébrale peuvent être une cause de lombalgies. Le présent exposé de cas rappelle au clinicien de rechercher les causes des signes et des symptômes pouvant faire soupçonner*

[1] Division of Graduate Studies, Canadian Memorial Chiropractic College
[2] Private practice
[3] Department of Graduate Education and Research

Corresponding author: Melissa Belchos, Sports Sciences Resident, Division of Graduate Studies, Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, ON M2H 3J1
Tel: 416-482-2340
E-mail: mbelchos@cmcc.ca

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The involved patient provided consent for case publication.

could lead to a suspicion of malignancy, to monitor patient progression, and consider further evaluations if the expected response to treatment is not achieved.

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KEY WORDS: chiropractic, differential diagnosis, golf, low back pain, multiple myeloma, sacroiliac joint

un cancer, de surveiller l'état du patient et d'envisager des examens plus approfondis si le traitement ne donne pas les résultats attendus.

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MOTS CLÉS : chiropratique, diagnostic différentiel, golf, lombalgie, myélome multiple, articulation sacro-iliaque

Introduction

Low back pain (LBP) is one of the most common musculoskeletal problems reported by recreational and professional golfers.[1] In one study of 402 recreational golfers, approximately half of the respondents reported having received chiropractic care and nearly all of those participants had positive experiences with their treatments.[2] Low back pain in golfers is most commonly secondary to non-complicated mechanical pain.[1] However, this does not preclude the possibility of these athletes presenting with a more sinister pathology mimicking back pain, such as a malignancy. In the general population, low back pain complaints account for approximately 50% of the reasons patients seek chiropractic care.[3] Five percent of these have serious underlying diseases or neurological impairments.[4] Less than one percent will have spinal malignancy[4], of which, multiple myeloma (MM), a malignant monoclomal plasma cell disease, is the most common bone marrow cancer in the adult population[5]. MM accounts for approximately one percent of all cancer types[6], and in industrialized countries, the incidence is estimated to be four per 100,000 people[7]. This condition is characterized by plasma cells that produce excessive amounts of immunoglobulins; these immunoglobulins (Ig) are composed of heavy chains (A, G, M, D and E) and light chains (kappa (κ) or lambda (λ))[7] (Figure 1). Of all the isotopes associated with MM disease, approximately 52% are IgG, 21% IgA, 20% Light chain, 3% Biclonal, 2% IgD, 2% Non-secretory, and 0.5% IgM.[8] In light chain multiple myeloma (LCMM), the light chain immunoglobulins are secreted in excess[8] and predispose the patient to complications such as bone disease, renal failure, and amyloidosis[9]. Although LCMM is rare[9], it may present in a patient seen by a primary contact provider, such as a chiropractor, in the form of back pain. We present a case of a 53-year old avid golfer who was diagnosed with κ light chain multiple myeloma after presenting to a chiropractor with a chief complaint of sacroiliac (SI) joint pain.

Case presentation

Initial visit – case history

A 53-year old lawyer and avid golfer presented to a chiropractor with a chief complaint of low back pain which began two weeks prior while working with a personal trainer. He was pushing a sled loaded with weights and subsequently felt pain in his left SI joint and buttock the next day. Two days prior to consulting the chiropractor, he saw his general practitioner (GP) and was diagnosed with

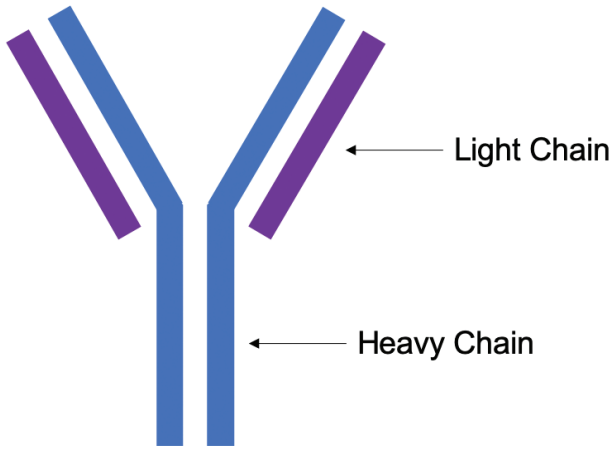

Figure 1.
Heavy and light chain components of immunoglobulins.

a low back strain. At the time of his initial chiropractic assessment, he reported his pain progressively worsened throughout the day, and was aggravated when sitting for extended periods of time. For the first few days of this new onset of LBP, he also experienced pain with forward flexion at the lumbar spine. He reported some relief with ibuprofen. The character of his pain was described as dull and achy, with constant pressure. He initially rated the pain as a 7-8/10. He did not report any radicular symptoms such as numbness, tingling, or sharp pain, and no changes to his bowel or bladder habits were noted. He also reported no abnormalities or changes to his gait; however, he felt more stiffness in his lower back when ambulating.

The patient reported an episode of low back pain a few years ago resulting from falling on his tailbone. Over the course of the last year he had also been seeing a physiotherapist for occasional LBP and plantar fasciitis. His past health history included Crohn's disease, which was managed with corticosteroids from the age of 13-20 and a subsequent small bowel resection at the age of 20. He was being monitored annually with no recent evidence of Crohn's disease activity. His only known family history was maternal diabetes and various other benign conditions associated with aging. He was not on medications at the time of the initial evaluation by the chiropractor. He was physically active, attended sessions once a week with his personal trainer and golfed two to three times per week on average.

Physical examination

On physical examination, gait evaluation was normal. A lower limb neurological exam evaluating deep tendon reflexes, sensation, and motor strength were all normal bilaterally. Plantar response was down-going bilaterally. Range of motion in the lumbar spine was unremarkable, except for pain in the low back with left lateral flexion. Kemp's tests caused pain bilaterally in the low back. Functional testing, such as Trendelenburg's stance, quarter-squat and body weighted squat, were unremarkable. Straight leg raise (SLR) testing was painful in the area of chief complaint on the left at 60 degrees. Open book test, psoas palpation, Patrick's FABER and seated SLR were all unremarkable bilaterally. SI joint palpation revealed pain on the left and restricted movement bilaterally. Joint challenge (Maigne's) was restricted bilaterally in the lower lumbar spine. Scour test revealed lack of mobility in the hips bilaterally (greater on the left) without pain or clicking. Muscle palpation revealed tenderness and hypertonicity of the bilateral lumbar spine erectors, gluteus muscles, tensor fascia latae, and piriformis. Pain was also elicited with the palpation of the dorsosacral ligaments and iliotibial bands bilaterally.

Diagnosis and treatment

This patient was diagnosed with SI joint dysfunction. Differential diagnoses included discogenic low back pain, dorsosacral ligament sprain and, given the patient's gastrointestinal history, enteropathic arthritis. The plan of management (POM) included spinal manipulative therapy (SMT) of the SI joint, soft tissue therapy (STT), rehabilitative exercises and stretches, as well as heat. On the initial visit, heat and soft tissue therapy were applied to the affected musculature, and the patient was given rehabilitative exercises to perform at home. This included single and double knee to chest stretches and pelvic tilts.

Follow-up visits

This patient was managed by the chiropractor in several follow-up visits detailed in Appendix 1.

Two and a half weeks (and five treatments) after his initial evaluation by the chiropractor, he reported a 60% improvement in his pain, but reported that at the end of the day his pain in the midline of his buttock area felt very tight, and "like it [was] being separated". However, he stated he could comfortably golf while taking ibuprofen and methocarbamol. The patient was reassessed at four and a half weeks, at which time he reported the pain in his SI joints was almost resolved, though his hamstring was now bothersome. Following the reassessment, the patient's diagnosis for SI joint dysfunction was unchanged and an additional diagnosis of hamstring tendinopathy was included. The patient was treated with STT and rehabilitative stretches for his hamstring.

Seven weeks after the initial presentation to the chiropractor, he reported that his pain was worse and aggravated with sitting, standing and lying down. The patient described his pain was as pulsating in nature, but did not present with radicular symptoms, night sweats, changes in gait, or changes to bowel or bladder function. He was still able to play golf if he took ibuprofen and metho-

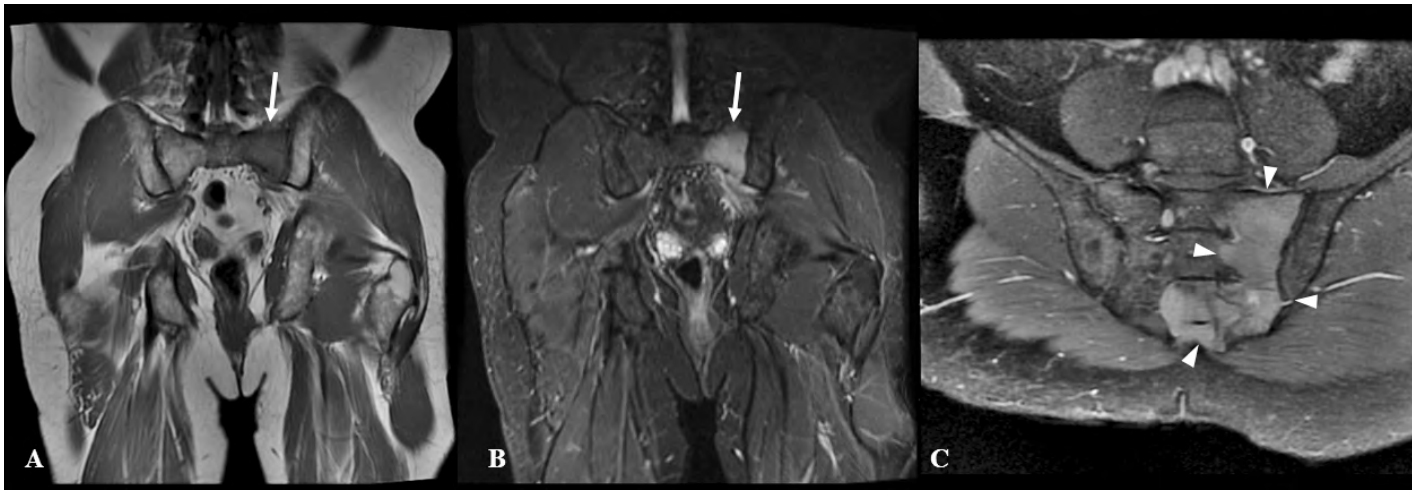

Figure 2.
T1-weighted (A) and STIR (B) coronal MRI sequence of the pelvis demonstrating hypointense T1 and hyperintense STIR signal signifying marked bone marrow edema in the left sacral ala (arrows). T1-weighted fat sat C+ coronal MRI sequence (C) of the sacrum demonstrating avid enhancement of the left-sided sacral lesion (arrowheads).

carbamol prior to playing. Electroacupuncture was incorporated into the POM at this time along with STT and SMT to the SI joints. Nine weeks after his initial presentation to the chiropractor, he reported terrible pain at the end of the day. He constantly felt pressure and discomfort in his upper gluteal and sacral areas. He still did not report radicular symptoms, night sweats, malaise, lethargy or fatigue. The chiropractor continued with the patient's POM (acupuncture, STT and SMT to the SI joints). However, at this time the chiropractor referred the patient to his GP suggesting a requisition for imaging. The GP requisitioned a magnetic resonance image (MRI) of the pelvis.

Imaging and further evaluations

The MRI revealed a large diffuse hypointense T1-weighted and hyperintense short tau inversion recovery (STIR) lesion of the left sacrum, extending into the coccyx and crossing midline at S3 and the remaining caudad segments. Cortical violation of the anterior sacrum and coccyx was present with spread of the lesion into the presacral soft tissue, extending approximately 50mm in the cephalad to caudad dimension. The lesion enhanced with intravenous gadolinium and was concerning for a malignant neoplastic process (Figure 2 and 3). The right

Figure 3.
STIR sagittal MRI sequence of the sacrum revealing high signal intensity of the S3 and caudal segments (arrows) with anterior soft tissue extension (arrowheads).

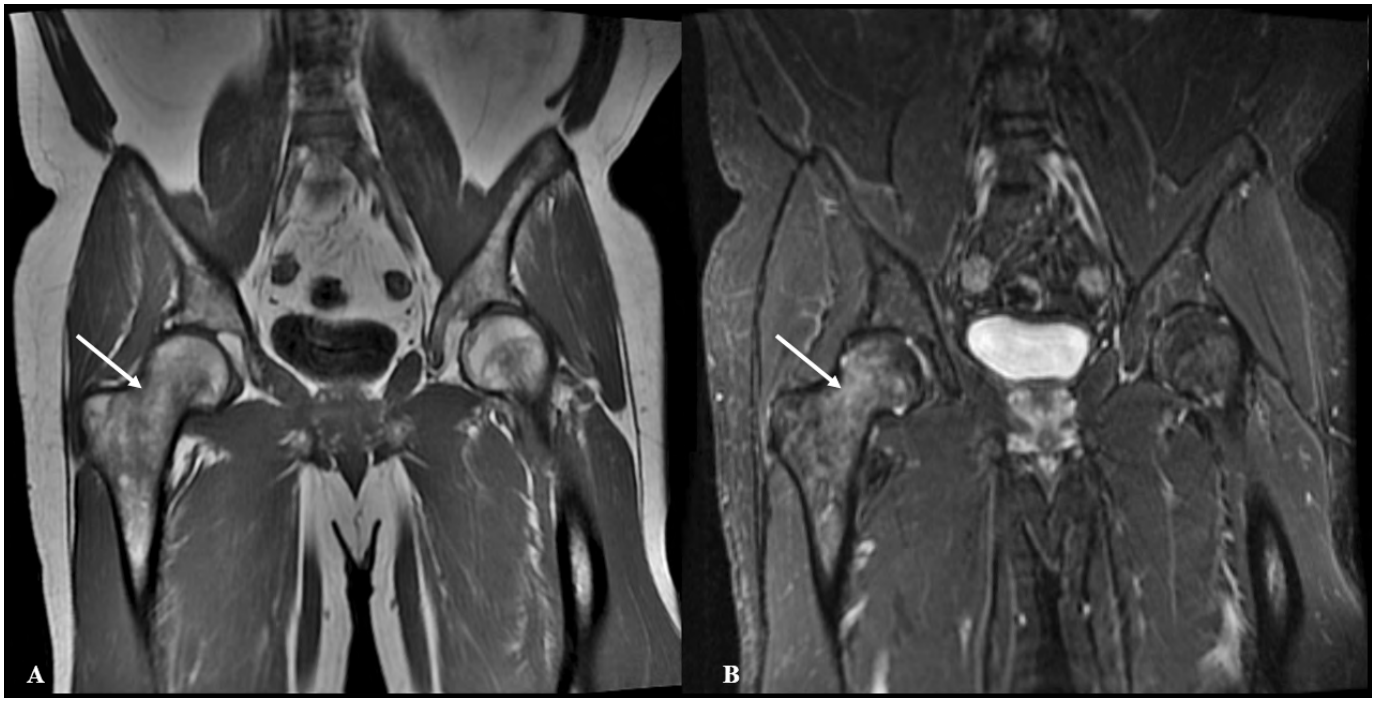

Figure 4.
T1-weighted (A) and STIR (B) coronal MRI sequence of the pelvis demonstrating hypointense T1 and hyperintense STIR signal signifying marked bone marrow edema in the right femoral head and neck (arrows).

femoral head and neck also demonstrated diffuse hypointense T1-weighted and hyperintense STIR signal (Figure 4). These signals are consistent with either bone marrow edema from an infiltrative process or, less likely, arthritic changes or marrow reconversion. Unfortunately, any sequences which included intravenous gadolinium did not provide visualization of the right femur to allow proper assessment of enhancement patterns. However, given the unilateral femoral presentation, the spread of the marrow changes beyond the physeal scar and the presence of the existing sacral lesion, the signal characteristics of the right femur was also suspicious to be neoplastic in nature. There was no evidence of pathological fractures within the pelvis and femurs.

The patient was subsequently sent for a bone scan, computed tomography (CT) scan of the head, and CT-guided skeletal bone biopsy. The bone scan further revealed multifocal skeletal abnormalities in the left orbit and right subarticular femoral and humeral heads. The nature of these lesions was unknown with these images. The patient's CT head scan revealed a soft tissue mass centered within the left frontal bone extending intracranially into the left orbit.

The patient's cytopathology report from left sacral skeletal fine needle aspiration revealed scant amounts of plasmacytoid cells, and cell block containing rare tissue fragments with plasma cells.

Laboratory reports revealed that his initial beta 2 microglobulin was 1.5mg/L, albumin 47g/L, and lactate dehydrogenase 240 U/L. His immunology profile showed a κ light chain of 32.4, λ light chain of 10.1, κ/λ ratio of 3.21 with a diffuse gamma region pattern on electrophoresis. His free light chain measurements revealed a free κ of 130.4mg/L (reference 3.3-19.4), free λ of 12 mg/L (reference 5.7-26.3) and κ/λ ratio of 10.87 (reference 0.26-1.65).

Diagnosis

This patient was diagnosed with κ light chain multiple myeloma, that was negative for bone marrow involve-

MM is defined by having both of the following:[9]
Clonal bone marrow plasma cells ≥ 10% or biopsy-proven bony or extramedullary plasmacytoma
Any one or more of the following myeloma defining events: ○ Evidence of end-organ damage that can be attributed to the underlying plasma cell proliferative disorder ▪ Hypercalcemia: serum calcium >0.25mmol/L (>1mg/dL) higher than the upper limit of normal or >2.75mmol/L (>11mg/dL) ▪ Renal insufficiency: creatinine clearance <40 mL/min or serum creatinine >177 μmol/ L (>2 mg/dL) ▪ Anemia: hemoglobin value of >2 g/dL below the lower limit of normal or a hemoglobin value < 10 g/dL ▪ Bone lesions: one or more osteolytic lesions on skeletalradiography,computerizedtomography(CT),or positron emission tomography–CT (PET-CT) ○ Clonal bone marrow plasma cell percentage ≥ 60% ○ Involved: uninvolved serum free light chain (FLC) ratio ≥ 100 (involved FLC level must be ≥ 100mg/L) ○ >1 focal lesion on magnetic resonance imaging (MRI) studies (at least 55 mm in size)

Figure 5.
The International Myeloma Working Group Diagnostic Criteria

ment (Figure 5). He presented with a painful bone lesion in his sacrum, and asymptomatic lesions in the femurs and left orbit. His MM was classified as International Staging System (ISS) Stage 1, and revised International Staging System (RISS) Stage 1.[10]

Management

The chiropractor followed up with treatment for the patient's ongoing musculoskeletal complaints, including myofascial pain, with treatment that included heat, STT, spinal mobilizations, and rehabilitative stretches of gluteus muscles and hamstrings. SMT was excluded from the POM moving forward due to the spinal malignancy.[11]

The medical POM for this patient's MM included three rounds of CYBOR-D (cyclophosphamide, bortezomib, and dexamethasone) induction therapy, and a subsequent autologous stem cell transplant. On last follow-up with this patient, he had nearly completed his Phase 1 induction therapy and was due to start stem cell transplantation. His induction therapy was extended for three more rounds (total of six rounds) due to the COVID-19 pandemic. So far, the patient reported a decrease of his pain following induction therapy. He currently rates his pain at a 1/10 though he reported that he feels less vital and quick. The patient's written consent was obtained to use his information for the purposes of this report.

Discussion

MM can be challenging to diagnose, especially in the current case study, where the initial report of symptoms only included LBP. Early detection of MM is associated with a 14% better overall survival rate.[12] Out of 24 common cancers, patients with MM experience the greatest diagnostic delays in primary care[12] with one study reporting an average of 137 days elapsing between the initial signs and symptoms and MM diagnosis[13]. The strongest predictor of diagnostic delay was the presence of at least one comorbidity in addition to anemia and back pain prior to diagnosis.[13] This delay may be directly related to primary care providers focusing on acute problems and therefore overlooking myeloma symptoms.[13] The challenging nature of diagnosing MM is further complicated by the lack of certainty and specificity around indications for MM in a clinical examination.[14] In the present case, the patient presented with Crohn's disease and back pain, however, his physical examination was very indicative of SI joint dysfunction. Chiropractors may play a part in the detection of MM, as they can and should routinely assess for signs and symptoms of malignancy in their clinical evaluation to determine when further investigations are warranted.

Clinical evaluation

When determining the level of concern for a serious spinal pathology, it is imperative that the clinician take into consideration all available information, including red flags, patient history and the physical examination.[15] Information gathering does not end at the initial assessment. The patient should be continuously reassessed for changes in signs and symptoms. Chiropractors are trained to screen for red flags. However, there are limitations to the utility of screening red flags based on current available evidence in the literature.[16] Many guidelines cite history of malignancies/cancer, and unexplained/unintentional weight loss as red flags for malignancies.[16] Still, when evaluating red flags, only "history of cancer" was determined to be of acceptable validity.[16] Another aspect of in-

vestigative questioning in developing a diagnosis is the determination of the character, frequency and duration of pain. Some signs of nonmechanical pain origins are unrelenting pain at rest, constant or progressive signs and symptoms.[17] In this patient's case, the initial report of pain did not seem sinister in nature. However, as time went on, there was a change in symptomatology and the patient's description of the pain, leading the chiropractor to investigate the patient's condition further.

To investigate other associated symptoms that may or may not be related to the presentation, a systems review is typically performed. Although this patient did not report any additional symptoms, MM patients often present with nonspecific symptoms, such as: malaise, weakness, recurrent infections, weight loss, nausea, or vomiting and more specific symptoms such as blood hyperviscosity (e.g. dyspnea, transient ischemic attack, deep vein thrombosis, retinal hemorrhage), peripheral neuropathy, or bone disease (e.g. pain from fracture, spinal cord compression).[14] Unfortunately, the nonspecific nature of some of these signs and symptoms may also account for the delayed diagnosis.[13] In one study, of those who had a delayed diagnosis, the time between the initial visit with a sign or symptom of MM and the cancer diagnosis exceeded 30 days.[13] The patient in the current report experienced less pain but more discomfort in general as time went on and continued his physical activities, including personal training sessions and golfing.

The last challenge of diagnosing MM in a timely manner is the lack of specific physical examination findings for this condition. Most patients with MM will have normal physical examination findings upon initial presentation.[14] This occurred in the current case. With each assessment and follow-up visit, his physical examination findings were normal or deemed to be related to a musculoskeletal condition. Nonetheless, if the patient is not recovering in the expected manner and/or time frame, laboratory evaluations and diagnostic imaging should be considered to rule out a more sinister pathology, such as MM.[15]

Further investigations

If a patient is not responding to treatment as expected or there is a clinical suspicion of malignancy, laboratory evaluations and diagnostic imaging may be warranted for further investigation.[15,17] The patient in this case underwent an MRI, CT and bone scintigraphy for lesion follow-ups, the last modality performed as a means to distinguish between metastatic and MM disease.[18]

Diagnostic Imaging Practice Guidelines for chiropractors recommend that imaging may provide gainful information in adult patients with musculoskeletal complaints that demonstrate failure to respond to expected treatment outcomes or worsening of symptoms after four to six weeks.[17] In addition, co-management or specialist referral is recommended if the radiographs are unremarkable and if any one of the following is present:[17]

- Presence of a potentially serious pathology as suggested by the patient history, examination, and/or radiograph
- Failed conservative therapy (four to six weeks)
- Patient's neurological status is deteriorating (progressive deficit, disabling leg pain)
- Clinical signs suggest instability
- For preoperative planning

The National Comprehensive Cancer Network (NCCN) Clinical Practice Guidelines suggest that Positron Emission Tomography (PET)/CT and MRI are more sensitive than plain film radiographs and are still indicated when symptomatic areas in patients with suspected MM show no radiographic abnormalities.[19] MRI is the gold standard imaging modality for the detection of bone marrow involvement in MM as they detect plasma cell infiltrations, and the pathomorphological features of plasma cell clusters.[4] PET/CT scans are useful to determine the response to therapy and provide prognostic data.[20] Bone scintigraphy, an imaging modality that relies heavily on the rate of new bone formation, is sensitive for metastatic bone disease, however, offers limited value in the detection of MM.[21,22] The osteoblastic response in MM is significantly low and thus often results in a normal or decreased uptake on bone scans.[18]

Initial laboratory testing for MM typically includes a complete blood count with differential and serum albumin, calcium, creatinine, electrolytes and urea nitrogen. Confirmatory lab tests include 24-hour urine protein, Beta-2-microglobulin, lactate dehydrogenase, serum free light chain assay, serum protein electrophoresis, serum immunofixation electrophoresis, serum quantitative immunoglobulins, urine immunofixation electrophoresis,

and urine protein electrophoresis.[14] Laboratory testing can aid in the confirmation of the diagnosis of MM using diagnostic criteria, and can track the progression of the disease over time.

Management

The treatment regimen by the patient's oncologist included four rounds of CYBOR-D (cyclophosphamide, bortezomib, and dexamethasone) induction therapy, followed by an autologous stem cell transplant. The preferred primary therapy regimens for patients eligible for transplants include bortezomib-based 3-drug regimens.[23] Cyclophosphamide is an alkylating agent with common adverse events including nausea, gastrointestinal toxicity, immune suppression, mucositis, and alopecia. Bortezomib is a proteasome inhibitor, with common adverse events including peripheral neuropathy, autonomic neuropathy, thrombocytopenia, and reactivation of varicella-zoster virus. Dexamethasone is a corticosteroid, with common adverse events including gastrointestinal toxicity, hyperglycemia, immune suppression, insomnia, altered mood, and fluid retention.[14] When following up with a patient with MM, it is important to be aware of the possible adverse effects from medication in addition to their signs and symptoms of MM, due to the potential for mimicry of musculoskeletal complaints (e.g. peripheral neuropathies). In addition to induction therapy, certain patients with MM such as the patient in this case, will undergo an out-patient autologous stem cell transplant. This is the process by which stem cells will be obtained from the patient themselves.[4]

Prognosis

Median survival outcomes in the literature for patients treated with modern therapy for MM have been reported to be approximately six years.[24] The prognosis can vary depending on many factors, including stage of the disease, cytogenic abnormalities, and response to therapy.[24] Patients eligible for treatment with an autologous stem cell transplant have a four-year survival rate of greater than 80%, and a median overall survival of approximately eight years.[24] Unfortunately, all forms of LCMM appear to have a poorer prognosis when treated with chemotherapy compared to IgG and IgA subtypes.[9]

Over time, this patient's ability to golf could be affected as it has been reported that patients with MM report a lack of endurance and energy, as well as pain.[6] Both the physical challenges associated with this condition such as fatigue, pain and lack of endurance, as well as the impact of MM treatment can lead to patients describing themselves as having a "different body".[6] In order to address their distress, patients use strategies including both physical and emotional coping mechanisms.[6] In MM patients, there are reported patient perceived benefits of physical activity, including: psychological health, recovery from treatment, social factors, and enjoyment.[6] Exercise has been shown to be beneficial for patients undergoing treatment for MM by increasing muscle mass and physical performance as well as decreasing fatigue and depression.[25] A regular aerobic exercise program has also been shown to improve quality of life in patients with hematologic malignancies.[14] The patient in the current report continued to exercise after his diagnosis. Exercise therapy is something most chiropractors are well-versed in and can help initiate or continue to advise the patient on.

Patients with MM are also at an increased risk of pathological fractures. The primary lytic lesions can affect the axial skeleton, with the main pathological feature (uncoupling of bone resorption from bone formation) leading to a state of predominant bone resorption.[26] This is an important consideration when treating a patient with MM, as extra caution must be taken to avoid fractures. This patient was treated with bisphosphonates, which are used in the management of MM to inhibit the progression of osteoclastic activity and subsequent skeletal morbidity and mortality.[27] Nevertheless, the World Health Organization (WHO) guidelines on basic training and safety in chiropractic reports malignancy of the spine as an absolute contraindication to SMT in area of the pathology and the immediate vicinity.[11] In addition, the WHO also deems spinal mobilizations inappropriate for this population as it may place patients at undue risk for injury.[11] Soft tissue manipulation may be safely used in patients with an absolute contraindication for SMT, such as those with spinal malignancy, if indicated for a musculoskeletal complaint.[11]

Limitations

The major limitation of this report is by nature the type of report being presented. With respect to the hierarchy of evidence, case studies are considered a lower level of evi-

dence and information such as rates, incidence and generalizability cannot be generated or inferred.[28] However, case reports help detect novelties[28] and in the current case report, we highlight a rare case presentation which may act as a reminder to practitioners to consider these serious pathologies.

Summary

We present a case of a 53-year old avid golfer presenting with a chief complaint of low back pain, initially suspected to be SI joint dysfunction. Following the appropriate referral and advanced diagnostic imaging, the condition was determined to be ISS Stage 1 and RISS Stage 1 κ light chain multiple myeloma. With less than one percent of back pain presentations resulting in a spinal malignancy, and the non-specific nature of the clinical presentation, a delayed diagnosis is typical. This was a challenging and rare case. The patient's most recent annual health assessment, carried out three months prior to his initial presentation to the chiropractor, revealed no abnormal findings. The only symptom he presented to the chiropractor was low back pain and he did initially respond to conservative management. Once his symptomatology changed, the chiropractor correctly identified the need for further evaluation and imaging. In doing so, the chiropractor referred this patient back to the MD allowing this patient to receive the diagnosis and treatment he required. This case presentation is a reminder to investigate signs and symptoms that could lead to a suspicion of malignancy, as well as to monitor patient progression and consider further evaluations if the expected response to treatment is not achieved.

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Appendix 1.
Follow-up visits

Treatment 2: The patient returned five days after his initial visit and reported that there was some relief of his pain after the last treatment. However, three days prior to this appointment he had golfed ten holes and reported an exacerbation of his low back pain afterwards. Treatment was rendered as outlined above.

Treatment 3: At the third appointment, two weeks after his initial presentation, he reported his pain was reduced by 20%. At this time, SMT was incorporated into the treatment which previously included heat, STT, and rehabilitative exercises.

Treatment 4: The patient reported that his pain was improved between 40-50%. He could comfortably golf while taking ibuprofen and methocarbamol. He reported that he believed that the SMT from the previous appointment made a difference.

Treatment 5: Two and a half weeks after his initial evaluation by the chiropractor, he reports a 60% improvement in his pain, but describes that at the end of the day his pain in the midline of his buttock area feels very tight, and "like it is being separated".

Treatment 6: Three and a half weeks after initial evaluation he reported he could not sit without discomfort, yet his pain had significantly improved. The POM remained the same, except SMT was not performed at this appointment.

Re-evaluation & Treatment 7*:* The chiropractor reassessed the patient four and a half weeks after his initial presentation. The patient reported being close to resolving the pain in his joints but his hamstring was bothersome. He reported pain in his low back when he would go to bed after sitting for a prolonged period of time. He was re-assessed by the chiropractor who found lumbar spine flexion and right sided Kemp's test caused pain in the patient's left hamstring. All other lumbar spine ranges of motion were unremarkable. Pain was reproduced on palpation of the insertion of the left hamstrings. Left sided resisted knee flexion and resisted prone leg extension were tender in the left hamstring. SI joint palpation was unremarkable bilaterally however, SI joint compression was restricted on the left. He was diagnosed with a SI joint dysfunction and hamstring tendinopathy, with a differential diagnosis of discogenic LBP or dorsosacral ligament sprain. No SMT was applied this day. The patient was treated with STT and rehabilitative stretches.

Treatment 8: Five weeks after his initial presentation, the patient reported that while his low back pain had improved, but the pain had not completely resolved. SMT was reintroduced during this appointment.

Treatment 9: Seven weeks after the initial presentation to the chiropractor, he reported that his pain was worse and aggravated with sitting, standing and lying down. The patient described that his pain was now pulsating in nature, but did not present with radicular symptoms, night sweats, changes in gait, or changes to bowel or bladder function. He was still able to play golf if he took ibuprofen and methocarbamol prior to playing. Electroacupuncture was incorporated into the POM at this time along with STT and SMT.

Treatment 10: Nine weeks after his initial presentation to the chiropractor, he reported terrible pain at the end of the day. He constantly felt pressure and discomfort in his upper gluteal and sacral areas. He still did not report radicular symptoms, night sweats, feeling of unwellness, lethargy or fatigue. The chiropractor continued with the patient's POM (acupuncture, STT and SMT). However, at this time the chiropractor referred the patient to a general practitioner (GP) suggesting a requisition for imaging.

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The use of a multi-modal approach in the rehabilitation of a pre-operative grade 3 ACL tear in a world-level Poomsae athlete: a case report

Michael Edgar, BKin, DC[1]
Mohsen Kazemi, RN, DC, FRCCSS(C), FCCPOR(C), MSc, PhD[1]

Objective: *This case is designed to aid practitioners in understanding the potential role of multi-modal care with vibration rehabilitative exercise for a complete ACL tear in a high-level Poomsae athlete.*

Case presentation: *A 16-year-old male world-class Poomsae athlete presented with a right ACL rupture and LCL sprain. An extensive clinical examination and imaging confirmed a right grade 3 ACL tear. Due to the complete tear and impending participation in World Championships, a pre-operative rehabilitation strategy was implemented with treatment modalities aimed to accelerate return-to-play.*

Summary: *An appropriate clinical history and physical examination of the knee is required when instability is present. Imaging is indicated when testing criteria are positive. Clinicians should be aware that*

Objectif : *Le présent exposé de cas vise à aider les praticiens à comprendre le rôle que pourrait jouer le traitement multimodal associé à des exercices de rééducation par vibrations chez un athlète de haut calibre pratiquant le poomsae ayant subi une déchirure complète du LCA.*

Exposé du cas : *Un athlète de 16 ans de calibre international, pratiquant le poomsae, avait subi une déchirure du LCA droit et une entorse du ligament latéral externe (LLE). Un examen clinique approfondi et un examen par imagerie ont confirmé une déchirure du LCA droit de grade 3. Comme il s'agissait d'une déchirure complète et que la participation de l'athlète aux championnats internationaux était imminente, on a opté pour une rééducation préopératoire et des modalités thérapeutiques pour accélérer le retour au jeu de l'athlète.*

Résumé : *Un examen du tableau clinique et un examen physique du genou s'avèrent nécessaires en cas de genou instable. Un examen par imagerie est indiqué lorsque les critères d'instabilité sont satisfaits.*

[1] Canadian Memorial Chiropractic College

Corresponding author:
Michael Edgar, Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, ON M2J 3J1
Tel: 416-482-2340
E-mail: medgar@cmcc.ca

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multiple therapies can each serve a role in conservative care to better suit patient demands, especially at high levels of sport. In the article, the author proposes a tailored protocol using vibration rehabilitative exercise, bracing, vibration therapy, neuromuscular electrical stimulation, and laser to improve healing and sport-specific outcomes.

Les cliniciens devraient savoir qu'on pourrait avoir recours à une approche multimodale lorsqu'on envisage un traitement conservateur pour mieux répondre aux besoins du patient, en particulier ceux qui pratiquent des sports de haut niveau. L'auteur de l'article propose un protocole personnalisé comprenant des exercices de rééducation par vibrations, le port d'une attelle, un traitement par vibrations, la neurostimulation électrique transcutanée et des traitements par laser pour favoriser la guérison et l'obtention de résultats axés sur ce sport en particulier.

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KEY WORDS: chiropractic, ACL, anterior cruciate ligament, taekwondo, poomsae, vibration, multimodal

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MOTS CLÉS : chiropratique, LCA, ligament croisé antérieur, taekwondo, poomsae, vibration, multimodal

Introduction

The traditional form of Taekwondo, which is a form of martial arts involving sparring, has been performed for many years. It has seen a recent popularization since the 2000 Summer Olympic Games, where it officially became a full medal sport. Overall, there has been an increase in the level of participation in Taekwondo with over 80 million athletes worldwide.[1,2] Due to Taekwondo's popularity, Poomsae has gained a recognized position in the sporting community with its first world-level championship in 2006.[3,4] Poomsae is the only non-contact form of Taekwondo and has a high degree of technical involvement due to the basis of its scoring.[3,4] In addition, it involves skill, technique, flexibility, fluidity and physical exertion. Recognized Poomsae involves 13 defined patterns of movement which are emphasized repeatedly during sport-specific practice.[3,4] On average, Poomsae athletes train up to six days a week with each session lasting for up to four hours and forty minutes.[3,4]

Due to the workload these athletes experience and the demand of the sport, injuries can be detrimental especially at higher levels of performance. In regard to the injury rates for Poomsae and sparring, it was found that lower limb and back were the most common areas of injury in females and males respectively.[4-6] Poomsae is the only non-contact and no opponent form of Taekwondo but despite its non-contact nature, the lower limb and back were still the most common areas of injury.[4]

A retrospective case series by Kazemi *et al*.[7] investigated the effects of injury on Taekwondo sparring performance by following 75 Taekwondo athletes over a ten-year period. They found that an injury that occurred during competition led to the athlete having an 88% less likely chance to win a medal.[7] A paper by Kasbparast *et al*.[8] highlighted the rates of anterior cruciate ligament (ACL) injury amongst Taekwondo sparring athletes. They found that the main mechanism of action for a torn ACL was that the athlete had a planted foot with the knee in an almost extended position (sometimes hyper-extended). In addition, they found the rates of ACL injury to be highest during practice compared to competition.[8] Although this is the case, the literature regarding the prevalence of ACL rupture in Poomsae-specific athletes is sparse. Due to the degree of pivoting that each of the fundamental movements requires, the stability of the knee plays an integral role to technique and scoring and therefore placing at a world-level event.[3]

An ACL injury can typically be separated into three grades, ranging from grade one involving mild damage to grade three which involves a complete rupture of the ligament.[9-11] Among young male athletes, the rate of ACL injuries has increased within the last 20 years while the rate of surgical repairs for ACL ruptures is estimated at 47 per

100,000 boys each year.[10] This injury can lead to several complications, including acute intra-articular swelling and instability, quadriceps strength deficits, and decreased range of motion.[10] As strength, stability and full range of motion are essential for the sport of Poomsae, the effects of these variables on performance can be significant.[9-11] The first line of treatment for an ACL rupture is conservative management and rehabilitation, followed by surgical intervention with postoperative rehabilitation if the patient develops functional instability.[12-14] Conservative management involves interventions such as, chiropractic manipulation, mobilization, exercise, soft tissue therapy, nonsteroidal anti-inflammatory drugs, and steroid injections.[12-14]

A case of an ACL rupture in a sixteen-year-old male, world-class Poomsae athlete is presented to illustrate clinical presentation, diagnosis, imaging assessment, and conservative chiropractic management. The patient ended up placing in the top 10 at the World Poomsae Championships, only two weeks after his last treatment and with no reported knee pain or instability during his competition.

Case report

A sixteen-year-old male, world-class Taekwondo Poomsae athlete, presented with right knee pain which started two days prior to his initial visit after executing a roundhouse kick, during which the right leg twisted and gave way after landing. Training was stopped after this and the pain was initially focused on the lateral side of the knee. After his practice session, he had discomfort bending and straightening the knee with noticeable aggravation upon walking with feelings of instability upon weight bearing. He focused on icing the area until his initial appointment with his sports chiropractor two days later. He did not have any prior injuries to his knee, and his past medical history and systems review were unremarkable and non-contributory to his chief complaint.

On examination, lower extremity deep tendon reflexes were 2+ bilaterally and light touch sensation examination was unremarkable. In addition, heel and toe walking were normal with pain at the end range of flexion during the squat test. His right knee (ROM) flexion and extension were reduced by 10% with pain in the lateral knee. The bounce home test, McMurray, Anderson and Lachman tests were positive on the right. Pivot shift, valgus loading, posterior drawer and posterior sag were negative. There was no noticeable clicking or locking upon examination and only mild swelling over the right lateral knee with sharp pain upon palpation. His right popliteus, iliotibial band, lateral collateral ligament (LCL), quadriceps and hamstrings were hypertonic and tender upon palpation.

Figure 1.
Front kick.

A clinical diagnosis of right LCL grade 1 sprain, right lateral meniscus lesion and right ACL grade 2 sprain were made with associated myofascial pain. Initial treatment consisted of 15 minutes of acupuncture (AC) of the following points: GB33, GB34, ST36, SP9 and BL39 with TENS at 2Hz; Local vibration therapy using VMTX® device (made by Thumper®, 25-45Hz, 4-5 mm vertical displacement) to the right popliteus, iliotibial band, quadriceps, hamstrings and posterior and lateral fascial chains. A brace was prescribed to improve walking ability and rehabilitation was started with straight leg raises and slow, non-explosive front snap kicks (Figure 1).

The patient was initially referred for an x-ray in his first week of treatment which found no acute fracture or dislocation of the knee, although moderate knee effusion was observed. He was subsequently referred to his family physician to obtain a referral for an MRI of the knee. The physician referred the patient to an orthopedic surgeon who agreed with the diagnosis, requested an MRI of the knee, and referred the patient back to his sports chiropractor for further conservative treatment. The right knee

Figure 2.
A T2-weighted oblique sagittal MR image of the right knee demonstrating a grade 3 complete ACL tear (white arrow).

Figure 3.
A T1-weighted oblique sagittal MR image of the right knee demonstrating a grade 3 complete ACL tear (white arrow).

Table 1.
Exercise progression.

Exercise and duration	Week implemented
SLR	Week 1
Front Kick	Week 1
Squat 90	Week 2
Boeing 747	Week 2
Heel Raises	Week 2
Side Kick Hold	Week 2
Lunge (front stance)	Week 2
One Legged Supine Hamstring Curl	Week 2
Hamstring Curl on Ball	Week 5
Front Snap Kick	Week 11
3 sets of 30 seconds	Week 1-12
3 sets of 40 seconds	Week 4-12

MRI indicated a complete ACL tear (Figures 2 and 3) and mid-grade partial tear of the LCL. It was decided that the focus should be on conservative, non-operative therapy as the Poomsae World Championships were taking place fourteen weeks later.

At the end of the second week, there was no visible swelling over the anterior knee and only minimal swelling on the lateral aspect. Right knee flexion and extension ranges of motion were full with a positive Lachman's test and negative Varus load test. Hyperalgesia and hypertonicity of the popliteus, iliotibial band, LCL, quadriceps and hamstrings were diminished. At this time, the treatment was changed to primarily rehabilitation. The rehabilitation program consisted of weight-bearing squats at 90 degrees (Figure 4), heel raises, 747 and sidekick holds (Figures 5 and 6), lunges (Figure 7), back stance and supine isometric one-legged hamstring curls (Figure 8) for three sets of thirty seconds on the whole body vibration (WBV) machine (VMAX® Elite 7) at 20 Hz with 3.2 mm vertical displacement. (See Table 1 for a more thorough chart of the exercise progression). This was done in conjunction with electro-muscular stimulation over the quad-

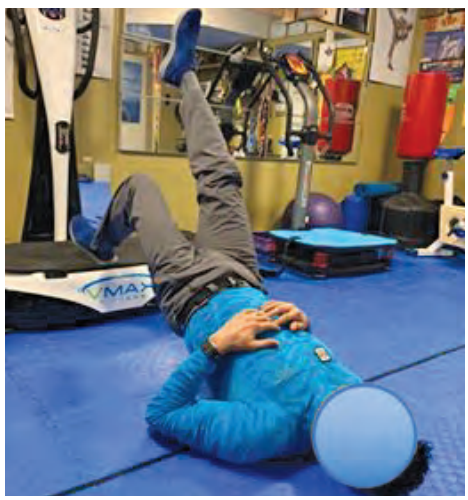
Left, Figure 4.
90 Degree Body Weight Squat

Above, Figure 5.
Boeing 747

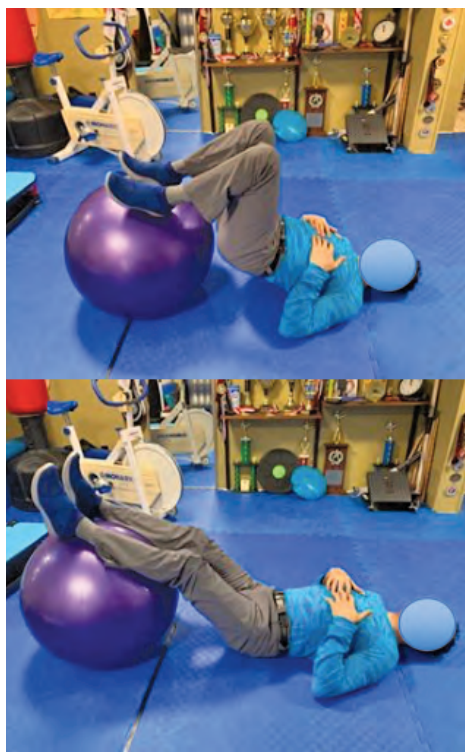
Right, Figure 6.
Side kick hold.

Left, Figure 7.
Lunge.

Below, Figure 8.
One legged supine hamstring curl.



Right, Figure 9.
Hamstring curl on ball.



riceps and hamstrings with 15 seconds on and 10 seconds off as he practiced on the WBV. Local vibration therapy using VMTX® (VMTX Thumper® massager) was done to the right popliteus, iliotibial band, LCL, quadriceps and hamstrings, posterior and lateral lower limb myofascial chains. The same exercises were prescribed for at-home use with an avoidance of rotation and sudden stopping on the right side.

At the end of the fourth week, modifications had been made to his Poomsae routine and the patient was fitted with a Donjoy® ACL brace based on the recommendation of his orthopedic surgeon. There was no longer pain or instability during his Taekwondo practice. The exercises on WBV increased to 40 second holds at week four. Rehabilitation exercises continued with incorporation of supine hamstring curls on a physiotherapy ball (figure 9) for 3 sets of 10 repetitions on week five. An advanced front snap kick was incorporated at week eleven to incorporate an explosive movement. Laser was applied to the anterior and lateral knee at 10J with cryotherapy for 10 minutes after the rehabilitation exercises.

The same treatment was continued one or two times per week for twelve weeks. At the end of this treatment course, the athlete felt no pain in the right knee and had full ability in his Taekwondo practice with no sensation of 'giving way.' Two weeks following his final appointment, the athlete competed in the Poomsae World Championships without using any brace and placed in the top 10. He did not report any give way or pain during the competition or training.

Discussion

In this case, the athlete experienced an immediate reduction in his knee ROM after a roundhouse kick. The athlete suffered from a full ACL and partial LCL tears. The main symptoms experienced by the athlete were localized knee pain, decreased range of motion, feelings of instability, and weakness, although significant swelling was not present. Parkarri *et al*.[15] found the knee was the most common location for injury in younger individuals. In addition, they found that participation in organized sports significantly increases the risk of a cruciate ligament injury of the knee.[15] An anterior cruciate ligament injury is typically sustained at foot strike with the knee close to full extension with a sudden deceleration prior to a change of direction or landing motion due to the rotational forces.[9,10] Previous literature has described several risk factors for the predisposition of ACL injury, including increased general joint laxity, increased patellar tendon length, increased knee abduction angles, and decreased knee flexion angles. Specific anatomical risk factors include the intercondylar notch width (NW) and tibial slope.[8-10]

In the current case, x-rays were initially ordered to rule out knee pathology. Several guidelines and rules are available to recognize red flags for radiographic imaging of this bodily region. The Ottawa Knee Rules recognize several red flags: age greater than 55 years old, inability to bear weight immediately or the inability to take four steps, isolated tenderness of the patella or fibular head, and inability to flex to 90 degrees.[11] However, the Pittsburgh Knee Rules differ by highlighting four red flags: fall or blunt trauma, less than 12 years old or greater than 50 years old, and an inability to take four steps.[14] In the case presented, an inability to flex to 90 degrees and issues weight bearing were noted; therefore, routine knee x-rays were ordered to rule out any osseous lesions. The x-ray appeared unremarkable, but the athlete was then referred to an orthopedic surgeon who confirmed a complete right ACL tear by clinical examination and MRI. One reason for the referral was to obtain an MRI since chiropractors in Ontario, Canada are unable to directly order MRI.[16] The orthopedic surgeon referred the athlete back to the sports chiropractor for conservative management. Major *et al*.[17] found MR imaging to be the gold standard for knee imaging in adolescents due to its avoidance of the exposure to ionizing radiation, and ability to illustrate the menisci and cruciate ligaments. The anterior cruciate ligament was the major focus of this case and highlights the utility of this imaging modality.

Conservative management is considered a first-line treatment option for anterior cruciate ligament injuries.[12,13] The case presented a conservative approach focusing on a multimodal treatment plan. Interventions for multimodal care include strengthening, proprioceptive exercises, sport-specific exercises, bracing, activity modifications, neuromuscular stimulation, vibration therapy and laser, which have been shown to be beneficial for the treatment of ACL injuries.[12,13, 18-27]

Many authors have reported success using progressive rehabilitation programs from partial weight-bearing to full weight-bearing with a predominant focus on quadriceps and hamstring strengthening.[12,13, 18] The goal for this

form of strengthening is to improve active stabilization of the major muscles around the knee to prevent translation of the tibia relative to the femur during loading of the lower limb.[18] In the case provided, strengthening and proprioceptive exercises were successfully implemented. This was done in conjunction with a Donjoy® brace which is designed to reduce knee instability following an anterior cruciate ligament injury by providing passive integrity.[26] The brace was warranted and utilized for the athlete's sport-specific Poomsae movements which require a high degree of pivoting and knee stabilization.[3] Knee bracing for pre-operative anterior cruciate ligament injury has shown to improve subjective perceptions of knee instability, although it had no effect on activation of the quadriceps or hamstrings, in conjunction with functional movements.[28,29]

Transcutaneous electrical nerve stimulation (TENS) is recognized to have several benefits physiologically and therapeutically by eliciting a current and contraction within the musculature it is applied to without voluntary control.[19,20] At the present time, no studies or literature reviews have been conducted into NMES efficacy prior to ACL reconstruction. However, Lee *et al*.[19] reported good outcomes for the use of TENS on the quadriceps for the reductions of pain and improved strength after ACL reconstruction. As well, Kim *et al*.[20] performed a systematic review and found neuromuscular electrical stimulation (NMES) combined with exercise may be more effective in improving quadriceps strength than exercise alone after ACL reconstruction. It is the authors' belief that this gave credence into the effectiveness of NMES stimulation combined with exercise during the case presented.

Vibration is believed to work through a tonic vibratory reflex (TVR).[30,31] This is purported to be through rapid, successive micro-muscular stretches which trigger intrafusal muscle spindle activity.[30,31] This is believed to lead to decreased muscle inhibition and improve the ability to recruit a higher threshold of motor units.[30,31] Vibration can be applied locally or through whole-body vibration (WBV). The neurophysiological mechanism may differ between both, as WBV generally activates multiple different mechanoreceptors which can synchronize motor unit firing and central motor commands to globally improve neuromuscular activation patterns.[30] In addition, WBV can potentially work as a neuromuscular training method where the subject stands on a platform that generates vertical sinusoidal vibrations.[21] In contrast, local muscle vibration (LMV) uses a smaller device typically applied to one bodily region. The neurophysiological mechanism for LMV is theorized to work through its activation of receptors proximal to the site of administration.[30,31]

Vibratory stimulation combined with resistance training has gained popularity in an attempt to gain greater neuromuscular activation. It has been shown to improve nerve-muscle function, realign muscle fibers, and induce relaxation of stretched muscle tissue.[21-23] It can be speculated from the research that in a rehabilitative exercise setting, vibration therapy can allow for improved strength, power and proprioception to better attenuate the sports-related deficits from an acute injury.[21-23, 30,31] Pain reduction has also been noted purportedly through the activation of skin mechanoreceptors leading to the stimulation of inhibitory interneurons. This is theorized to downregulate pain signals by alpha and C-fibers by the gate control mechanism.[23] Macintyre and Kazemi[21] found that the best analgesic and pain-reducing effect occurred when vibration was localized to the region of pain on the affected muscle or tendon. On a systemic level, vibration therapy has been found to elicit increased angiogenesis through promoting pro-healing growth factors and chemokines.[32,33] Improved blood flow has also been found in the lower extremity for healthy individuals and is theorized to potentiate increased healing rates and ability.[34] Typically, frequency and amplitude of vibration stimulus can range from five to 300Hz and 0.12 to 12 mm respectively.[35] However, higher frequencies required exposure of 30 minutes to achieve the same results of one to two minutes exposure of 20-50Hz.[35] In addition, higher frequencies above 60Hz (60-500Hz) have been associated with cumulative trauma disorders.[36,37] As such for the patient in this case, vibration with 20-50Hz range with amplitude of 3.2-5mm was used as this is more time efficient and safer.[35-37]

For the athlete described in the case, the use of whole body and local vibration was used for several purposes. Arthrogenic muscle inhibition (AMI) of the quadriceps muscles is a common occurrence after ACL injury.[38,39] The phenomenon involves quadriceps activation failure by neural inhibition. There are several theories for this occurrence relating to resting motor thresholds, aberrant articular sensory receptor discharge, spinal reflexes and executive function related to abnormal cortical func-

tion.[38] Vibration was implemented to improve motor unit recruitment for the athlete due to AMI of the knee. This had the dual benefit of improving strength capacity and reducing the degree of atrophy in the lower limb musculature.[30] Vibration also was used to stimulate afferent input within the intrafusal structures within the knee to improve proprioceptive capacity, an aspect which appears to be reduced when intra-articular derangement is present within the knee.[30,38,39] As the athlete's sport required high degrees of coordination and balance, proprioceptive input and overall kinesthetic awareness was a top priority.[4] Whole-body platform vibration combined with exercise was incorporated successfully into the plan of management of the athlete presented in the current case study.

The goal of improved healing time was also prioritized due to the time demands until his next tournament. As the athlete presented at acute onset of the injury, mitigating the initial inflammatory response at the knee was focused on. Upon ACL injury, local cytokines and inflammatory mediators like IL-6, IL-8, VEGF, and TGFβI are released within the synovium and ligaments to accelerate both catabolic and anabolic activities.[40] Local vibration therapy to the affected tissues has shown to improve perfusion to both increase uptake of nutrients within the tissues and recycling of damaged structures.[32,33] For this athlete, vibration was applied to the knee region with the goal of accelerated healing in mind. It was also applied directly over the knee itself to elicit an analgesic response.[21] The use of local vibration was appropriately implemented within the treatment plan of this patient.

Basic research into low-level laser therapy (LLLT) has shown to reduce knee inflammation in rat models and LLLT with 50 mW reduced cellular inflammation and decreased the expression of IL-1β and IL-6.[24,25] The utility of LLLT can be two-fold due to its therapeutic window for anti-inflammatory actions overlapping with its ability to improve tissue repair. A new hypothesis into its efficacy revolves around it having a systemic effect through nitric oxide synthesis (NOS) and local TNF levels.[24-26] Although the clinical effectiveness of laser therapy for acute ACL rupture in the athletic populations remains controversial, inflammation was treated. LLLT and ice was utilized on the right knee and localized tissues to decrease inflammation after the rehabilitation exercises and possibly improve healing times.

Limitations

Limitations of this case report include the initial symptomatology and complexity of the plan of management, meaning that the effects of each treatment or their combined effect cannot be determined when natural history is also accounted for. Firstly, the minimal swelling noted on initial examination may have led to a more rapid progression to rehabilitation. This paramount factor could have been the determining factor in the success of this athlete. In addition, the case also presented an elite-level athlete which current research populations do not generalize to. Furthermore, research into NMES primarily looked at post-ACL reconstruction whereas the current case highlights an athlete prior to ACL reconstruction. More so, LLLT research is sparse for ACL injuries and is limited to basic research at the current time. Higher quality research is recommended to investigate prognostic factors revolving around swelling and rehabilitation rates, in conjunction with the effectiveness of the management protocol described in the case.

Summary

Lower limb injuries are a common occurrence in Taekwondo athletes. This case demonstrates the use of multimodal care in conjunction with active therapy using WBV for an acute, destabilizing lower limb injury in a world-level athlete who requires high levels of coordination and control. Exercise and progressive strengthening are considered the first line of care for rehabilitation as they have the ability to improve function and stability. Despite the lack of research into combined treatments, there may be benefits to simultaneous care with exercise, vibration therapy, and neuromuscular activation when peak performance requirements and time constraints are present. The current literature combined with the clinical outcome described in the case suggests that multimodal care, including progressive exercise, vibration therapy, NMES and LLLT can potentially offer a therapeutic benefit greater than simply one modality alone. Further research is required to investigate the efficacy and associations of these modalities when used in conjunction in a larger study population.

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