NEW ZEALAND
Journal of Sports Medicine
Vol 47 • No 2 • 2020
Official Journal of Sports Medicine New Zealand Inc.

CONTENTS

PUBLISHER
SPORTS MEDICINE NEW ZEALAND
PO Box 6398
Dunedin
NEW ZEALAND
Email: admin@sportsmedicine.co.nz
Web: www.sportsmedicine.co.nz

ISSN 0110-6384 (Print)
ISSN 1175-6063 (On-Line)

GENERAL

The New Zealand Journal of Sports Medicine (NZJSM) is the official journal of Sports Medicine New Zealand, publishing material relevant to sports medicine and related disciplines. The NZJSM welcomes submissions of original manuscripts from both members and non-members of Sports Medicine New Zealand in the following areas:

- sports medicine
- sports physiotherapy
- clinically relevant sports science
- rehabilitation
- coaching issues as they relate to sports medicine
- exercise prescription and training
- sports chiropractic
- sports podiatry
- sports psychology

Manuscripts must not have been published elsewhere except in abstract form.

Manuscripts will be reviewed by the editorial board and/or experts in the field of interest. Submissions are in the following categories:

a Original Research
b Case Reports
c Review Articles
d Editorials
e Letters to the Editor
f Sports Medicine Tips
g Policy Statements

SUBMISSION DETAILS

Manuscripts are to be submitted to:
The Editor, NZJSM
Sports Medicine New Zealand
PO Box 6398
Dunedin, New Zealand

The manuscript may be sent via email: admin@sportsmedicine.co.nz.

The manuscript text should be submitted in Microsoft Word format. Please do not use styles for headings, etc, ensure your manuscript is in the style 'Normal'. (For submission of graphics, please see Tables, Illustrations, Figures, Photos below).

Manuscripts should be double-spaced with wide margins. Each page should be numbered. The manuscript should include the following: title page; structured abstract (followed by five key words); introduction; methods; results; discussions; conclusion; acknowledgements; references; tables; figures.

Case reports are to have no more than two figures and are not to include an abstract. There should be no more than 12 references for a case report. The structure of a case report is as follows: introduction; case report; discussion.

Structured abstracts are to be no longer than 300 words and should use the following subheadings:

- Aim
- Study design
- Setting
- Participants/subjects
- Interventions
- Outcome measures
- Results
- Conclusions

Abstracts for review articles should use the following headings:

- Aim
- Data sources
- Study selection
- Data extraction
- Data symphysis
- Conclusions

The title page should include the title of the article and a running title not exceeding 45 letters and spaces, authors' names (first name, middle initials, last name), degrees, affiliations with institutes, contact details for the corresponding author (to include name, address, telephone and email).

The standard for spelling is to be in accordance with the Oxford Dictionary.

Tables, Illustrations, Figures, Photos

Tables, illustrations, figures, photos, etc, should be included on a separate sheet rather than in the body of the text. Please identify all illustrations with the manuscript title, name of author, figure number, and, if necessary, identification of the top of the image.
All markings should be removed from x-rays before photographing.

Please do not produce graphics in Microsoft Word. Graphics should be supplied in TIF or JPEG format, at a resolution of no less than 300 dpi.

Style

Drug names: generic only are to be used.

Abbreviations: the American Medical Association Manual of Style (9th edition 1998) (published by the American Medical Association, 535 North Dearborn St, Chicago, IL 60610, USA) is to be used for abbreviation style. The List of Journals Indexed in Index Medicus (Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA, DHEW Publication No. (NIH) 83-267;ISSN0093-3821) is to be used for abbreviations for journal titles.

References

References are to be numbered in alphabetical order. Names of journals should be abbreviated according to the format approved by Index Medicus. All references listed must be sited in the text. Journal titles that are single words only should be spelt out in full. All authors must be listed. Pagination should be inclusive. Examples of the appropriate formatting of references are given below:

Journal Article:
Speedy D B, Kelly M, O'Brien M. The effect of pre-exercise feeding on endurance exercise performance. NZ J Sports Med 1998; 26:34-37.

Book:
McRae R. Practical fracture treatment. Edinburgh; Churchill Livingstone, 1989.

Chapter in Book:
Figoni S F. Spinal cord injury. In, Wikgren S (ed.): ACSM's exercise management for persons with chronic diseases and disabilities. Champaign: Human Kinetics, 1997; 175:179.

Author Bios

Manuscripts must be accompanied by short (50-60 word) bios for all authors.

COPYRIGHT

CONTRIBUTORS - VOLUME 47, ISSUE 2

Chris Milne

Chris is a sports physician in private practice at Anglesea Sports Medicine in Hamilton. He has been team doctor for the NZ Olympic and Commonwealth Games teams from 1990 to the present and was team doctor for the Chiefs Super Rugby team from 1997 to 2003. A past President of the Australasian College of Sports Physicians he has also served as National Chairman and is a Fellow and Life Member of Sports Medicine New Zealand.

Chloe McKenzie

Chloe is a research assistant with AUT and a strength and conditioning coach, working with netball athletes from youth to elite levels. Her research interests include injury prevention and performance in netball and female athletes.

Scott Brown

Scott is an Assistant Professor of Exercise Science and rugby coach at Aquinas College in Grand Rapids, MI, USA. His courses and research focus on athletic performance and injury prevention through strength and conditioning, biomechanics, and exercise physiology. He remains connected to the Auckland University of Technology (AUT) Sport Performance Research Institute New Zealand (SPRINZ) as a member of the Rugby Codes Research Group.

Chris Whatman

Chris is a Physiotherapist and Associate Professor, Sport and Exercise Science at Auckland University of Technology.

Matt Brughelli

Matt is a Senior Lecturer, Sport and Exercise Science at Auckland University of Technology.

Alexander Stapleton

Alex is a general practitioner and urgent care specialist based in Auckland working towards dual fellowship. He has also worked with the New Zealand Medical Council as a Vocational Representative involved in reviewing training programmes and Health boards. He has a keen interest in Paediatric acute care in the community and forming best practice guidelines.

Shauna Sim

Shauna is a registrar training in Sports Medicine at Khoo Teck Puat Hospital, Singapore. She currently works with the Singapore Women's Water Polo Team, having previously represented Singapore in water polo. Her current research interests include sports performance and injury prevention in water polo, concussion prevention and management, and female athlete health and performance.

Ong Joo Haw

Joo Haw is a consultant sports physician at Khoo Teck Puat Hospital, Singapore. He has sub-specialty interests in strength sports and ultrasound guided interventions. He is also program director (musculoskeletal) for the Alexandra Academy for Clinical and Emergency Ultrasonography.

Robert Ng

Robert is an optometrist with an interest in sports vision. He currently splits his time in private practice at Frith and Laird Optometrists, at the University of Auckland as a Teaching Fellow and at the Ophthalmology Department at Counties Manukau District Health Board. He completed his Master of Health Sciences (Optometry) and Bachelor of Optometry, both with Honours from The University of Auckland.

Sol Bae

Sol is an Emergency registrar practicing at Concord Hospital in Sydney. He has previously worked at Sydney Eye Hospital. He has a keen interest in ophthalmology and sports medicine. This interest in sports medicine came from being a former New Zealand representative in Taekwondo.

Carmen Chan

Carmen Chan is a emergency medicine senior house officer currently working in the Wellington Region. She studied medicine at the University of Auckland, and is currently undertaking postgraduate study in sport & exercise medicine through the University of Otago.

In this issue ...

CHRIS WHATMAN

This first edition for 2021 starts as always with another great instalment of 'Best of British' from Dr Chris Milne where he highlights topics of interest from the British Journal of Sports Medicine.

Speaking to Chris briefly at the recent Sports Medicine NZ conference in Tauranga I once again thanked him for his contribution which has been a welcome one over 15 years, the first column having been published in volume 33, issue 1. Keep them coming Chris!

We then step into the netball world where Chloe McKenzie and colleagues look at the impact of the now common neuromuscular warm-up on strength. This is an important consideration in terms of underlying mechanisms for injury prevention.

Next, we have an excellent review on the use of cannabidiol, a topic of growing interest in professional sports and one the authors suggest needs urgent investigation to determine safety and efficacy.

Two informative case studies follow which I'm sure are always welcome reading for the clinicians, the first focused on wrist pain and the second on shoulder pain.

Robert Ng then introduces us to the specialty area of sports vision, providing a great overview for those (such as myself) not familiar with this area and presenting some useful examples of its application. I'm sure this will provide food for thought for those working with athletes who haven't been exposed to sports vision and the potential benefits it may offer.

We finish with an informative review from Carmen Chan looking at iron supplementation in iron deficient non-anaemic athletes.

As always, I am thankful to all the authors for their contributions and to all the reviewers for kindly providing their expertise during the review process.

Chris Whatman
Editor, NZJSM

CHRIS MILNE

HIGHLIGHTS FROM THE BRITISH JOURNAL OF SPORTS MEDICINE

2019

September to December

Mass participation events attract large numbers of participants and with the increasing number of older participants, serious medical events can occasionally occur. The rate of sudden death during mass endurance events varies between 0.4 and 3.3 per 100,000 entrants. However, other serious medical events such as exertional heat stroke or hyponatremia can be up to 100x higher than that of sudden death. Martin Schwellnus and colleagues[14] provide a useful international consensus statement on definitions and methods of data recording and reporting. International sports federations are responsible for running world championships, but they also have a role in promoting the health of their athletes. Margo Mountjoy and colleagues[10] recommend greater focus by international federations on health issues such as prevention of chronic disease and post elite career management.

High intensity interval training (HIIT) has become increasingly popular as a method of gaining fitness and providing health benefits. Emmanuel Stamatakis and colleagues[16] stress the economic use of time and recommend vigorous intensity activity such as climbing a few flights of stairs three to four times per day where practicable to obtain the benefits. This is an attractive idea, but with high intensity activity also comes the sweating response and so this may limit its applicability in many workplaces.

What is the rate of knee osteoarthritis ten years after ACL injury? Marthe Lie and colleagues[7] performed a systematic review of 41 studies. They found the prevalence of symptomatic OA was 35% and the reported incidence of radiographic knee OA varied between 0 and 100% regardless of follow up time.

Femoroacetabular impingement is an increasingly recognised condition. Joanne Kemp and colleagues[6] report on non-surgical management including strengthening hip abductors and improving lower trunk strength. One additional non operative intervention I have found useful is provision of orthotics to reduce excess subtalar joint pronation and thereby reduce internal rotation of the hip during the midstance phase of gait. This may delay the need for surgical management. Acute lateral ankle sprains are one of the most common lower limb injuries. Eamonn Delahunt and colleagues[1] provide a useful infographic addressing the important issues. Chronic ankle instability develops due to the interaction of mechanical and sensory motor impairments. Therefore, working on everter strength and proprioception is an essential part of rehabilitation.

Does MRI add value in general practice with patients with traumatic knee complaints? Nynke Swart and colleagues[17] from the Netherlands report on a one year randomised control trial including 356 patients. They found that MRI in general practice for patients aged 18 to 45 years with traumatic knee complaints was not worse but also not better than usual care regarding knee related daily function during one year follow up. The study is relevant to the New Zealand situation as ACC is currently piloting wider availability of MRI scans in for appropriately trained GP's in New Zealand.

Relative energy deficiency is sport is a complex issue. Nicola Keay and Alan Rankin[5] provide a useful series of infographics describing the effect of cumulative energy deficit and the secondary endocrine dysfunction that develops. As this is a complex area, these infographics are useful for patient education. The Choosing Wisely campaign has gained significant momentum in recent years. Daniel Friedman and Karim Khan[3] discussed this issue and recommend selective use of imaging and education of patients with regard to potentially unnecessary medical tests, treatments and procedures. We need to be mindful of this in our daily practice. Isometric exercise has been popularised for acute pain relief and Ebonie Rio presented on this topic at the SMNZ conference a few years ago. Karin Silbernagel Gravare and colleagues[4] revisited the data and found that their results could not be replicated using the same methods and outcomes in 20 individuals suffering from patella tendinopathy. They recommend that clinicians should be comfortable and competent prescribing progressive exercise that fits the individual athlete and progress following current evidence-based principles of load and exercise progression.

What is the risk of sustaining an ACL injury whilst playing football (soccer)? Alicia Montalvo and colleagues[8] performed a systematic review with meta-analysis of 28 studies. They found that the incidence rate of ACL injury amongst female football players over four years was 2.2x higher than that amongst males. This was independent of participation level. Achilles tendinopathy is a common overuse injury. Arco van der Vlist and colleagues[19] conducted a systematic review and found risk factors included prior lower limb tendinopathy or fracture, use of Quinolone antibiotics, training during cold weather, more lateral foot rollover at the forefoot flat phase and decreased isokinetic plantar flexor strength. Hamstring injuries are common in sport, and the Nordic hamstring exercise protocol has proven effective at preventing these. Nicol van Dyk and colleagues[20] performed a systematic review of 15 studies and found that Nordic hamstring exercises reduced hamstring injuries by up to 51% across multiple sports and different athletes. This supports their widespread use in the athletic population.

Issue 22 was produced in collaboration with the Australasian College of Sport and Exercise Physicians. The editorial authored by Hamish Osborne[11] was entitled 'Just Listen!'. He explained that in the first minute of a consultation, if you just stay quiet, your patients will tell where they hurt, how it started and be quite happy that you actually listened to them. We all need to bear this in mind in our daily practise. Further to this, Mary O'Keeffe and colleagues[12] explain that clinical education can change the trajectory of individuals with back pain. They recommend giving

time and space for the patient to tell their story and reassuring them that low back pain has a positive natural history. It is worth emphasising that spines are inherently strong structures and people should try and lift in a natural way. The end game for them is putting the person with the pain in the driver's seat. I would emphasise the value of empowering patients.

Leisure time physical activity has long been associated with reduced mortality. Min Zhao and colleagues[22] reported on a national cohort study of 88,000 US adults. They found that beneficial association between leisure time physical activity and mortality starts from a low dosage. Even those performing 10-60 minutes per week of physical activity had an 18% lower risk of all-cause mortality. Oral health is an often neglected area for athletes. Ian Needleman and colleagues[13] produced a useful infographic on this topic. They note that sports drinks with high sugar content may promote a pro inflammatory response, favouring the development of gum diseases. Therefore, rehydrating with water or washing the mouth out with water after having a sports drink can help minimise intra oral effects. Brushing twice per day with a fluoridated toothpaste is highly recommended. It has been increasingly recognised that the neighbourhood environment can influence physical activity. Ding Ding and colleagues[2] provide a useful infographic on the effects of residential relocation on walking, physical activity and travel behaviour. They note that moving to activity friendly neighbourhoods may lead to more walking. These findings are increasingly being recognised by town planners and hopefully will be incorporated into future urban planning.

Should this systematic review and meta-analysis change my practise? Mervin Travers and colleagues[18] explore this issue with two articles. The first of these explored the treatment effect and trustworthiness. They encourage clinicians to consider the pooled estimate of the treatment effect with respect to whether the mean difference or standardised mean difference is reported. If it is the standardised mean difference, it is important to assess what outcome measures have been combined in a meta-analysis. The second article explores the role of the comparator, diversity, risk advice and confidence. Forest plots are widely used in the research literature. Results from different trials may vary widely and a graphical expression of these results can be helpful to clinicians. They encourage clinicians to read systematic reviews and meta-analyses with a critical and forensic eye.

The final issue of the year was assembled in collaboration with the European College of Sports and Exercise Physicians. After a stroke, secondary vascular risk reduction is critical to prevent a recurrence. Cheng Wang and colleagues[21] conducted a systematic review and meta-analysis of twenty studies including 1,031 participants. They found that exercise interventions resulted in reduction of systolic blood pressure by an average of 4.3mmHg and diastolic blood pressure by an average of 2.58mmHg. There were also reductions in total cholesterol but not fasting, glucose or body mass index. Collectively, these changes have the potential to reduce the risk of recurrent stroke. This is a good reason to recommend them. The authors recommend starting an exercise programme within six months of a stroke or TIA incorporating health education. Protein supplementation is frequently used to enhance muscle mass. Robert Morton and colleagues[9] produced a useful infographic. They found that protein supplementation improved gains in muscle mass by about 500g with an average 9% increase in strength. Protein supplementation was more effective in people who were previously trained and was less effective in people over the age of 60. Protein supplementation beyond a total daily protein intake of about 1.6g/kilogram/day during resistance exercise training provided no further benefit in gains of muscle mass.

Roy Shephard,[15] Canadian researcher, re-examined the data on the association between heavy occupational work and cardiac health. The epidemiologists of the 1980's and earlier pointed out a favourable association between a physically demanding job and the risk of premature death. A recent meta-analysis has cast doubt on the original data. Shephard concluded that the choice of articles for the meta-analysis probably skewed the results. Cigarette smoking and socioeconomic status are major determinants of premature mortality and both are associated with heavy work. The early epidemiological studies had the important advantage of making comparisons within a single work force. These minimised the impact of socioeconomic status and related lifestyle characteristics. Therefore, he concludes that all other things being equal, being in a physically demanding job can lead to a longer life.

That concludes this instalment.

REFERENCES

1 Delahunt E, Bleakley CM, Bossard DS, et al. Infographic. International Ankle Consortium Rehabilitation-Oriented Assessment. *British Journal of Sports Medicine* 2019;**53**:1248-1249.

2 Ding D, Williamson C, Nguyen B, et al. Infographic:The effects of residential relocation on walking, physical activity and travel behaviour *British Journal of Sports Medicine* 2019;**53**:1486-1487.

3 Friedman DJ, Khan KM. Preventing overdiagnosis and the harms of too much sport and exercise medicine. *British Journal of Sports Medicine* 2019;**53**:1314-1318.

4 Gravare Silbernagel K, Vicenzino BT, Rathleff MS, et al. Isometric exercise for acute pain relief: is it relevant in tendinopathy management? *British Journal of Sports Medicine* 2019;**53**:1330-1331.

5 Keay N, Rankin A. Infographic. Relative energy deficiency in sport: an infographic guide. *British Journal of Sports Medicine*2019;**53**:1307-1309.

6 Kemp JL, King MG, Barton C, et al. Is exercise therapy for femoroacetabular impingement in or out of FASHIoN? We need to talk about current best practice for the non-surgical management of FAI syndrome. *British Journal of Sports Medicine* 2019;**53**:1204-1205.

7 Lie MM, Risberg MA, Storheim K, et al. What's the rate of knee osteoarthritis 10 years after anterior cruciate ligament injury? An updated systematic review. *British Journal of Sports Medicine* 2019;**53**:1162-1167.

8 Montalvo AM, Schneider DK, Silva PL, et al. 'What's my risk of sustaining an ACL injury while playing football (soccer)?' A

systematic review with meta-analysis. *British Journal of Sports Medicine* 2019;**53**:1333-1340.

9 Morton RW, Murphy KT, McKellar SR, et al. Infographic. The effect of protein supplementation on resistance training-induced gains in muscle mass and strength. *British Journal of Sports Medicine* 2019;**53**:1552.

10 Mountjoy M, Junge A, Budgett R, et al. Health promotion by International Olympic Sport Federations: priorities and barriers. *British Journal of Sports Medicine* 2019;**53**:1117-1125.

11 Osborne HR. Just listen! *British Journal of Sports Medicine* 2019;**53**:1383.

12 O'Keeffe M, O'Sullivan PB, O'Sullivan K. Education can 'change the world': Can clinical education change the trajectory of individuals with back pain? *British Journal of Sports Medicine* 2019;**53**:1385-1386.

13 Needleman I, Rankin A, Ashley P, et al. Infographic. Nutrition and oral health in sport: time for action. *British Journal of Sports Medicine* 2019;**53**:1432-1433.

14 Schwellnus M, Kipps C, Roberts WO, et al. Medical encounters (including injury and illness) at mass community-based endurance sports events: an international consensus statement on definitions and methods of data recording and reporting. *British Journal of Sports Medicine* 2019;**53**:1048-1055.

15 Shephard RJ. Is there a 'recent occupational paradox' where highly active physically active workers die early? Or are there failures in some study methods? *British Journal of Sports Medicine* 2019;**53**:1557-1559.

16 Stamatakis E, Johnson NA, Powell L, et al. Short and sporadic bouts in the 2018 US physical activity guidelines: is high-intensity incidental physical activity the new HIIT? *British Journal of Sports Medicine* 2019;**53**:1137-1139.

17 Swart NM, van Oudenaarde K, Bierma-Zeinstra SM, et al. Does MRI add value in general practice for patients with traumatic knee complaints? A 1-year randomised controlled trial. *British Journal of Sports Medicine* 2019;**53**:1285-1292.

18 Travers MJ, Murphy MC, Debenham JR, et al. Should this systematic review and meta-analysis change my practice? Part 1: exploring treatment effect and trustworthiness. *British Journal of Sports Medicine* 2019;**53**:1488-1492.

19 van der Vlist AC, Breda SJ, Oei EHG, et al. Clinical risk factors for Achilles tendinopathy: a systematic review. *British Journal of Sports Medicine* 2019;**53**:1352-1361.

20 van Dyk N, Behan FP, Whiteley R. Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta-analysis of 8459 athletes. *British Journal of Sports Medicine* 2019;**53**:1362-1370.

21 Wang C, Redgrave J, Shafizadeh M, et al. Aerobic exercise interventions reduce blood pressure in patients after stroke or transient ischaemic attack: a systematic review and meta-analysis. *British Journal of Sports Medicine* 2019;**53**:1515-1525.

22 Zhao M, Veeranki SP, Li S, et al. Beneficial associations of low and large doses of leisure time physical activity with all-cause, cardiovascular disease and cancer mortality: a national cohort study of 88,140 US adults. *British Journal of Sports Medicine* 2019;**53**:1405-1411.

2020
January to April

The January edition of BJSM started with a provocative article titled, 'Neovascularisation in Tendinopathy: From Eradication to Stabilisation', by Tero Jarvinen.[14] He translates data from cancer biology explaining that hypoxia induced new vessels are extra permeable. In essence, they leak and do not provide proper perfusion of tissues. He therefore proposes that it is somewhat counterintuitive to assume that eradication of new vessels – those originally induced by cells struggling to survive under hypoxic conditions – could offer a viable long term solution for tendinopathy. It may well just worsen the underlying condition. Food for thought. Alan Vernec, the medical director of WADA and colleagues[24] wrote an excellent article on glucocorticoids in elite sport. These substances are the focus of much controversy. There are concerns regarding their side effects and the possibility of enhanced athletic performance in limited settings. Where systemic glucocorticoids are medically necessary, therapeutic use exemptions may be granted after careful evaluation by a TUE committee. This article will provide a useful overview of the problem with treatment recommendations from major event organisations and professional sports leagues. There was another provocative article later in the issue entitled 'Wild Goose Chase – No Predictable Patient Subgroups Benefit from Meniscal Surgery', written by Kenneth Pihl and colleagues.[18] It describes 641 patients undergoing arthroscopic meniscal surgery in Southern Denmark. They found no clear predictable patient subgroups that would benefit. Those factors that tended towards a predictive feature included no previous meniscal surgery on the index knee and more severe preoperative knee related symptoms.

Do antioxidants prevent or reduce muscle soreness after exercise? Mayur Ranchordas and colleagues[19] conducted a Cochrane systematic review. They found moderate to low quality evidence that high dose antioxidant supplementation did not provide a clinically relevant reduction of muscle soreness. People with knee osteoarthritis are frequently prescribed exercise. Alessio Bricca and colleagues[5] produced a useful infographic explaining that therapeutic exercise is safe for articular cartilage and may actually improve articular cartilage health. This is worth emphasising to our OA patients. Tramadol is a powerful analgesic and there is debate regarding whether it should be banned in athletes while competing. Joao Baltazar-Martins and colleagues[3] produced a useful infographic based on data obtained from drug testing results. They found that of the 900 samples in 2017 obtained in competition with greater than 50 nanograms/ml of Tramadol, cycling accounted for 61% of all of the samples. The remainder were spread amongst all of the other sports. On receipt of this information the International Cycling Federation (UCI) banned Tramadol in cycling competitions from 1 March 2019. There were concerns that it might be affecting cyclists' safety because of dizziness and loss of alertness. These factors are worth bearing in mind for all our patients for whom Tramadol is prescribed.

Issue 3 in February 2020 highlighted the IOC World Conference on Prevention of Injury and Illness in Sport. This had to be postponed for over a year due to the coronavirus pandemic. Can the vertical drop jump test be used to predict the risk of ACL injury? Anne Mortvedt and colleagues[16] examined 152 video clips of elite female handball and football players performing this test. They concluded that

assessors have a poor predictive ability, no better than chance, so this remains a poor test for predicting ACL injury risk. Sleep disorders are very common in athletes. Claudia Reardon and colleagues[20] produced a useful infographic showing that 49% of Olympic athletes were classified as poor sleepers. They recommended tracking and monitoring of sleep, encouraging healthy sleep as part of the training protocol and scheduling training around sleep and circadian rhythms. Sleep problems were compounded by travel across multiple time zones which is common for athletes travelling from New Zealand to major overseas competitions. Therapeutic use exemptions are granted so that athletes can have access to medications that are medically necessary to treat illness. Even if those medications that are on the prohibited list. Strict criteria apply. Professor Ken Fitch,[10] who is one of the leading figures in anti-doping, evaluated the use of TUE's. He concluded that ensuring a level playing field is a fundamental principle of antidoping and that we should never forget those years of systematic doping and sporting successes by athletes of the former East Germany who denied so many clean athletes the chance of Olympic medals.

Blood borne pathogens have potential risks for athletes. The American Medical Society for Sports Medicine recently updated its position statement. Christopher McGrew and colleagues[15] produced a useful five-page document with 117 references. They concluded that the risk of transmission for any blood borne pathogen in the athletic setting is minute, but that standard precautions should be followed by anyone providing care to athletes. Later in the same issue, the American Medical Society for Sports Medicine produced a position statement on mental health issues in athletes. Written by Cindy Chang and colleagues,[7] it provided a useful overview of this important area with 68 references. Travelling athletes are particularly prone to illness that may keep them out of competition. Martin Schwellnus and colleagues[23] studied athletes from six South African Super Rugby teams from 2010 to 2016. They instituted certain preventive strategies including discouraging sharing of utensils or water bottles, ensuring good sleeping habits, regular hand washing and use of hand gel plus early reporting of symptoms and early isolation of players at the onset of symptom development. These measures, amongst others, resulted in a 50% reduction in acute illness during the period of follow up once the interventions were applied. This is pretty compelling evidence for this strategy.

Issue 5 was notable for promoting achievements of sports physiotherapy specialists. In particular, our own Jacinta Horan from Tauranga, has provided a model of excellence in sports physiotherapy and has been duly recognised for that. The issue was discussed by Blair Jarratt[13] in the warm-up page to Issue 5. Mental health issues have assumed increasing importance in recent years. Melanie Beland and colleagues[4] conducted a meta-analysis of the effect of exercise. They included 24 studies with 4,111 patients and found that aerobic exercise alleviated depressive symptoms in patients living with a major non communicable disease, particularly in cardiac populations. New Zealand Rugby has been proactive in managing concussion in its players. Danielle Salmon and colleagues[21] provided a useful infographic on the management pathway. This attempts to close the loop between suspected concussion recognition and return to play following medical clearance. A subsequent article with infographic by the same authors including our own Chris Whatman described the Rugby Smart initiative.[22] This provides a useful model for other sports to adopt.

Can caffeine help your exercise performance? It would seem so. Jozo Grgic and colleagues[11] provided a useful infographic including 21 meta-analyses. They concluded that caffeine was ergogenic for a broad range of exercise tasks including aerobic endurance, muscle strength, muscle endurance and anaerobic power. The recommended dosage is two cups of coffee consumed about one hour before exercise.

Can weight training influence cardio metabolic health outcomes? Ruth Ashton and colleagues[2] looked at 173 trials and concluded a positive effect of weight training on blood pressure, insulin resistance and fasting insulin levels. They caution that the quality of evidence was relatively low. There was limited evidence of adverse effects, however, which is good news. Subclinical coronary artery disease is common in veteran athletes. Helder Dores and colleagues[9] studied 105 asymptomatic male athletes aged over 40 years with low to moderate cardiovascular risk. They found abnormal exercise testing in 12.4% of athletes. They recommend inclusion of more objective data particularly that derived from cardiac CT scanning to provide more accurate cardiovascular risk stratification for these athletes. Exercise in pregnancy has long been shown to provide better health outcomes for both mother and baby in most circumstances. Margi Davenport and colleagues[8] produced a useful infographic entitled, 'Prenatal Physical Activity: Baby Steps for Better Health'. Exercise helped reduce the incidence of gestational diabetes, hypertension and depression compared with those women who did not exercise.

Relative energy deficiency in sport (RED-S) is an important and challenging condition. Kathryn Ackerman,[1] who was an invited speaker at the 2019 SMNZ conference, and colleagues provide a useful summary of this condition. The aim is to improve awareness of the condition amongst all those who are involved with athlete training or medical care. In particular, they recommend a revolution in sport culture and awareness regarding energy availability so that athletes can be more healthy and perform better.

Can head impact sensors help via medical engineers to design better head gear? Lyndia Wu[25] found that the sensors may provide valuable estimates as to exposure statistics over time, but they do not provide the high accuracy necessary to measure

accelerations of individual impacts that may cause injury. Glucocorticoids are frequently prescribed by doctors working in high performance sport. David Hughes and colleagues[12] studied the prescribing habits of 603 sports medicine doctors from 30 different countries. They concluded that although these medications are widely prescribed by sports physicians, there is a great variation in how long before competition the use of glucocorticoids would cause the doctor to consider applying for a TUE. Further research is needed to clarify clearance times for glucocorticoids administered by a variety of roots. The Nike Vaporfly has been used by runners who have broken world records in endurance events in the past three years. Geoffery Burns and Nicholas Tam[6] asked the question, 'Is it the shoe?'. They conclude that a standard for maximal shoe mid sole thickness would provide a simple robust enforceable regulation for footwear in athletics. It would prevent running competition from devolving into an arms race of larger and more complex shoes and retain the essence of the competition for what it is – a foot race.

Can resistance training be used for older people with peripheral artery disease? It would seem so. Belinda Parmenter and colleagues[17] conducted a meta-analysis of 15 trials including 826 patients. They concluded that resistance training clinically improved treadmill and flat ground walking ability in people with peripheral artery disease. Higher intensity training was associated with better outcomes.

That concludes this issue. Another update in a few months' time.

REFERENCES

1 Ackerman KE, Stellingwerff T, Elliott-Sale KJ, et al. #REDS (Relative Energy Deficiency in Sport): time for a revolution in sports culture and systems to improve athlete health and performance. *British Journal of Sports Medicine* 2020;**54**:369-370.

2 Ashton RE, Tew GA, Aning JJ, et al. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: systematic review with meta-analysis. *British Journal of Sports Medicine* 2020;**54**:341-348.

3 Baltazar-Martins JG, Plata MDM, Muñoz-Guerra J, et al. Infographic. Tramadol: should it be banned in athletes while competing, particularly in road cycling? *British Journal of Sports Medicine* 2020;**54**:120-121.

4 Béland M, Lavoie KL, Briand S, et al. Aerobic exercise alleviates depressive symptoms in patients with a major non-communicable chronic disease: a systematic review and meta-analysis. *British Journal of Sports Medicine* 2020;**54**:272-278.

5 Bricca A, Roos EM, Juhl CB, et al. Infographic. Therapeutic exercise relieves pain and does not harm knee cartilage nor trigger inflammation. *British Journal of Sports Medicine* 2020;**54**:118-119.

6 Burns GT, Tam N. Is it the shoes? A simple proposal for regulating footwear in road running. *British Journal of Sports Medicine* 2020;**54**:439-440.

7 Chang C, Putukian M, Aerni G, et al. Mental health issues and psychological factors in athletes: detection, management, effect on performance and prevention: American Medical Society for Sports Medicine Position Statement—Executive Summary. *British Journal of Sports Medicine* 2020;**54**:216-220.

8 Davenport MH, Horbachewsky T, Brown M, et al. Infographic. Prenatal physical activity: baby steps for better health. *British Journal of Sports Medicine* 2020;**54**:360-361.

9 Dores H, de Araújo Gonçalves P, Monge J, et al. Subclinical coronary artery disease in veteran athletes: is a new preparticipation methodology required? *British Journal of Sports Medicine* 2020;**54**:349-353.

10 Fitch K. Therapeutic Use Exemptions (TUEs) are essential in sport: but there is room for improvement. *British Journal of Sports Medicine* 2020;**54**:191-192.

11 Grgic J, Grgic I, Pickering C, et al. Infographic. Wake up and smell the coffee: caffeine supplementation and exercise performance. *British Journal of Sports Medicine* 2020;**54**:304-305.

12 Hughes D, Vlahovich N, Welvaert M, et al. Glucocorticoid prescribing habits of sports medicine physicians working in high-performance sport: a 30-nation survey. *British Journal of Sports Medicine* 2020;**54**:402-407.

13 Jarratt B. Celebrating sports physiotherapy specialist: kudos Jacinta Horan (SEPNZ). *British Journal of Sports Medicine* 2020;**54**:255.

14 Järvinen TA. Neovascularisation in tendinopathy: from eradication to stabilisation?*British Journal of Sports Medicine* 2020;**54**:1-2.

15 McGrew C, MacCallum D, Narducci D, et al. AMSSM position statement update: blood-borne pathogens in the context of sports participation. *British Journal of Sports Medicine* 2020;**54**:200-207.

16 Mørtvedt AI, Krosshaug T, Bahr R, et al. I spy with my little eye … a knee about to go 'pop'? Can coaches and sports medicine professionals predict who is at greater risk of ACL rupture? *British Journal of Sports Medicine* 020;**54**:154-158.

17 Parmenter BJ, Mavros Y, Ritti Dias R, et al. Resistance training as a treatment for older persons with peripheral artery disease: a systematic review and meta-analysis. *British Journal of Sports Medicine* 2020;**54**:452-461.

18 Pihl K, Ensor J, Peat G, et al. Wild goose chase – no predictable patient subgroups benefit from meniscal surgery: patient-reported outcomes of 641 patients 1 year after surgery. *British Journal of Sports Medicine* 2020;**54**:13-22.

19 Ranchordas MK, Rogerson D, Soltani H, et al. Antioxidants for preventing and reducing muscle soreness after exercise: a Cochrane systematic review. *British Journal of Sports Medicine* 2020;**54**:74-78.

20 Reardon CL, Hainline B, Aron CM, et al. Infographic. Sleep disorders in athletes. *British Journal of Sports Medicine* 2020;**54**:188-189.

21 Salmon D, Romanchuk J, Murphy I, et al. Infographic. New Zealand Rugby's concussion management pathway. *British Journal of Sports Medicine* 2020;**54**:298-299.

22 Salmon D, Sullivan J, Romanchuk J, et al. Infographic. New Zealand rugby's community concussion initiative: keeping kiwi communities RugbySmart. *British Journal of Sports Medicine* 2020;**54**:300-301.

23 Schwellnus M, Janse van Rensburg C, Bayne H, et al. Team illness prevention strategy (TIPS) is associated with a 59% reduction in acute illness during the Super Rugby tournament: a control–intervention study over 7 seasons involving 126 850 player days. *British Journal of Sports Medicine* 020;**54**:245-249.

24 Vernec A, Slack A, Harcourt PR, et al. Glucocorticoids in elite sport: current status, controversies and innovative management strategies—a narrative review. *British Journal of Sports Medicine* 2020;**54**:8-12.

25 Wu L. Sports concussions: can head impact sensors help biomedical engineers to design better headgear? *British Journal of Sports Medicine* 2020;**54**:370-371.

The effects of the NetballSmart Dynamic Warm-up on isokinetic strength in youth netball

CHLOE R MCKENZIE, SCOTT R BROWN, CHRIS S WHATMAN AND MATT BRUGHELLI

See end of article for author affiliations.

Correspondence
Chloe McKenzie
Sports Performance Research Institute New Zealand
Auckland University of Technology
Level 2, AUT-Millennium Campus
17 Antares Place
Mairangi Bay, Auckland, 1020
New Zealand
Tel: +64 21 277 0673
Email: chloe.mckenzie@aut.ac.nz

ABSTRACT

Aim

The aim of this study was to investigate the effect of the NetballSmart Dynamic Warm-up on isokinetic knee strength in female youth netball players.

Method

Secondary school netball players (n=23) participated in a seven-week intervention study. Isokinetic dynamometry was used to assess concentric and eccentric peak torque measures of the right leg during seated knee flexion and extension actions at 60%.

Results

There were no significant differences found between pre- and post-measures in peak torque, angle of peak torque and hamstrings-to-quadriceps ratio.

Conclusions

There was no improvement in knee strength after performing the NetballSmart Dynamic Warm-up. This could indicate that the programme does not contain sufficient stimulus to improve isokinetic knee strength in female youth netball players.

Keywords

Netball, ACL injury, eccentric strength, quadriceps to hamstring ratio

INTRODUCTION

Weakness about the knee, in particular the hamstring, has been shown to be associated with increased anterior cruciate ligament (ACL) injury risk in female athletes.[1] The combination of increased internal tibial rotation, greater quadriceps activity, and low hamstring to quadriceps ratio while landing could contribute to the explanation of why female athletes have a higher incidence of non-contact ACL injuries.[2] Netball is an intermittent court sport, that is predominantly played by females, involving explosive movements such as sprinting, cutting, change of direction, and jumping.[3] Court restrictions confine players to positional areas of the court, often requiring players to abruptly stop to avoid going off-side. Additionally, upon receiving a pass, a player must rapidly decrease horizontal velocity to come to a complete stop to avoid violation of the unique footwork rule (players are not allowed to step once in possession of the ball).[4] To perform such movements, deceleration capability is required.

During deceleration, the forces applied to the body can be very large, especially when the time over which these forces are absorbed is short.[5] Deceleration requires the muscles to act like a shock-absorbing structure or brake by eccentrically contracting.[6,7] The muscle-tendon unit assists in the dissipation, or temporary storage of energy during deceleration.[7] Injury can occur when the forces needed to decelerate the body are greater than the muscle-tendon unit can tolerate.[7] Recurring hamstring injury has been associated with greater impairment of eccentric strength, compared to concentric strength, suggesting improvements in eccentric strength may reduce injury risk.[7] Eccentric strength training can lead to increases in tendon stiffness and an improved ability to absorb energy at the musculotendinous junction; as well as enhanced muscular strength, power and jumping, and sprinting performance.[6,7]

To help prevent injury and improve performance in netball, Netball New Zealand have implemented a warm-up programme (NetballSmart Dynamic Warm-up). The programme includes a strength component intended to improve the players' quadriceps, hamstrings and core strength; consisting of exercises such as Nordic hamstring, prone holds, squats, and lunges. Similar warm-up programmes, completed two to three times per week, have been shown to decrease lower limb injuries by at least 40%.[8] Currently there is no research investigating the effect of the NetballSmart Dynamic Warm-up on knee strength. Therefore, the aim of this study was to determine if the NetballSmart Dynamic Warm-up can improve isokinetic knee strength in youth netball players.

METHODS

Participants

A total of 23 female youth netball players (mean ±SD: age=13.09 ±0.29 yr, height=165.74 ±5.98 cm, body mass=52.87 ±9.02 kg) were recruited through local secondary schools. Data for this cross-sectional study were collected from two teams in one school as a component of a larger study (involving five schools) investigating the effects of the warm-up on a range of physical performance measures. All participants were training and competing in a netball programme and were healthy and free from injury in the last six months. The warm-up was delivered by a qualified trainer 2x per week before training, and 1x per week by the team coach before games. Prior to participation, all participants and guardians were fully informed of the experimental procedures before giving their informed consent and assent. This study was approved by the Auckland University of Technology Ethics Committee.

Design

This study used a single group intervention design. Isokinetic data was collected one week before and one week following a seven-week intervention. The warm-up programme was performed three times each week. The warm-up programme consisted of four parts: Part A- strength and balance exercises; Part B- running exercises at slower speeds and some controlled partner contact; Part C- dynamic preparation exercises, including dynamic stretches and plyometric movements; and Part D- netball specific exercises involving running at faster speeds, cutting and stopping. The warm-up took approximately 15 to 20

minutes to complete per session. For full details of the warm-up see the manual and instructions which are freely available on the Netball New Zealand website (http://www.netballnz.co.nz/Downloads/Assets/41254/1/Dynamic%20Warm-up.pdf)

Methodology

Following a standardised warm-up, a Humac Norm dynamometer (Lumex, Ronkonkoma, NY, USA) was used to assess isokinetic knee extensor and flexor strength of the right leg. Participants were seated and strapped to the device with the lateral femoral epicondyle aligned with the dynamometer axis of rotation.[9] A 90^0 range of knee motion (0^0=full extension) was set for all tests and gravity adjustments were made.[10] The testing protocol consisted of concentric and eccentric actions at a fixed angular velocity of 60°/s (5 repetitions). Familiarisation required three movements at an individually perceived 75%, 90% and 100% of maximum exertion at each position.[11] Verbal feedback was given to each participant to encourage maximum effort at each trial. Participants had 45 to 60 s rest between each trial. As per previous research,[11] torque-angle curves with a fourth-order polynomial were fitted using a custom-made LabView program (Version 11.0, National Instruments Corp, Austin, TX, USA) to identify peak torque and the angle of peak torque using the averages of the last 4 repetitions. Hamstring-to-quadriceps ratios (H:Q ratio) were calculated by dividing the concentric peak flexion torque by the concentric peak extension torque using Excel (2010, Microsoft, Redmond, WA, USA).

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) (IBM SPSS Statistics v. 25; IBM Corporation, Chicago, IL) was used to perform all analyses. Normality was tested using the Shapiro-Wilk test and by visual review of histogram graphs. Data was not normally distributed and therefore the non-parametric Wilcoxon Signed Rank Test was used to determine pre-post differences in all measures. Mean differences with 95% confidence intervals and Hedges' g effect sizes (ES) were reported (Table 1). The following scale was used to interpret the ES's 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large).[12] The threshold of $p<0.05$ for statistical significance was set for all analyses.

RESULTS

All results are presented in Table 1. No significant effect of the intervention was found between pre-and post-knee peak torque measures. The H:Q ratio was also non-significant. Additionally, there were no significant changes in the angle of peak torque. The overall compliance rate for completing the warm-up at least once per week was 65%.

Table 1: Mean pre-post differences (n=23)

Variable	Pre Test Mean ±SD	Post Test Mean ±SD	Difference Mean + 95% CI	ES Hedge's g	P value
Knee peak torque (N.m)					
Concentric Flexion	54.88 ±15.23	53.28 ±14.38	-1.60 (-5.0 to 1.8)	-0.11	0.27
Concentric Extension	103.60 ±24.73	103.81 ±22.44	0.22 (-4.7 to 5.1)	0.01	0.90
Eccentric Flexion	71.10 ±20.50	69.85 ±22.20	-1.25 (-5.8 to 3.3)	-0.06	0.35
Eccentric Extension	127.18 ±40.17	117.00 ±28.68	-10.18 (-21.9 to 1.6)	-0.29	0.08
Angle of peak torque (degrees)					
Concentric Flexion	41.51 ±15.52	37.88 ±15.03	-3.63 (-10.0 to 2.7)	-0.23	0.25
Concentric Extension	66.96 ±6.40	62.66 ±7.62	-4.30 (-7.6 to -1.0)	-0.60	0.14
Eccentric Flexion	34.53 ±12.82	34.23 ±16.38	-0.30 (-7.2 to 6.6)	-0.02	0.93
Eccentric Extension	66.37 ±10.85	59.22 ±13.40	-7.15 (-14.9 to 0.5)	-0.58	0.07
Hamstrings:quadricep ratio	0.53 ±0.11	0.52 ±0.09	-0.02 (-0.06 to 0.02)	-0.10	0.25

Values are mean ±SD; ES=effect size; CI=confidence interval

DISCUSSION

The main findings of this study were that no improvements in concentric and eccentric knee peak torque or angle of peak torque were observed after the introduction of the NetballSmart Dynamic Warm-up in female youth netball players. These findings are in agreement with a previous study in competitive female football players of a similar age (17.1 ±0.8 yr) that did not show improvements in knee concentric and eccentric maximal strength after 10 weeks of the FIFA 11.[13] The authors concluded the training volume, intensity and progression may have been insufficient to elicit strength improvements and this is also a likely explanation for the non-significant findings in the current study. As with the current study, the authors also suggested the strength testing procedures may not have detected all potential strength gains. Additionally, only 67% of participants attended all of the warm-up sessions which further reduces the training stimulus.

Previous studies have shown improvements in knee strength after a similar warm-up programme, the FIFA 11+.[14,15] Concentric hamstring strength in young professional male football players (mean age 19 years) increased after 24 sessions of the FIFA 11+.[14] Quadriceps concentric and hamstring concentric and eccentric strength was also found to improve in adolescent male futsal players after 12 weeks of the FIFA 11+.[15] In comparison to the current study, both studies involved adolescent male futsal or football players. Therefore, the differences in findings may be due, in part, to gender, age and training experience. As the NetballSmart Dynamic Warm-up is based on the FIFA 11+, the programmes contain similar exercises; however, there are differences in the prescription of the exercises between the programmes. The FIFA 11+ has more sets and repetitions compared to the NetballSmart programme, increasing the volume and intensity of each exercise. For example, FIFA 11+ prescribes two sets of squats and walking lunges and 12-15 repetitions of hamstrings strengthening exercises, whereas NetballSmart prescribes one set and 7-10 repetitions, for the respective exercises. Therefore, if one intention of the NetballSmart programme is to improve maximal effort strength as well as prevent injury, the design of the programme needs to contain the correct training stimulus to promote this. Although this study did not show improvements after a seven-week programme, we suggest further research addressing the short-term nature, low player compliance, and training volume and intensity of this intervention.

Practical applications

These findings suggest a greater training stimulus is needed to produce improvements in knee strength. This could be achieved by adding more sets, with adequate rest time, to exercises during each training session. This would increase the overall volume of the exercise. It is also important to ensure the exercises are being performed correctly. As the participants in this study were younger, untrained female netball players, it is possible the movements were not being performed with maximal effort (low intensity). Therefore, it is important to have a coach or qualified trainer who understands the exercise and correct technique when required. If such training protocols are designed to help improve performance, players and coaches

may be more encouraged to participate in the programme with the potential for higher player compliance. Coaches may also be able to create ways to ensure the exercises are engaging to ensure youth athletes engage in higher intensity exercises. For example, allowing the athletes to lower for longer during the Nordic hamstring will increase the length of the muscles and increase the intensity.[16]

Readers need to be aware that although this study focused on gains in knee strength there are several other potential benefits to undertaking the NetballSmart Dynamic Warm-up (improved balance and landing technique for example) and there is preliminary evidence it can improve prone hold and jump performance.[17] Additionally, the true efficacy of the NetballSmart Dynamic Warm-up requires a study of its effects on injury rates and given the multifactorial nature of injury risk it may be that injuries can be reduced without gains in knee strength. Finally, study limitations including a relatively small sample size and low compliance need to be acknowledged when interpreting the results.

CONCLUSION

There was no improvement in knee strength after performing the NetballSmart Dynamic Warm-up. This could indicate that the programme does not contain sufficient stimulus to improve isokinetic knee strength in female youth netball players.

AUTHOR AFFILIATIONS

Chloe R McKenzie MSp&Ex
Sports Performance Research Institute New Zealand, School of Sport and Recreation
Auckland University of Technology
Auckland, NZ
Scott R Brown PhD
Sports Performance Research Institute New Zealand, School of Sport and Recreation
Auckland University of Technology
Auckland, NZ
Neuromuscular and Rehabilitation Robotics Laboratory (NeuRRo Lab)
Department of Physical Medicine and Rehabilitation
University of Michigan
Ann Arbor, MI, USA
Chris Whatman PhD
Sports Performance Research Institute New Zealand, School of Sport and Recreation
Auckland University of Technology
Auckland, NZ
Matt Brughelli PhD
Sports Performance Research Institute New Zealand, School of Sport and Recreation
Auckland University of Technology
Auckland, NZ

REFERENCES

1 Myer GD, Ford K, Barber Foss KD, Liu C, Nick TG, Hewett TE. The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clin J Sport Med*. 2009;**19**:3-8.

2 Nagano Y, Ida H, Akai M, Fukubayashi T. Gender differences in knee kinematics and muscle activity during single limb drop landing. *The Knee*. 2007;**14**:218-223.

3 Thomas C, Comfort P, Jones PA, Dos' Santos T. Strength and conditioning for netball: A needs analysis and training recommendations. *Strength Cond J*. 2017;**39**:10-21.

4 Stuelcken M, Greene A, Smith R, Vanwanseele B. Knee loading patterns in a simulated netball landing task. *Eur J Sport Sci*. 2013;**13**:475-482.

5 Hewit J, Cronin J, Button C, Hume P. Understanding deceleration in sport. *Strength Cond J*. 2011;**33**:47-52.

6 Vogt M, Hoppeler HH. Eccentric exercise: Mechanisms and effects when used as training regime or training adjunct. *J Appl Physiol*. 2014;**116**:1446-1454.

7 LaStayo PC, Woolf JM, Lewek MD, Snyder-Mackler L, Reich T, Lindstedt SL. Eccentric muscle contractions: their contribution to injury, prevention, rehabilitation, and sport. *J Orthop Sports Phys Ther*. 2003;**33**:557-571.

8 Bizzini M, Dvorak J. FIFA 11+: An effective programme to prevent football injuries in various player groups worldwide—A narrative review. *Br J Sports Med*. 2015;**49**:577-579.

9 Montgomery MM, Shultz SJ. Isometric knee-extension and knee-flexion torque production during early follicular and postovulatory phases in recreationally active women. *J Athl Train*. 2010;**45**:586-593.

10 Brito J, Figueiredo P, Fernandes L, et al. Isokinetic strength effects of FIFA's "The 11+" injury prevention training programme. *Isokinet Exerc Sci*. 2010;**18**:211-215.

11 Brown SR, Brughelli M, Griffiths PC, Cronin JB. Lower-extremity isokinetic strength profiling in professional rugby league and rugby union. *Int J Sports Physiol Perform*. 2014;**9**:358-361.

12 Hopkins W, Marshall SW, Batterham A, Hanin J. Progressive statistics. Sportscience. 2009;13:55-70.

13 Steffen K, Bakka HM, Myklebust G, Bahr R. Performance aspects of an injury prevention program: a ten-week intervention in adolescent female football players. *Scand J of Med Sci Spo*. 2008;**18**: 596-604

14 Daneshjoo A, Mokhtar A, Rahnama N, Yusof A. The effects of injury prevention warm-up programmes on knee strength in male soccer players. *Biol Sport*. 2013;**30**:281.

15 Reis I, Rebelo A, Krustrup P, Brito J. Performance enhancement effects of Federation Internationale de Football Association's "The 11+" injury prevention training program in youth futsal players. *Clin J Sport Med*. 2013;**23**:318-320.

16 Opar DA, Williams MD, Shield AI. Hamstring strain injuries: Factors that lead to injury and re-injury. *Sports Med*. 2012;**42**:209-226.

17 McKenzie CR, Whatman C, Brughelli M, Borotkanics R. The effect of the NetballSmart Dynamic Warm-up on physical performance in youth netball players. *Phys Ther Sport*, 2019;**37**: 91-98.

The role of cannabidiol in professional sports: A scoping review

BENJAMIN VENN, S JOHN SULLIVAN

ABSTRACT

Aim

The purpose of this scoping review was to map and examine the available literature on the use of cannabidiol in professional sports.

Methods

Scopus, SPORTDiscus and Web of Science online databases were searched using a three different search protocols for traditional white literature purporting to the use of cannabidiol in sports for pain and/or inflammation. Grey literature was searched in a similar manner using ProQuest Dissertations & Thesis, PubMed, the Cochrane Library, the World Health Organisation International Clinical Trials Registry Platform Search Portal, Australian New Zealand Clinical Trials Registry, and ClinicalTrials.gov. Records were considered for analysis if they were of any study designs including reviews and blogs pertaining to the use of cannabidiol in any sport at any level of participation, involving people of any age or gender. All texts written in English regarding any physical and/or mental health condition pertaining to pain and/or inflammation and/or recovery in a sporting context were considered.

Results

Three records were identified for inclusion from the traditional white literature search. A further 30 blog articles were selected from the grey literature search and were included in this scoping review.

Conclusion

There is a vast gap in the current scientific literature supporting the use of cannabidiol in professional sports. There appears to be an ever-increasing amount of grey literature anecdotally supporting the use of cannabidiol for reducing pain, inflammation and enhancing athlete recovery. As cannabidiol is currently sold in un-regulated markets around the world, there is an urgent need for human clinical trials to determine its safety and efficacy.

Keywords

Cannabidiol, CBD, Sports, Athlete, Pain, Inflammation, Recovery, Scoping Review.

See end of article for author affiliations.

Correspondence
S John Sullivan
School of Physiotherapy
University of Otago, PO Box 56
Dunedin 9054
New Zealand
Email: jsrandft@gmail.com

INTRODUCTION

Cannabidiol, or CBD, is one of over one hundred compounds derived from the marijuana and hemp plants.[1] However, unlike tetrahydrocannabinol (THC), cannabidiol contains no psychoactive properties.[2] Furthermore, it is regarded as a safe, non-addictive substance with no evidence to suggest cannabidiol carries a potential for abuse with no known adverse effects on health.[2-4] Until 2018, the World Anti-Doping Agency (WADA) prohibited the use of cannabidiol in professional sports. Since its legalisation for athletes in competitive sports,[5] it is well-known that an increasing number of athletes are turning to cannabidiol products to aid their recovery and improve their performance. Athletes from a multitude of sports are promoting cannabidiol, with both athletes and sporting bodies signing multi-million-dollar sponsorship deals.[6] Famous athletes like Mike Tyson are becoming entrepreneurs and starting their own cannabidiol companies.[7] These bring cannabidiol into the public eye, further increasing product awareness and opening the door for potential research. Podcasts, documentaries, blogs and increasing literature discussing cannabidiol and its purported benefits are ever-increasing, however there is a common theme that there is little literature to support its applications specifically within a sporting context.

Countries around the world have varying rules and regulations on restricting public access to cannabidiol. Countries such as New Zealand for example only allow access to cannabidiol products via prescription,[8] where the products available on prescription have previously been too expensive, therefore limiting access.[9] Other countries such as Great Britain and USA commonly sell cannabidiol products in unregulated markets, most often advertised and sold as supplements, thus carrying an inherent risk of contamination and mislabelling.[10] Additionally, global views and political climates on marijuana have meant very few clinical trials have been performed on compounds such as cannabidiol, making it difficult for clinicians to recommend cannabidiol products, its potential uses, dosages or product safety. As it currently stands, for example, the National Institute for Health and Care Excellence guidelines (NICE) are still only in the development stages of producing guidelines on the use of cannabidiol products for the treatment of seizures in the UK,[11,12] with the National Health Service in the UK not recommending cannabidiol for any other conditions.[13]

Some of the purported benefits of cannabidiol include; pain relief, reduction of inflammation, reducing anxiety and depression,[2,14,15] the potential to provide neuroprotection[16,17] and improve fracture healing times.[18] However, there is currently a paucity of traditional literature addressing the role of cannabidiol in sports, despite it being a legal product under the WADA code while other natural and synthetic cannabinoids remain strictly prohibited (37). This suggests that a wide-ranging review of available literature and information sources would be of interest to both athletes and the wider sports and exercise medicine community. This scoping review will focus on the use of cannabidiol in professional sports as it would appear the purported benefits are already being realised by athletes around the world.

All athletes regardless of level of participation, however, need to be able to make informed decisions on supplements they intend to use, especially when they risk taking tainted

supplements. With the evident interest by professional sportspersons in the use of cannabidiol it is appropriate to investigate literature relating to this group of athletes in the first instance. The scoping review methodology[19] provides an ideal forum to locate and collate this information.

METHODS

The five-stage scoping review process proposed by Arksey and O'Malley was adopted for this study.[19] A scoping protocol was chosen for this review as the nature of the review allows for the mapping and examination of emerging "evidence" on a topic which may reveal very little available literature.[20] The PRISMA-ScR checklist was also used in the design and reporting to validate the methodology and reporting of the review.[21]

Study selection

Step 1: Identify the research question

Considering this is a relatively new area of research with potentially very little literature available, a research question was formulated to encompass any potential literature specific to the topic:

What is the current literature on the use of cannabidiol (CBD oil) on pain and inflammation in professional sports?

Step 2: Identifying relevant studies

Studies meeting the following inclusion criteria were considered for review;

1 All study designs including reviews, opinions and blogs pertaining to the use of cannabidiol in any sport at any level of participation, involving people of any age or gender.
2 All texts written in English with no restriction on date of publication.
3 All texts regarding any physical and/or mental health condition pertaining to pain and/or inflammation and/or recovery within a sporting context.

Studies were excluded based on the following exclusion criteria;

1 Records which were not accessible within the timeframe of the study (cut-off 1st September 2019).
2 Records which were not specifically relevant to the use of cannabidiol in sports or were considered commercial material.
3 Records specific only to marijuana, medical marijuana or THC in sports.

Search strategy and databases

A limited search of the Scopus search engine was conducted on 1st August 2019 using basic, broad search terms to identify potential literature and identify key index terms surrounding the use of cannabidiol in sports for pain management. The search strategy was designed in in consultation with an experienced health sciences librarian.

Key search terms were: **"CBD oil OR Cannabidiol AND sport* OR player* OR athlete* AND pain"**

A further search was also performed on the World Anti-Doping Agency website[5] to find any potential supporting literature on cannabidiol. This would serve as a point of reference for effectiveness of the search strategy.

The initial search results suggested that the literature may not focus entirely on cannabidiol and pain management, and that there may be additional literature on cannabidiol and inflammation, and cannabidiol on pain and inflammation. The initial search also revealed additional terms which could directly replace those used within the initial strategy. For example;

1 Cannabidiol/CBD oil may not necessarily consider medical cannabis, medical marijuana, cannabis, marijuana or hashish. Thus, the scope of the search was broadened to include these terms.
2 Pain was too specific and did not consider pain relief, pain management, and analgesia or pain control.
3 Inflammation was not considered at all in the initial search, and so "inflam*" was included for its own niche search.

Three individual searches were therefore performed on three traditional white literature databases to encompass all potential literature on the use of cannabidiol for pain, inflammation and pain and inflammation. All sports and all levels of participation were considered for the search as narrowing the search to professional sports only may not have produced any results. The three databases chosen for the white literature search were; Scopus, SPORTDiscus and Web of Science. These databases were specifically chosen because of their access to other search engines: Scopus and Web of Science databases access PubMed, Medline and Embase databases, thus, the proposed search strategy essentially covered five peer-reviewed databases which was considered to be a comprehensive search, and a manageable workload within the time constraints of the study.

The three individual searches are described below;

1 Pain only:
Cannabidiol OR CBD OR "medical cannabis" OR "medical marijuana" OR marijuana OR cannabis OR hashish AND Sport* OR player* OR athlete* AND pain OR "pain relief" OR "pain management" OR analgesia OR "pain control"
2 Inflammation only:
Cannabidiol OR CBD OR "medical cannabis" OR "medical marijuana" OR marijuana OR cannabis OR hashish AND Sport* OR player* OR athlete* AND Inflam*
3 Pain AND Inflammation:
Cannabidiol OR CBD OR "medical cannabis" OR "medical marijuana" OR marijuana OR cannabis OR hashish AND Sport* OR player* or athlete* AND pain OR "pain relief" OR "pain management" OR analgesia OR "pain control" OR inflam*

As there may be limited information available in published literature, a search of the grey literature was also performed in order to gather the most current sources of information.[22] Full details of each search strategy can be found under Appendix 1. To begin with, a basic search was performed on the ProQuest Dissertations & Thesis search engine to determine if there was any published or unpublished material relevant to the research question. Following this, five clinical trial databases were searched for any potential clinical trials or registered protocols. These were PubMed, the Cochrane Library, the World Health Organization International Clinical Trials Registry Platform Search Portal, Australian New Zealand Clinical Trials Registry (ANZCTR) and ClinicalTrials.gov. These clinical trial databases were chosen as they were able to search a wide field and were easily accessible within the timeframe of the study.

Finally, a Google blog search was performed to locate any potential blogs relevant to the research question. Details of the search strategy can be found in Appendix 1.

Step 3: Study selection

All identified records were uploaded to Microsoft Endnote (Version X9.2) according to each database and then collated into one compiled results folder. Duplicates were manually removed. Titles and abstracts were reviewed by the lead author (BV), with full texts reviewed only when relevance according to the title and/or abstract to the research question was unclear. It has been previously reported that scoping reviews are known to be iterative in nature as researchers become more familiar with the data.[19] It became apparent that some documents sourced in the search were not appropriate for inclusion in this scoping review – namely

commercial material. As such, the inclusion criteria were modified accordingly to discard commercial material.

Step 4: Charting the data

A basic charting table was developed using Microsoft Excel to record and assimilate extracted data. This data included title, author(s), date of publication, and a brief summary of each article. This allowed for a second Microsoft Excel charting table to be drawn to record recurring themes which were identified within the texts by the lead author.

Step 5: Collating, summarising and reporting the results

Each source was examined and read several times by the lead author (BV). Phrases and references to the use of cannabidiol were highlighted in the text and confirmed following a re-read of the article. Themes which emerged were documented on an Excel document, then each source was re-examined to confirm if it potentially discussed any of the key themes.[23] One example was the potential for cannabidiol to be effective for athlete recovery. The key themes were then recorded and tabulated so that grand totals could be calculated to determine the three most discussed themes. Although the study was specifically looking for sources discussing the use of cannabidiol as a recovery agent, there was no confirmation bias and so a variety of themes were considered for discussion.

RESULTS

The initial white literature search identified 175 records as illustrated in Figure 1. After duplicates were removed, 70 records remained. A further seven records were removed due to being written in a language other than English. The resulting 63 records were screened to determine if they met the study criteria for inclusion, 33 did not meet the criteria (irrelevant) and were thus excluded. A further 20 records were not specific to the research question but either reported on marijuana in sports or contributed nothing to the search topic and so were excluded. Three further records were removed as they were commercial material. A final four records were excluded as they could not be accessed within the timeframe of the study, as this was written as part of a master's degree.

A total of three records were included from the white literature search. This resulted in three magazine articles published between 2017 and 2019 being retained for analysis. These are presented in Table 1.

A basic search was performed on the ProQuest Dissertations & Thesis search engine which returned 79 results. Following screening, no records were found to be relevant and this search concluded. Five clinical trial databases were searched for potential clinical trials. Cochrane Library yielded one result, with the search engine "ClinicalTrials.gov" a further 578. After screening, no results were found to be relevant to the current study. A Google blog search yielded an incredibly large number of results. Therefore, for pragmatic purposes the first four pages of results were considered for inclusion in the current review, each page consisting of 10 blog articles. After eligibility assessment, a total of 30 blogs were included. The blog results can be seen under Table 2.

Overall, the search strategy identified 33 eligible records relevant to the research question "What is the current literature on

Table 1: White literature Search Results

Study	Source Type	Purpose
Averill, G. Why Athletes Are Ditching Ibuprofen for CBD. Outside. 2018:42-424	Magazine Article	Narrative review on benefits of CBD from the perspective of a professional athlete
Beall, J. Players are using and endorsing CBD, but the PGA Tour is wary. Golf Digest. 2019;70(8):6825	Magazine Article	Narrative review on the benefits of CBD and use in the PGA Tour.
Lee, C. The Need for Weed. Men's Fitness. 2017;33(3):96-10126	Magazine Article	Narrative review on the benefits of CBD and use in a variety of sports.

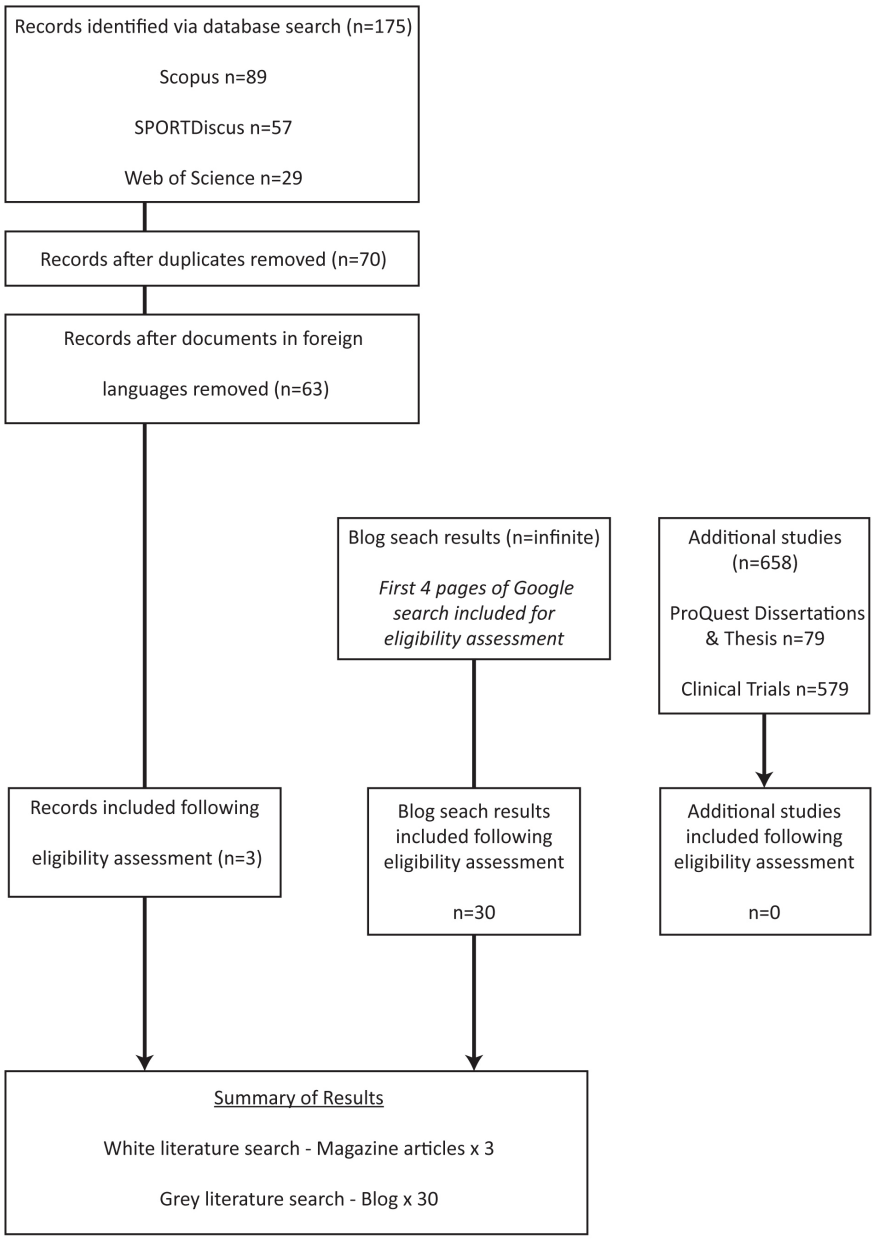

Figure 1: PRISMA style search flow diagram

Table 2: Blog Results

Author	Year	Place of Publication	URL
Petkovic, B30	2019	New Orleans, USA	https://www.bigeasymagazine.com/2019/08/06/cbd-in-professional-sports-how-safe-is-it
Raimondi, M48	2019	Anaheim, USA	https://www.espn.com/mma/story/_/id/27389706/nate-diaz-lights-joint-ufc-open-workout
Vegotsky, J59	2019	California, USA	https://www.cbdtoday.com/game-changer-top-athletes-turn-to-cbd/
Kruis, G57	2019	Dublin, Ireland	https://www.thesportschronicle.com/rugby/george-kruis-england-rugby/
Ok, L29	2019	Could not be determined	https://thevistek.com/cbd-and-sports-performance-a-summary-review-of-cannabidiols-role-in-professional-sports/
PR Newswire60	2019	Las Vegas, USA	https://mjobserver.com/investments/aurora-cannabis-and-ufc-launch-clinical-research-on-use-of-hemp-derived-cbd-products-by-mma-athletes/
Reed, D61	2019	California, USA	https://www.cbdtoday.com/john-isner-joins-growing-list-of-pro-athletes-promoting-cbd/
Ennette, F46	2019	Could not be determined	https://basketballsocietyonline.com/how-cbd-is-introducing-itself-to-basketball
Keller, J62	2019	Could not be determined	https://investingnews.com/innspired/cannabinoids-medical-cannabis-health-and-wellness/
Hudson, R47	2019	Could not be determined	https://www.boxrox.com/cbd-optimise-performance-recovery/
Frometa, R.J28	2019	Could not be determined	https://ventsmagazine.com/2019/07/07/hemp-and-cbd-oil-taking-the-world-by-storm-for-athletes-and-chronic-pain-sufferers/
Brooke, A45	2019	Weymouth, MA. USA	https://blog.lhasaoms.com/product-reviews/cbd-and-acupuncture-a-powerful-combination-for-sports-recovery-and-performance/
English, N32	2019	New York, USA	https://barbend.com/cbd-athletes/
Sappal, A63	2019	Las Vegas, USA	https://www.freedomleaf.com/cbd-athletes-sports/
Stober, E64	2019	Toronto, Canada	https://greencamp.com/cannabis-and-sports/
XWERKS35	2019	Texas, USA	https://ministryofhemp.com/blog/cbd-for-recovery/
Mackinnon, S58	2019	Ontario, Canada	https://triathlonmagazine.ca/feature/is-cannabis-the-next-recovery-secret/
Reed, D65	2019	California, USA	https://www.cbdtoday.com/eaze-to-exclusively-deliver-former-nba-star-paul-pierces-new-cbd-line/
Kaplan, E66	2019	Could not be determined	https://www.espn.com/nhl/story/_/id/26046596/is-nhl-future-marijuana-pro-sports-why-be
Omax Health27	2019	California, USA	https://www.biospace.com/article/releases/omax-health-launches-cryofreeze-cbd-pain-relief-roll-on-for-joints-and-amp-muscles/
Corso, J31	2019	Georgia, USA	https://www.singletracks.com/blog/mtb-training/cbd-and-mountain-biking/
Reed, D67	2019	California, USA	https://www.cbdtoday.com/pro-athletes-taking-cbd-research-into-their-own-hands/
Hughes, E68	2019	Could not be determined	http://theharvestinvestor.com/2019/07/07/former-nba-player-al-harrington-says-sports-need-to-embrace-pot/
Harris, R69	2019	Florida, USA	http://balleralert.com/profiles/blogs/paul-pierce-launches-cbd-company-the-truth-will-target-athletes/
Medical Marijuana, Inc.70	2019	San Diego, USA	https://www.biospace.com/article/releases/u-s-paralympic-athlete-samantha-tucker-joins-medical-marijuana-inc-subsidiary-kannaway-sports-team/
Reed, D71	2019	Los Angeles, USA	https://www.cbdtoday.com/cbdmd-becomes-an-official-professional-basketball-sponsor/
Whyno, S72	2018	New York, USA	https://www.apnews.com/18bcef171ffe49a7a832453d9d101b8b
Jewell, J33	2018	Texas, USA	https://ministryofhemp.com/blog/endurance-athletes-use-cbd/
Stober, E55	2019	Toronto, Canada	https://greencamp.com/toronto-wolfpack-will-be-first-pro-sports-team-to-launch-own-cbd-product/
Pickering, E34	2018	Texas, USA	https://ministryofhemp.com/blog/cbdmedic-active-sport-ointment/

the use of cannabidiol (CBD oil) on pain and inflammation in professional sports?" Nine recurring themes appeared across the 33 eligible records – full details can be seen under Table 3. The themes included purported use of cannabidiol [for]:

1 Recovery.
2 Reducing pain.
3 Reducing inflammation.
4 Reducing anxiety.
5 Improving sleep.
6 Reducing stress.
7 Although there is poor supporting evidence for its use.
8 As it has no psychoactive properties.
9 As a natural/safer alternative to more commonly prescribed medication(s) such as NSAIDs and opioid based pain killers.

As Table 3 shows, the three most common themes for the use of cannabidiol were; the use of cannabidiol in reducing pain, as a recovery agent, and as an anti-inflammatory. The least common themes identified included using cannabidiol to improve sleep, the lack of evidence supporting the use of cannabidiol and the use of cannabidiol to reduce anxiety.

DISCUSSION

The scope of this review was to map and report on any current and existing literature on the use of cannabidiol in professional sports by searching both the white and grey literature for sources of information. The key themes that emerged from the literature search are discussed in the following paragraphs, with focus primarily on the three most common themes; cannabidiol for reducing pain, as a recovery agent, and for reducing inflammation. Other themes to appear in the literature, such as cannabidiol improving sleep or reducing anxiety, are not discussed due to comparatively little supporting literature.

Cannabidiol for reducing pain

The most common theme was the "use of cannabidiol for reducing pain" which was referenced in 24 blogs and all 3 white literature records. All three white literature records were magazine articles, traditionally regarded as low quality evidence, published in what appear to be non-peer reviewed journals.[24-26] Each record quoted anecdotally the pain-relieving properties of cannabidiol.[24-26] One article's[24] statements were further supported by two references: the first, a review published in 2008 of preclinical studies and animal trials by a pharmaceutical company which found the use of cannabidiol successful for pain management without any adverse side effects.[24] The second, an animal study published in 2016 which found cannabidiol to be effective in reducing pain and inflammation in arthritic rats.[37] While neither study was specific to cannabidiol use in sports, however, one of these discussed the benefits of topical cannabidiol application

Table 3: Summary of the thematic analysis.

Grey Literature - Blogs										
Author	**Year**	**Recovery**	**Reduce Pain**	**Anti-Inflammatory**	**Reduce Anxiety**	**Improve Sleep**	**Reduce Stress**	**Poor Evidence**	**Non-Psychoactive**	**Natural/Safer Alternative**
Petkovic, B30	2019		✓	✓	✓	✓	✓	✓		
Raimondi, M48	2019		✓	✓	✓			✓	✓	
Vegotsky, J59	2019	✓	✓	✓	✓		✓		✓	
Kruis, G57	2019				✓	✓	✓	✓		✓
Ok, L29	2019	✓	✓	✓	✓					
PR Newswire60	2019	✓	✓	✓						
Reed, D61	2019	✓	✓						✓	✓
Ennette, F46	2019	✓	✓	✓		✓	✓		✓	
Keller, J62	2019	✓								
Hudson, R47	2019	✓	✓	✓	✓		✓		✓	
Frometa, R.J28	2019		✓							✓
Brooke, A45	2019	✓	✓	✓		✓	✓		✓	✓
English N32	2019		✓	✓						✓
Sappal, A63	2019	✓	✓	✓	✓				✓	
Stober, E64	2019	✓	✓	✓					✓	
XWERKS35	2019	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mackinnon, S58	2019	✓	✓	✓	✓			✓		
Reed, D65	2019									✓
Kaplan, E66	2019		✓						✓	✓
Omax Health27	2019	✓	✓							
Corso, J31	2019	✓	✓	✓	✓			✓		✓
Reed, D67	2019		✓							✓
Hughes, E68	2019	✓	✓				✓		✓	✓
Harris, R69	2019				✓		✓		✓	✓
Medical Marijuana, Inc.70	2019	✓								
Reed, D71	2019	✓	✓							✓
Whyno, S72	2019	✓	✓	✓	✓		✓	✓		✓
Jewell, J33	2019	✓	✓	✓	✓		✓	✓		✓
Stober, E55	2019		✓	✓					✓	
Pickering, E34	2019	✓	✓	✓						
Sub-total		18	24	17	11	5	10	7	13	15
White Literature – Articles										
Averill, G24	2018	✓	✓	✓	✓	✓				✓
Beall, J25	2019	✓	✓	✓				✓		
Lee, C26	2017	✓	✓	✓						✓
Sub-total		3	3	3	1	1	0	1	0	2
Grand Total		21	27	20	12	6	10	8	13	17

versus oral application[24] which may have implications in a sporting context. The authors suggested that with oral ingestion cannabidiol may be broken down too fast in the digestive tract to be absorbed into the blood stream, therefore potentially not providing as effective an analgesic as via topical application.[24]

Twenty-four blogs reported cannabidiol was effective for reducing pain. One of the 24 blogs had limited relevance to the research question as it was a news article promoting a product from another agency. It was included as it advertised the benefits of a cannabidiol product, aimed specifically for athletes and pain relief. However, their statements had no supporting literature.[27] Sixteen blogs had no references to support their statements of cannabidiol being effective for pain relief, however, three blogs were supported by further blogs,[28-30] and five blogs were either supported directly by studies cited in-text, or indirectly by studies found in another blog they referenced.[31-35] A total of nine studies were referenced in the five blogs. Five of these were animal studies supporting the use of cannabidiol for pain relief.[36-40] One study was a review of the effect of cannabidiol on inflammation and how this may reduce pain41 while two studies were not relevant to cannabidiol and pain and so did not support the statements made in the blogs.[42,43]

Ultimately, no studies were relevant to the use of cannabidiol in reducing pain in sports, which might explain why they were not found in this scoping review's traditional white literature search.

Finally, one study was a report surveying 2,400 participants and found that 80% of participants reported cannabidiol to be very or extremely effective for pain, and that cannabidiol was most commonly used to treat anxiety, insomnia, joint pain/inflammation and depression.[44] This report also suggested that 43% of cannabidiol-dominant and hemp-derived cannabidiol users now use cannabis instead of other medications to treat their conditions, and that 40% of marijuana-derived

cannabidiol-only users similarly only use cannabis to treat their conditions.[44] Although this study sounds promising, supporting the use of cannabidiol as an analgesic it appears to have only been performed on a biased population who were HelloMD subscribers – a medical cannabis education and advocacy website (https://hellomd.com/) where participants in the study were already using medicinal cannabis products.

With little evidence in the white literature, it would appear there are some grounds to consider assessing the use of cannabidiol for pain relief. Many of the resulting blogs made mention of cannabidiol potentially acting on or mimicking the endocannabinoid system, in turn reducing pain.[30,32,45-47] According to the WHO report,[2] however, these statements are unsubstantiated as it is suggested that cannabidiol may not in-fact act directly at CB1 or CB2 receptors in the same way that tetrahydrocannabinol may, but instead may act on alternative systems in the body to alleviate pain. Similarly, one blog[31] suggested that cannabidiol acted in a similar way to non-steroidal anti-inflammatories; inhibiting cyclooxygenase/prostaglandin and lipoxygenase pathways and two inflammatory biomarkers (involved in training adaptations). This does question the credibility of some statements made in some of the literature sourced in this scoping review, but in turn highlights how unclear and sparse the scientific literature surrounding the use of cannabidiol in sports is, a point acknowledged in at least one of the blogs reviewed.[48]

Cannabidiol as a recovery agent

The second most common theme carried by 18 blogs and all three white literature studies discussed the role of cannabidiol as a recovery agent for athletes.

All three articles in the white literature search made anecdotal claims supporting the use of cannabidiol as a recovery agent.[24-26] However, none of these claims were underpinned by any research. Eighteen blogs supported the use of cannabidiol as a recovery agent. Upon closer inspection only one blog offered supporting literature.[35] This supporting article, however, did not focus on cannabidiol as a recovery agent in a sporting context,49 which might explain why it was not found in the initial white literature search of this scoping review. This leads to suggest that the use of cannabidiol as a recovery agent following sports participation may only be recommended anecdotally as there is no evidence to support its use.

Cannabidiol as an anti-inflammatory agent

The third most common theme with 17 blogs and all three white literature opinion articles discussed the role cannabidiol may play in reducing inflammation. All three opinion articles anecdotally claimed cannabidiol was an effective anti-inflammatory in sports,[24-26] including one from the perspective of a professional athlete who advocated the use of cannabidiol for improving hip pain.[24] This narrative review[24] suggested that cannabidiol was anecdotally becoming the drug of choice for managing inflammation over more commonly prescribed anti-inflammatories such as ibuprofen; a view shared by 17 blogs (Table 3). None of these views, however, were supported by references or clinical trials advocating efficacy and safety of cannabidiol over more readily prescribed anti-inflammatories. Averill's statements[24] were, on the other hand, supported by the same study cited previously which found cannabidiol effective in reducing inflammation and overall pain in arthritic rats.[37]

Seventeen blogs purported that cannabidiol could be used as an anti-inflammatory, however, many of the claims made were unsubstantiated. Two blogs referenced further blogs to support their statements, however, these blogs did not have any supporting research data.[29,30] One blog[32] referenced a literature review summarising how cannabidiol effects inflammation; specifically, the biochemistry of how cannabidiol acts on the body.[41] Another blog[35] referenced three articles supporting cannabidiol as an anti-inflammatory[49-51] and a National Cancer Institute document which suggested cannabidiol had a significant anti-inflammatory effect without the psychoactive effect of THC.[52] One blog[33] referenced another blog from the same website which had two United States Patents promoting the use of cannabidiol for reducing inflammation.[53,54] As previously discussed, this blog[33] also referenced the HelloMD study[44] which advocated cannabidiol for reducing inflammation. One blog[55] referenced two further blogs promoting the use of cannabidiol for reducing inflammation. Finally, one blog[34] referenced a further three blogs – one of which had no supporting literature, one of which was referenced by one previously discussed blog in this review,[33] and another which referenced a previously discussed study[40] who also supported the use of cannabidiol in reducing pain. None of the supporting literature, however, was specific to sports which might explain why it was not found in this scoping review search.

Scoping reviews map the literature by including all information, of varying degrees of quality, thus identifying gaps in knowledge and allowing readers to get a "feel" of the body and type of evidence available.[56] This style of data collection and reporting inherently identifies whether a full systematic review is feasible with the literature available.[19] The aim of this scoping review was to map the existing literature on the use of cannabidiol in professional sports. A large gap in the scientific literature was identified which is important for clinicians working within professional sports to recognise, as it is their responsibility to keep on top of evolving subjects and "hot" topics in order to provide an evidence-based service to the athletes they work with. In this day and age athletes have access to information on supplements and drugs through the internet and social media. As such, clinicians need to be one step ahead and the current study did this. We were able to identify that whilst cannabidiol may be legal for athletes to use under the World Anti-Doping Agency code, there are currently no clinical trials on the use of cannabidiol in sports, nor were any clinical trials being planned (according to the databases searched). What appeared to be some of the strongest and most referenced literature, in-fact, focussed on animal studies observing the potential beneficial effects cannabidiol has on various ailments, rather than the potential uses of cannabidiol in a sporting context. Furthermore, this study was able to identify that some products may carry a potential contamination risk for which athletes could be sanctioned.

The lack of clinical trials may be reflective of the previous nature of marijuana being a schedule 1 drug in USA thus making it hard to access in order to perform clinical trials – a view acknowledged in one of the narrative reviews.[24] Equally, the lack of clinical trials or literature – as acknowledged by eight records[24,30,31,33,35,48,57,58] – may be because cannabidiol is now easily accessible to the public in countries like USA and Great Britain, suggesting pharmaceutical companies have no incentive to perform clinical trials to justify its efficacy.[24] This leaves advertising companies to sell the purported benefits of cannabidiol to the general public, which may explain why some commercial material was found in the traditional white literature search. This carries its own risks as companies

may inadvertently advertise products with potential side effects that have not yet been tested or proven.

Study limitations

This scoping review is the first of its kind to investigate the literature supporting the use of cannabidiol in sports, following a recognised scoping review methodology which incorporated both white and grey literature. However, this pioneering study is not without limitations. Time constraints allowed for only the first four pages of blog search results to be reviewed. More time would have allowed for more blogs to be analysed, although based on the sample examined it is unlikely that any new themes or supporting evidence were likely to emerge is it appeared that the same references were used to support the use of cannabidiol for a number of conditions. Some of the records identified in the search were inaccessible within the timeframe of the study. Some of the documents identified in the search were not in English, and only literature focussing specifically on the use of cannabidiol in a sporting context was considered. Texts focussing on more global products and terms such as medical marijuana were not considered, however, these may have provided more information of indirect relevance.

Implications for future research

The findings of this scoping review suggest that the scientific literature on the use of cannabidiol in sports of any participation level is sparse and wanting. Thus potential for clinical trials or original research using cannabidiol in professional sports is vast. Simple anonymous questionnaires could investigate athletic populations both within and between sporting groups to identify what percentage of athletes in each sport currently use cannabidiol. High quality trials on humans are also required, not only to compare cannabidiol to more readily prescribed analgesics and anti-inflammatories, but to draw conclusions on its efficacy compared to already proven recovery modalities such as contrast water therapy, massage and compression gear.

CONCLUSION

Despite the anecdotal claims by athletes supporting the use of cannabidiol, there remains a vast gap in the scientific literature supporting the use of cannabidiol in professional sports. This scoping review was unable to source any studies supporting the use of cannabidiol in professional sports, and so thorough clinical trials are required to allow conclusions to be drawn on its efficacy. The un-regulated market and lack of literature does not currently support the use of cannabidiol in professional sports, leaving athletes at risk of taking contaminated supplements, inadvertently causing bodily harm, or simply becoming victims of exploitation.

FUNDING

This scoping review was conducted as part of a Master's project at the University of Otago's School of Physiotherapy and was not funded in any way.

AUTHOR AFFILIATIONS

Benjamin Venn

School of Physiotherapy, University of Otago, Dunedin, New Zealand

S John Sullivan

Centre for Health, Activity and Rehabilitation Research , School of Physiotherapy, University of Otago, Dunedin, New Zealand

REFERENCES

1 Grinspoon P. Cannabidiol (CBD) - what we know and what we don't [Internet]: Harvard Medical School. 2018. [cited 2019]. Available from: https://www.health.harvard.edu/blog/cannabidiol-cbd-what-we-know-and-what-we-dont-2018082414476

2. World Health Organization. Cannabidiol (CBD). Pre-Review Report. Agenda Item 5.2. Geneva 2017. Available from: https://www.who.int/medicines/access/controlled-substances/CannabidiolCriticalReview.pdf.

3. Project CBD. What is CBD? 2019 [cited 2019 Jul]. Available from: https://www.projectcbd.org/cbd-101/what-is-cbd

4. United States Anti-Doping Agency. Athletes: 6 Things to Know About Cannabidiol. 2018 [cited 2019 Aug]. Available from: https://www.usada.org/spirit-of-sport/education/six-things-know-about-cannabidiol/.

5. World Anti-Doping Agency. Is cannabidiol (CBD) oil probihited? 2019 [cited 2020 Feb]. Available from: https://www.wada-ama.org/en/questions-answers/cannabinoid.

6. UFC Staff Report. Aurora Cannabis and UFC join forces to advance CBD research, education, and product development. 2019 [cited 2019 Aug]. Available from: https://www.ufc.com/news/aurora-cannabis-and-ufc-join-forces-advance-cbd-research-education-and-product-development.

7. Tyson Ranch. Better Cannabis. 2019 [cited 2019 Jul]. Available from: https://tysonranch.com/home-construction/

8. Ministry of Health. CBD products. Wellington: New Zealand Governement; 2019 [cited 2019 Jun]. Available from: https://www.health.govt.nz/our-work/regulation-health-and-disability-system/medicines-control/medicinal-cannabis/cbd-products.

9. Newton K. Medical cannabis oil arrives in NZ. Wellington: Radio New Zealand; 2017 [cited 2019 Apr]. Available from: https://www.rnz.co.nz/news/national/345752/medicinal-cannabis-oil-arrives-in-nz

10. Bonn-Miller MO, Loflin MJE, Thomas BF, Marcu JP, Vandrey R. Labeling accuracy of cannabidiol extracts sold online. JAMA. 2017;318(17):1708-1709.

11. Powell J. Cannabidiol for adjuvant treatment of seizures associated with Dravet syndrome [ID1211]. London: National Institute for Health and Care Excellence.; 2019 [cited 2019 Aug]. Available from: https://www.nice.org.uk/guidance/indevelopment/gid-ta10274.

12. Powell J. Cannabidiol for adjuvant treatment of seizures associated with Lennox-Gastaut syndrome [ID1308]. London: National Institute for Health and Care Excellence.; 2019 [cited 2019 Aug]. Available from: https://www.nice.org.uk/guidance/indevelopment/gid-ta10410.

13. Schraer R. CBD oil: Have the benefits been overstated? London: BBC News; 2019 [cited 2019 Sep]. Available from: https://www.bbc.com/news/health-48950483.

14. Campos AC, Moreira FA, Gomes FV, del Bel EA, Guimarães FS. Multiple mechanisms involved in the large-spectrum therapeutic potential of cannabidiol in psychiatric disorders. Philos Trans R Soc Lond B Biol Sci. 2012;367(1607):3364-3378.

15. Maroon J, Bost J. Review of the neurological benefits of phytocannabinoids. Surg Neurol Int. 2018;9:91.

16. Alvarez FJ, Lafuente H, Rey-Santano MC, Mielgo, VE, Gastiasoro E, Rueda M, Pertwee RG, Castillo AI, Romero J, Martínez-Orgado, J. Neuroprotective effects of the nonpsychoactive cannabinoid cannabidiol in hypoxic-ischemic newborn piglets. Pediatr Res. 2008;64(6):653-658.

17. Tishchenko D. The medicinal benefits of CBD oil and medical cannabis. United Kingdom: Open Access Government; 2019 [cited 2019 Jun]. Available from: https://www.openaccessgovernment.org/medicinal-benefits-of-cbd/64896/.

18. Kogan NM, Melamed E, Wasserman E, Raphael, B. Breuer A, Stok KS, Sondergaard R, Escudero AVV, Baraghithy S, Attar-Namdar M, Friedlander-Barenboim S, Mathavan N, Isaksson H, Mechoulam R, Müller R, Bajayo A, Gabet Y, Bab I. Cannabidiol, a major non-psychotropic cannabis constituent enhances fracture healing and stimulates lysyl hydroxylase activity in osteoblasts. J Bone Miner Res. 2015;30(10):1905-1913.

19. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19-32.

20. Aromataris E, Munn Z, (Editors). Scoping reviews. 2017. In: Joanna Briggs Institute Reviewer's Manual [Internet]. University of

Adelaide, South Australia Available from: https://reviewersmanual.joannabriggs.org/.

21. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, Hempel S, Akl EA, Chang C, McGowan J, Stewart L, Hartling L, Aldcroft A, Wilson MG, Garritty C, Lewin S, Godfrey CM, MacDonald MT, Langlois EV, Soares-Weiser K, Moriarty J, Clifford T, Tunçalp Ö, Straus SE. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med. 2018;169(7):467-473.
22. Bonato S. Searching the Grey Literature. A handbook for searching reports, working papers, and other unpublished research. 1st ed: Rowman & Littlefield; 2018 June 13.
23. Terry G, Hayfield N, Clarke V, Braun V. Thematic Analysis. In: Willig C, Stainton Rogers W, editors. The SAGE Handbook of Qualitative Research in Psychology. London: SAGE Publications Ltd; 2017.
24. Averill G. Why Athletes Are Ditching Ibuprofen for CBD. 2018 [cited 2018 May]. Available from: https://www.outsideonline.com/2296261/athletes-ditching-ibuprofen-cbd-marijuana.
25. Beall J. Players are using and endorsing CBD, but the PGA Tour is wary. 2019 [cited 2019 Aug]. Available from: https://www.golfdigest.com/story/players-are-using-and-endorsing-cbd-but-the-pga-tour-is-wary.
26. Lee C. The Need for Weed. Men's Fitness [Internet]. 2017 2019 Jul [cited 2019 Jul]; 33(3):[96-101 pp.]. Available from: https://mensfitnessmagazine.com.au/marijuana-for-recovery/.
27. Omax Health. Omax Health launches CryoFreeze CBD pain relief roll-on for joints & muscles. BioSpace [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.biospace.com/article/releases/omax-health-launches-cryofreeze-cbd-pain-relief-roll-on-for-joints-and-amp-muscles/
28. Frometa RJ. Hemp and CBD oil taking the world by storm for athletes and chronic pain sufferers. VENTS Magazine [Internet]. 2019 [cited 2019 Aug]. Available from: https://ventsmagazine.com/2019/07/07/hemp-and-cbd-oil-taking-the-world-by-storm-for-athletes-and-chronic-pain-sufferers/
29. Ok L. CBD and sports performance. A summary review of cannabidiol's role in professional sports. The Vistek [Internet]. 2019 [cited 2019 Aug]. Available from: https://thevistek.com/cbd-and-sports-performance-a-summary-review-of-cannabidiols-role-in-professional-sports/.
30. Petkovic B. CBD in Professional Sports: How Safe Is It? Big Easy Magazine [Internet]. 2019 Aug [cited 2019 Sep]. Available from: https://www.bigeasymagazine.com/2019/08/06/cbd-in-professional-sports-how-safe-is-it/.
31. Corso J. CBD and mountain biking: will it help my training? Singletracks [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.singletracks.com/blog/mtb-training/cbd-and-mountain-biking/
32. English N. What every athlete should know about CBD. BarBend [Internet]. 2019 [cited 2019 Aug]. Available from: https://barbend.com/cbd-athletes/
33. Jewell J. How endurance athletes use CBD: CBD oil helps you go the extra mile. Ministry of Hemp [Internet]. 2018 [cited 2019 Aug]. Available from: https://ministryofhemp.com/blog/endurance-athletes-use-cbd/.
34. Pickering E. CBDMEDIC active sport ointment relieves aches & pains to keep you exercising. Ministry of Hemp [Internet]. 2018 [cited 2019 Aug]. Available from: https://ministryofhemp.com/blog/cbdmedic-active-sport-ointment/.
35. XWERKS. CBD for recovery: How elite athletes use CBD for recovery. Ministry of Hemp [Internet]. 2019 [cited 2019 Aug]. Available from: https://ministryofhemp.com/blog/cbd-for-recovery/
36. Costa B, Trovato AE, Comelli F, Giagnoni G, Colleoni M. The non-psychoactive cannabis constituent cannabidiol is an orally effective therapeutic agent in rat chronic inflammatory and neuropathic pain. Eur J Pharmacol. 2007;556(1-3):75-83.
37. Hammell DC, Zhang LP, Ma F, Abshire SM, McIlwrath SL, Stinchcomb AL, Westlund KN. Transdermal cannabidiol reduces inflammation and pain-related behaviours in a rat model of arthritis. Eur J Pain. 2016;20(6):936-948.
38. Malfait AM, Gallily R, Sumariwalla PF, Malik AS, Andreakos E, Mechoulam R, Feldmann M. The nonpsychoactive cannabis constituent cannabidiol is an oral anti-arthritic therapeutic in murine collagen-induced arthritis. Proc Natl Acad Sci U S A. 2000;97(17):9561-9566.
39. Philpott HT, O'Brien M, McDougall JJ. Attenuation of early phase inflammation by cannabidiol prevents pain and nerve damage in rat osteoarthritis. Pain. 2017;158(12):2442-2451.
40. Xiong W, Cui T, Cheng K, Yang F, Chen SR, Willenbring D, Guan Y, Pan HL, Ren K, Xu Y, Zhang L. Cannabinoids suppress inflammatory and neuropathic pain by targeting α3 glycine receptors. J Exp Med. 2012;209(6):1121-1134.
41. Burstein S. Cannabidiol (CBD) and its analogs: a review of their effects on inflammation. Bioorg Med Chem. 2015 Apr 1;23(7):1377-1385.
42. Klauke AL, Racz I, Pradier B, Markert A, Zimmer AM, Gertsch J, Zimmer A. The cannabinoid CB<inf>2</inf> receptor-selective phytocannabinoid beta-caryophyllene exerts analgesic effects in mouse models of inflammatory and neuropathic pain. Eur Neuropsychopharmacol. 2014;24(4):608-620.
43. Woodhams SG, Sagar DR, Burston JJ, Chapman V. The role of the endocannabinoid system in pain. Handbook of Experimental Pharmacology2015. p. 119-143.
44. Understanding Cannabidiol / CBD. Industry Expert Report [Electronic article]. Brightfield Group; 2017. Available from: https://daks2k3a4ib2z.cloudfront.net/595e80a3d32ef41bfa200178/59946dd86c6b200001c5b9cb_CBD_-_HelloMD_Brightfield_Study_-_Expert_Report_-_FINAL.pdf.
45. Brooke A. CBD and acupuncture: A powerful combination for sports recovery and performance. . LHASA OMS [Internet]. [cited 2019 Aug]. Available from: https://blog.lhasaoms.com/product-reviews/cbd-and-acupuncture-a-powerful-combination-for-sports-recovery-and-performance/
46. Ennette F. How CBD is introducing itself to basketball. Basketball Society Online [Internet]. 2019 [cited 2019 Aug]. Available from: https://basketballsocietyonline.com/how-cbd-is-introducing-itself-to-basketball
47. Hudson R. How to use CBD (Cannabidiol) to optimise your performance and recovery. BOXROX [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.boxrox.com/cbd-optimise-performance-recovery/
48. Raimondi M. Nate Diaz lights up joint at UFC open workout.: ESPN; 2019 [cited 2019 Nov]. Available from: https://www.espn.com/mma/story/_/id/27389706/nate-diaz-lights-joint-ufc-open-workout.
49. Booz GW. Cannabidiol as an emergent therapeutic strategy for lessening the impact of inflammation on oxidative stress. Free Radic Biol Med. 2011;51(5):1054-1061.
50. Iffland K, Grotenhermen F. An Update on Safety and Side Effects of Cannabidiol: A Review of Clinical Data and Relevant Animal Studies. Cannabis Cannabinoid Res. 2017;2(1):139-154.
51. Rudroff T, Sosnoff J. Cannabidiol to Improve Mobility in People with Multiple Sclerosis. Front Neurol. 2018;9:183.
52. PDQ® Integrative A, and Complementary Therapies Editorial Board,. Cannabis and Cannabinoids (PDQ®)–Health Professional Version. [PMID: 26389198] Bethesda, MD: National Cancer Institute; [updated Jan 7 2020]. Available from: https://www.cancer.gov/about-cancer/treatment/cam/hp/cannabis-pdq.
53. Lowe GA, Lowe V, inventors. Composition of cannabinoids, odorous volatile compounds, and Emu oil for topical application, and a method for cannabinoid transdermal delivery. . United States patent US9526752B1. 2016.
54. Wallace W, inventor. Method of relieving analgesia and reducing inflammation using a cannabinoid delivery topical liniment. patent US6949582B1. 2002.
55. Stober E. Toronto Wolfpack will be first pro sports team to launch own CBD product. Greencamp [Internet]. 2019 [cited 2019 Aug]. Available from: https://greencamp.com/toronto-wolfpack-will-be-first-pro-sports-team-to-launch-own-cbd-product/.

56. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1).
57. Kruis G. Culture Club. . The Sports Chronicle [Internet]. 2019 Aug [cited 2019 Aug]. Available from: https://www.thesportschronicle.com/rugby/george-kruis-england-rugby/.
58. Mackinnon S. Is cannabis the next recovery secret? What role does CBD play in sport? Triathlon Magazine Canada [Internet]. 2019 [cited 2019 Aug]. Available from: https://triathlonmagazine.ca/feature/is-cannabis-the-next-recovery-secret/
59. Vegotsky J. Game-Changer: Top Athletes Turn to CBD. 2019 [cited 2019 Aug]. Available from: https://www.cbdtoday.com/game-changer-top-athletes-turn-to-cbd/.
60. Aurora Cannabis and UFC launch clinical research on use of hemp-derived CBD products by MMA athletes. . Daily Marijuana Observer [Internet]. 2019 [cited 2019 Aug]. Available from: https://mjobserver.com/investments/aurora-cannabis-and-ufc-launch-clinical-research-on-use-of-hemp-derived-cbd-products-by-mma-athletes/.
61. Reed D. John Isner joins growing list of pro athletes promoting CBD. CBD Today [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.cbdtoday.com/john-isner-joins-growing-list-of-pro-athletes-promoting-cbd/
62. Keller J. Why cannabis health products are gaining momentum. CANNABIS: Investing News [Internet]. 2019 [cited 2019 Aug]. Available from: https://investingnews.com/innspired/cannabinoids-medical-cannabis-health-and-wellness/
63. Sappal A. CBD catching on among professional athletes like Rob Gronkowski. FreedomLeaf [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.freedomleaf.com/cbd-athletes-sports/.
64. Stober E. The current state of cannabis use in sports. Greencamp [Internet]. 2019 [cited 2019 Aug]. Available from: https://greencamp.com/cannabis-and-sports/
65. Reed D. Eaze to exclusively deliver former NBA star Paul Pierce's new CBD line. CBD Today [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.cbdtoday.com/eaze-to-exclusively-deliver-former-nba-star-paul-pierces-new-cbd-line/
66. Kaplan E. Is the NHL the future of marijuana in pro sports? Why it could be: ESPN; 2019 [cited 2019 Aug]. Available from: https://www.espn.com/nhl/story/_/id/26046596/is-nhl-future-marijuana-pro-sports-why-be.
67. Reed D. Pro athletes taking CBD research into their own hands. CBD Today [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.cbdtoday.com/pro-athletes-taking-cbd-research-into-their-own-hands/
68. Hughes E. Former NBA player Al Harrington says sports need to embrace pot. The Harvest Investor [Internet]. 2019 [cited 2019 Aug]. Available from: http://theharvestinvestor.com/2019/07/07/former-nba-player-al-harrington-says-sports-need-to-embrace-pot/.
69. Harris E. Paul Pierce launches CBD company "The Truth" will target athletes with mental and physical ailments. Baller Alert [Internet]. 2019 [cited 2019 Aug]. Available from: http://balleralert.com/profiles/blogs/paul-pierce-launches-cbd-company-the-truth-will-target-athletes/
70. Medical Marijuana Inc. U.S. Paralympic athlete Samantha Tucker joins Medical Marijuana, Inc. subsidiary Kannaway Sports team. BioSpace [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.biospace.com/article/releases/u-s-paralympic-athlete-samantha-tucker-joins-medical-marijuana-inc-subsidiary-kannaway-sports-team/.
71. Reed D. CBDMD becomes an official professional basketball sponsor. CBD Today [Internet]. 2019 [cited 2019 Aug]. Available from: https://www.cbdtoday.com/cbdmd-becomes-an-official-professional-basketball-sponsor/.
72. Whyno S. NHL stays with status quo as Canada pot legalization looms. APNews [Internet]. 2018 [cited 2019 Aug]. Available from: https://www.apnews.com/18bcef171ffe49a7a832453d9d101b8b.

APPENDIX 1
Grey Literature Search Strategies

ProQuest Dissertations & Thesis
(CBD OR cannabidiol) AND sport*
Filtered: 2010-2019
Filtered: English only
Filtered: public health, physiology, studies, medicine, biology, no ProQuest subject assigned

Pubmed, Cochrane Library and World Health Organization International Clinical Trials Registry Platform Search Portal
cannabidiol OR CBD OR "medical cannabis" OR "medical marijuana" OR marijuana OR cannabis OR hashish
AND
Sport* OR player* or athlete*
AND
pain OR "pain relief" OR "pain management" OR analgesia OR "pain control" OR inflam*

ANZCTR
A simplified search was used due to the available search parameters on the website.
"cannabidiol OR CBD OR "medical marijuana" AND sport* OR athlete* AND pain* OR inflam*"

ClinicalTrials.gov
A simplified search used due to the available search parameters on the website.
Cannabidiol OR CBD OR "medical marijuana" AND sport* OR athlete* AND pain*
OR inflam*

Google Blog Search
cannabidiol OR CBD OR "medical cannabis" OR "medical marijuana" OR marijuana OR cannabis OR hashish AND Sport* OR player* or athlete* AND pain OR "pain relief" OR "pain management" OR analgesia OR "pain control" OR inflam*
Results were adjusted to "most recent" and "relevance".

Extensor digitorumbrevis manus muscle: An unusual case of dorsal wrist pain and swelling with weightlifting

SIM HWEI SIAN SHAUNA AND ONG JOO HAW

See end of article for author affiliations.

Correspondence
Dr Shauna Sim
Email: sim.shauna.christine@ktph.com.sg
Tel: (+65) 91381019
Khoo Teck Puat Hospital
90 Yishun Central, Singapore 768828

INTRODUCTION

Dorsal wrist pain and swelling is a common presentation in the setting of sports medicine. The more commonly encountered etiology includes tendonitis or tenosynovitis and ganglion cysts. Accessory muscles of the extensor compartment of the hand are rare, but should be considered as a potential cause. First described in 1734, the extensor digitorum brevis manus (EDBM) muscle is an accessory muscle of the extensor compartment of the wrist and hand, with an incidence of 2.3% in cadaveric studies reported in a recent pooled systemic review,[12] although earlier articles had described an incidence of 1-9%4,8. This article includes a case report of a patient with unilateral symptomatic EDBM who presented with wrist pain during exercise.

CASE REPORT

Patient was a 21-year-old male, who was serving in the military as an air force signaler, as part of his 2-year compulsory national service. He was right-handed and engaged in regular strength training. He had no pre-existing medical conditions.

He presented with a 6-week history of left wrist pain. This was precipitated by doing shoulder press and bench press as part of his routine gym exercises, and was noted to be worse with heavier weights. He had been doing similar exercises previously without any discomfort, but had recently increased the weight for these exercises. There was no precipitating fall or injury, and no prior episodes of wrist pain or injury. He denied any wrist swelling, instability, or upper limb numbness. The wrist pain was always accompanied by a feeling of tightness and sometimes difficulty fully extending his middle and ring fingers. The wrist pain did not affect any other activities of daily living, and did not occur with activities in the military including physical activity and sports.

On examination, there was a visible swelling over the dorsum of the left wrist, that was soft, not warm or tender, did not transilluminate and was not associated with any skin changes. Palpation of the wrist did not reveal any tenderness. Wrist range of motion was full, and there was no pain with resisted movements of the wrist. However, pain was reproduced with axial loading (pushing off a chair with the wrist in extension). Range of motion of all fingers was full and pain free, and there was no tenderness over the small joints of the hand. There were no neurovascular deficits.

Plain radiographs of the hand were ordered and revealed no abnormalities. An ultrasound done in clinic (figure 1) showed a hypoechoic swelling in the 4th extensor compartment, surrounding the extensor indices pollicis tendon. There was no vascularity within the swelling. A comparative ultrasound of the right wrist was done and this was unremarkable. A provisional diagnosis of an accessory muscle of the extensor compartment of the wrist was made. As symptoms were minimal, a referral was made to a hand therapist for a wrist splint and analgesia was prescribed. He was advised on activity modification and to temporarily stop lifting weights. He was also referred to physiotherapy for wrist extensor stretches and strengthening exercises.

He was reviewed 6 weeks later. During the

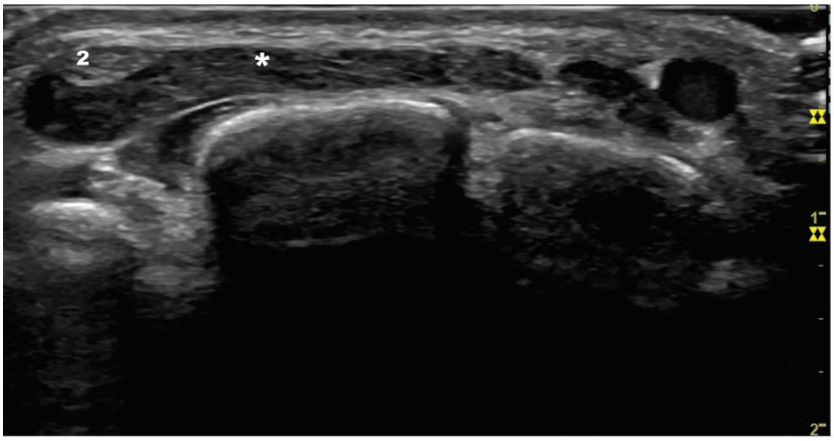

Figure 1a: Ultrasound of dorsum of wrist obtained in axial plane shows swelling (*) around extensor tendon of second digit (2). On closer inspection this has typical echo texture of muscle.

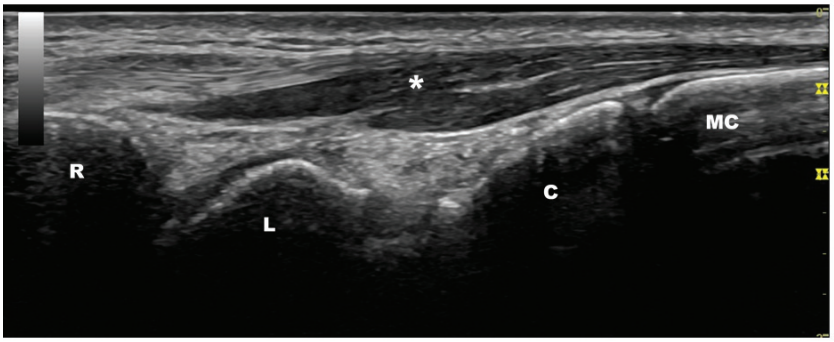

Figure 1b: Ultrasound of dorsum of wrist obtained in sagittal plane shows swelling in dorsum of wrist (*). On closer inspection this has typical echo texture of muscle. M = base of third metacarpal, C = capitate, L = lunate, R= radius.

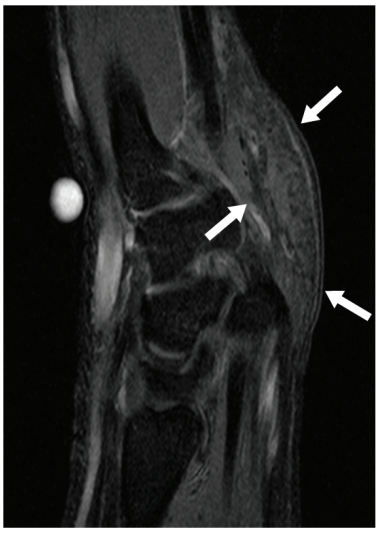

Figure 2a: A sagittal proton density fat suppressed (PD FS) MRI scan image of the wrist showing a mass (white arrows) in the dorsal aspect with typical appearance of muscle

Figure 2b: A sagittal T1 MRI scan image of the wrist showing a mass (white arrows) in the dorsal aspect with typical appearance of muscle

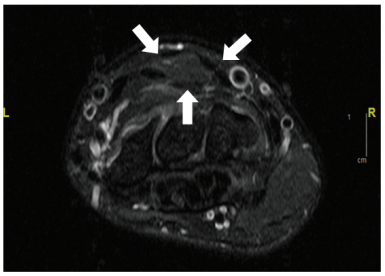

Figure 2c: An axial PD FS MRI scan image of the wrist showing a mass (white arrows) in the dorsal aspect with typical appearance of muscle

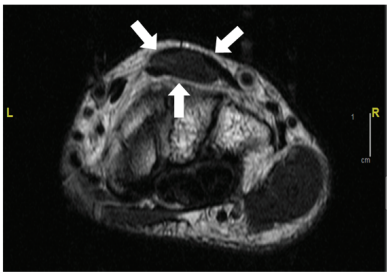

Figure 2d: An axial T1 MRI scan image of the wrist showing a mass (white arrows) in the dorsal aspect with typical appearance of muscle

initial period of rest his symptoms had resolved, however they had recurred with resumption of doing shoulder and bench press, even though he had not progressed back to full loads. The wrist swelling was still visible on examination, and the mass still present on ultrasound examination with no change in size or characteristics. In view of persistent symptoms, magnetic resonance imaging (MRI) of the wrist was ordered to further characterize this mass.

MRI showed a fusiform lesion underlying the marker showing signal characteristics of muscle extending over the dorsal surface of the wrist from the distal radius to the 2nd webspace (figure 2). It arose from the level of the distal radius deep to the extensor retinaculum and lay deep to the extensor digitorum tendon. There were no other abnormal findings.

On review after MRI, he had progressed with increasing his weight for bench press against medical advice. He reported symptoms were worse when his wrist went into extension to support the weight during bench and shoulder press, or when he flexed his wrist against resistance to complete the bench press. Symptoms were better with use of a wrist guard. He was advised to reduce the weights used during bench and shoulder press, and progress with wrist strengthening exercises and improve his technique before progressively increasing weights. He was also advised to use wrist supports, and against excessive weighted wrist extension exercises to reduce hypertrophy of the EDBM. On follow-up, he was coping well with a modified grip and change in bench press technique and hence not keen for further intervention.

DISCUSSION

In patients presenting with dorsal wrist swelling and pain in the absence of trauma, diagnosis including ganglion cysts, extensor tenosynovitis, metacarpal bossing, soft tissue tumours, and accessory muscles of the extensor compartment of the wrist should be considered.

Accessory muscles of the extensor compartment of the wrist include accessory EDBM, accessory extensor carpi radialis muscle and its variants, and variations of the extensor indices proprius (EIP).[4] This article focuses on the EDBM. The most common origin for the EDBM is the inside of the radiocarpal joint capsule, attaching either to the dorsal metacarpal surface, the distal end of the radius, or the proximal portion of the radiocarpal ligament.[5,9,12] The distal insertion of the EDBM is often joined to the EIP, which serves to extend the index finger, and the two muscles share the same innervation and blood supply from the posterior interosseous nerve and anterior interosseous artery, respectively.[9,12] When inserted on to the second finger it is sometimes termed the extensor indices brevis. Depending on its insertion it has also been termed the extensor digiti III brevis, extensor medius brevis, extensor brevis digiti indicis vel medii, extensor medii, and annularis brevis.[4,8] Ogura et al. classified the EDBM into three types on the basis of its insertion and relationship to the EIP: type I—inserted on to the dorsal aponeurosis of the index finger with the absence of EIP; type II—both the EIP and EDBM inserted on to the index finger; type III—EIP inserted on to the index finger and EDBM inserted on to the middle finger with or without an accessory EIP to the middle finger.[4,5]

Some studies have reported a slight predominance in males,[8] whilst other studies show no difference in incidence between right and left hands, different genders, and no familial inheritance.[2,4,5,8,12] Bilateral EDBM has been reported to occur in 26-50% of affected individuals.[2,5,9,12]

Accessory muscles of the extensor compartment of the wrist are rare, hence the literature in regard to diagnosis, imaging and management consists of isolated case reports and case series, with limited reviews of the literature available. The largest case series in the literature consists of 38 cases.[2]
EDBM is usually asymptomatic, being an incidental finding on imaging or in cadaveric studies. However, it can present with pain and discomfort, or dorsal wrist swelling, usually precipitated by repetitive wrist extension movements, particularly against resistance.[4,5,7,9,12] Symptoms occur more commonly in the dominant hand if bilateral EDBM is present[7,9,12] due to increased activity. It is more often more symptomatic in adults than children and this has been postulated to be due to more developed muscle from increased activity and labour.[2] The exact etiology of the pain experienced by some patients with EDBM is not clear. While hypertrophy of the muscle alone may be sufficient to cause increased

pressure in the 4th extensor compartment and hence discomfort, some authors suggest that pain results when the firm distal edge of the extensor retinaculum impinges on the contracting muscle belly.[3,5,7] Increased pressure in the 4th compartment can result in indirect or direct impingement on the posterior interosseous nerve and "fourth compartment syndrome" as termed by Hayashi et al.[3] EDBM can also co-exist with other lesions, most commonly ganglion cysts,[2,5,9,12] but also lipomas,[12] metacarpal bossing1, and other accessory wrist extensor muscles, which may contribute to symptoms. On clinical examination, EDBM usually presents as an elongated fusiform swelling in the dorsum of the wrist or proximal part of the dorsum of hand between the middle and index finger extensor tendons, which may be more prominent in the dominant hand.[2] EDBM is most prominent with the wrist flexed to 30 degrees and the fingers fully extended.[7] An anomalous muscle can be differentiated from a ganglion cyst clinically, as usually it becomes more prominent, firm or painful during flexion of the wrist and extension of the finger, whereas a ganglion cyst is better outlined only by wrist flexion. Pain can also be reproduced when patients push their palms against a table with dorsiflexion of the wrists.[5]

Most times, imaging is useful in helping to diagnose EDBM, however, the clinician must consider EDBM in their work-up for imaging to be useful. Plain radiographs are usually unremarkable.[2] Ultrasound has been shown to be useful in several case reports.[5,6,12] Ouellette et al[6] described a technique to identify EDBM with dynamic ultrasound. The linear ultrasound probe is placed over the swelling in the dorsum of the wrist, and on static ultrasound imaging a soft-tissue mass with muscle like echo texture is identified. The patient is then requested to perform finger extension that is opposed by the sonographer's non-imaging hand leading to enlargement of the dorsal wrist mass. On axial images, the EDBM typically protrudes dorsally between the extensor tendons of second and third digits with active digital extension. Sagittal imaging of alternating extension and relaxation should show a muscle-like structure undergoing morphologic changes. Although MRI scans can aid in the diagnosis they do not always help if the radiologist fails to consider the EDBM as a differential.[9] Also, electrophysiological studies can help distinguish cysts or tumors from EDBM, but the physician again needs to consider EDBM as a differential in order to perform those studies.[5,7,9,12]

Asymptomatic EDBM does not require treatment.[2,5,8,9,12] In cases of symptomatic EDBM, patient can undergo a trial of conservative treatment, which can include rest, avoidance of precipitating activity and activity modification, wrist splint, pharmacological management including anti-inflammatory medication or analgesia and hand occupational therapy or physiotherapy.[2,9,10,12] If the symptoms persist despite conservative management, surgical intervention can be considered. Surgical intervention described in the literature includes extensor compartment release, and partial or complete excision of the EDBM.[5,9,10,12] There is no consensus in the literature between preference for extensor compartment release or excision as the initial procedure of choice, due to the variations in insertion and function of the muscle, possible co-existing lesions and the limited number of cases in the literature. However, there is some consensus in recommending surgical excision over debridement or retinacular release if the EDBM is not a sole extensor for the index finger.[5,7,10,12] There has also been a case report of successful use of botulinum toxin injection in treatment of a patient with symptomatic EDBM.[11]

Our patient has some of the classical symptoms of EDBM, and this case illustrates how this diagnosis needs to be considered as a differential in the approach of wrist swelling. Specific clinical examination can be performed to differentiate an accessory muscle from tenosynovitis or ganglions, and ultrasound is useful in achieving a diagnosis, with dynamic ultrasound able to further demonstrate specific features of EDBM. The patient's symptoms occurred in his non-dominant hand, indicating EDBM is likely unilateral in his case and this is supported by normal ultrasound findings in the contralateral wrist. This case also demonstrates work-up for this patient's dorsal wrist pain and swelling including imaging findings, and the successful management of this patient non-operatively, including considerations when patients are symptomatic due to their work or sporting activities.

AUTHOR AFFILIATIONS

Sim Hwei Sian Shauna MBBS (Singapore), MMed (Family Medicine)
Sports Medicine Centre
Department of Orthopaedic Surgery
Khoo Teck Puat Hospital
Singapore

Ong Joo Haw MBBS (Singapore), MRCS (Edin), MMed (Family Medicine), Dip (OM), FAMS (Sports Medicine)
Sports Medicine Centre
Department of Orthopaedic Surgery
Khoo Teck Puat Hospital
Singapore

REFERENCES

1 Capo JT, Shamian B, Li Y. Extensor digitorum brevis manus muscle in association with a metacarpal boss. J Plast Surg Hand Surg. 2014 Apr;48(2):152–4.
2 Gama C. Extensor digitorum brevis manus: A report on 38 cases and a review of the literature. *J Hand Surg*. 1983 Sep;**8**(5):578–82.
3 Hayashi H, Kojima T, Fukumoto K. The Fourth-Compartment Syndrome: Its Anatomical Basis and Clinical Cases. *Handchir · Mikrochir · Plast Chir.* 1999 Jan;**31**(1):61–5.
4 Georgiev GP, Tubbs RS, Iliev A, Kotov G, Landzhov B. Extensor indicis proprius muscle and its variants together with the extensor digitorum brevis manus muscle: a common classification. Clinical significance in hand and reconstructive surgery. *Surg Radiol Anat.* 2018 Mar;**40**(3):271–80.
5 Ogura T, Inoue H, Tanabe G. Anatomic and clinical studies of the extensor digitorum brevis manus. *J Hand Surg*. 1987 Jan;**12**(1):100–7.
6 Ouellette H, Thomas BJ, Torriani M. Using Dynamic Sonography to Diagnose Extensor Digitorum Brevis Manus. *Am J Roentgenol.* 2003 Nov 1;**181**(5):1224–6.
7 Patel MR, Desai SS, Bassini-Lipson L, Namba T, Sahoo J. Painful extensor digitorum brevis manus muscle. *J Hand Surg*. 1989 Jul;**14**(4):674–8.
8 Rodríguez-Niedenführ M, Vázquez T, Golanó P, Parkin I, Sañudo JR. Extensor digitorum brevis manus: Anatomical, radiological and clinical relevance: A Review: Extensor Digitorum Brevis Manus Revisited. *Clin Anat.* 2002 Jul;**15**(4):286–92.
9 Shereen R, Loukas M, Tubbs RS. Extensor Digitorum Brevis Manus: A Comprehensive Review of this Variant Muscle of the Dorsal Hand. Cureus [Internet]. [cited 2019 Dec 21];9(8). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5640384/.
10 Waterman BR, Dunn JC, Kusnezov N, Romano D, Pirela-Cruz MA. Surgical Management of Symptomatic Extensor Digitorum Brevis Manus: A Proposed Algorithm for Treatment. *Mil Med.* 2015 Oct 1;**180**(10):e1115–7.
11 Wendel I, Cole J. Treatment of Extensor Digitorum Brevis Manus Myalgia With Botulinum Toxin. *PM&R*. 2014 Mar;**6**(3):284–6.
12 Yammine K. The prevalence of extensor digitorum brevis manus and its variants in humans: a systematic review and meta-analysis. *Surg Radiol Anat.* 2015 Jan;**37**(1):3–9.

Calcific tendinopathy

ALEX STAPLETON

INTRODUCTION

Calcific tendinopathy of the rotator cuff is a common disorder affecting predominantly the 40- to 60-year-old age group. Women are overrepresented compared to men. Calcific tendinopathy occurs in 2.5%–7.5% of healthy shoulders in adults.[9] Studies also demonstrate that persons involved in hard physical manual labour or athletic pursuits are no more prevalent than those leading a sedentary life.[2] Various factors have been suggested to contribute to this condition, such as abnormal activity of the thyroid gland, metabolic diseases and genetic predisposition.[2] There are two main theories with regards to pathophysiology; the degenerative model and multiphasic model.[1] Calcific tendinopathy involving the substance of the tendon is particularly common in the rotator cuff. The most commonly affected tendon in the rotator cuff is the supraspinatus tendon.[1]

CASE REPORT

Mrs S is a 63 year old female shopkeeper of Fijian Indian descent. She has type 2 diabetes, hypercholesterolaemia, well controlled hypertensive disease, subclinical hypothyroidism and is overweight. Her only form of physical activity is stocking shelves and walking her dog. She is right hand dominant, doesn't smoke or drink and eats a vegetarian diet. Her medications include metformin, gliclazide, cholecalciferol, cilazapril and aspirin.

Mrs S attended my GP clinic with increasing right shoulder discomfort for many months. She reports no injury or traumatic event. She described the general shoulder area as the area of discomfort but isn't able to specify any pinpoint pain. Resting alleviates pain. She reports no radiation or radicular pain. She states the pain increases with overhead movement, especially when stocking shelves and hanging washing. She reports occasional 'cracking' in her shoulder with flexion movements. She reports no night pain and has no constitutional symptoms. She has no prior history of any injury to the shoulder. She has been seeing an acupuncturist for two weeks with no benefit.

On exam, she had normal vitals and her right shoulder demonstrated mild anterior shoulder tenderness compared to left. There were no overlying skin changes, atrophy or warmth. Her provocation tests were positive with a painful arc, Neers and empty can testing. Although these tests are limited by poor specificity and only marginal sensitivity. No frank deformity of shoulder girdle and full range of motion was achieved both passively and actively. With active movement eliciting discomfort anteriorly. There was no weakness or neurology elicited. Her neck and elbow were unremarkable. Contralateral examination was unremarkable.

She was referred for laboratory tests (CRP, FBC, Rheumatoid screen) to assess for inflammatory and rheumatological causes and these were all normal. She had X-ray and ultrasound imaging demonstrating calcific tendinopathy of the supraspinatus tendon and mild thickening of the subacromial bursa. They also reported a possible partial thickness tear of supraspinatus but in the presence of calcific changes couldn't be certain. This would also be non-specific in this age group given population prevalence. No other bone, joint or soft tissue concerns were reported.

She was diagnosed with a possible partial thickness supraspinatus tear and calcific tendinopathy with probable bursitis. It is unlikely given population prevalence of her age group the possible partial tear is contributing to pain in her case. It is more likely her pain is from bursitis and poor shoulder proximal movement but we cannot exclude whether calcific tendinopathy is contributing. We restricted her overly painful overhead activities until symptoms were improving. Physiotherapy input was initiated for shoulder rehabilitation to improve scapulothoracic functioning and to strengthen the proximal chain. She was also referred to my urgent care colleague who proceeded to inject the bursa with no further action in relation to the calcific tendinopathy given her full range of movement. Her pain improved after the injection and she has ongoing physiotherapy input for rehabilitation. If this fails then consideration of a sport medicine specialist review would be appropriate.

DISCUSSION

Rotator cuff calcific tendinopathy may cause highly disabling shoulder pain. Cross-sectional studies report that no treatment is required for asymptomatic calcification.[6] Mild symptoms may be treated conservatively with physiotherapy and extracorporeal shock-wave therapy.[7] For more intense pain or if debilitating ultrasound-guided percutaneous irrigation of calcific tendinopathy is currently accepted as the first-line safe and effective treatment, with significant pain improvement and a very low rate of complications.[8]

The majority of cases of symptomatic calcific tendinopathy are self-limiting. In which the calcification spontaneously resorbs after a period of a few years or is treated successfully conservatively.[5]

There are three phases to this disease, Uhthoff and colleagues described three distinct stages in the disease process; precalcific, calcific, and postcalcific stages. Depending on which stage of the disease, the imaging appearances and composition of the calcification differ significantly as do patient symptoms.[10] Precalcific changes demonstrate fibrocartilaginous metaplasia of the tendon, clinically this stage is pain-free. The second stage is calcific and is further subdivided into three phases; formative phase, which is characterised by cell-mediated calcific deposits and can be painful. The resting phase which lacks inflammation or vascular infiltration. Lastly, the resorptive phase which is characterised by a phagocytic resorption and vascular infiltration. Clinically this phase is the most painful.[10]

In the formative and resting phases of the disease, if non-operative measures fail and the patient presents with progressive symptoms interfering with usual activities of daily living, physical removal of calcific deposits may be indicated.[8] The resolution of calcification has been shown to correlate well with clinical improvement of symptoms, and therefore various treatments have been devised to promote their removal. There is also good evidence of benefit from arthroscopic or mini-open operations.

REFERENCES

1 Bureau NJ. Calcific tendinopathy of the shoulder. Semin Musculoskelet Radiol. 2013;17(1):80–4.

2 Carli D, Pulcinelli F, Delle G. Calcific tendonitis of the shoulder. Joints. 2014;2(3):130–6.

3 Carlisi E, Lisi C, Dall'angelo A. Focused extracorporeal shock wave therapy combined with supervised eccentric training for supraspinatus calcific tendinopathy. Eur J Phys Rehabil Med. 2018;54(1):41–7.

4 Chianca V, Albano D, Messina C. Rotator cuff calcific tendinopathy: From diagnosis to treatment. Acta Biomed. 2018;89:186–96.

5 Cho N, Lee B, Rhee Y. Radiologic course of the calcific deposits in calcific tendinitis of the shoulder: Does the initial radiologic aspect affect the final results? J Shoulder Elb Surg. 2010;19(2):267–72.

6 Greis A, Derrington S, McAuliffe M. Evaluation and Nonsurgical Management of Rotator Cuff Calcific Tendinopathy. Orthop Clin North Am. 2015;46(2):293–302.

7 Malliaropoulos N, Thompson D, Meke M. Individualised radial extracorporeal shock wave therapy (rESWT) for symptomatic calcific shoulder tendinopathy: A retrospective clinical study. BMC Musculoskelet Disord. 2017;18(1).

8. Messina C, Sconfienza L. Ultrasound-Guided Percutaneous Irrigation of Calcific Tendinopathy. Semin Musculoskelet Radiol. 2016;20(5):409–13.

9 Serafini G, Sconfienza L, Lacelli F. Rotator cuff calcific tendonitis: Short-term and 10-year outcomes after two-needle US-guided percutaneous treatment - Nonrandomized controlled trial 1. Radiology. 2009;252(1):157–64.

10 Uhthoff H, Loehr J. Calcific Tendinopathy of the Rotator Cuff: Pathogenesis, Diagnosis, and Management. J Am Acad Orthop Surg. 1997;5(4):183–91.

Sports vision, not just seeing 20/20

ROBERT J NG AND SOL BAE

See end of article for author affiliations.

Correspondence
Robert Ng
School of Optometry and Vision Science, Faculty of Medical and Health Sciences
University of Auckland
Private Bag 92019
Auckland 1142
r.ng@auckland.ac.nz

ABSTRACT

Sports vision can be defined as the clinical application of visual science for the improvement of visual function and performance in sport. The two primary aims of sports vision are 1) To enhance an athlete's vision and 2) To improve an athlete's performance through a variety of procedures and training techniques that target visual skills.

Visual performance plays a critical role in sport as vision is our primary sensory input. However, most athletes do not undergo a vision screening, with even fewer undergoing a sports vision training programme.[1] The practice of sports vision is comprised of multiple tiers. The basic, entry level tier concentrates on fundamental visual skills. These visual skills involved in sport are often measured and examined by an optometrist and other eye care professionals.

The aim of this paper is to introduce and give a brief overview to the readers on the specialty area of sports vision and the importance of performing a sports vision screening on athletes as a minimal standard of practice.

INTRODUCTION

Philosophy and overview

Former Major League Baseball player, Pete Rose, once said "see the ball, hit the ball" and coaches often tell their athletes to keep their "eye on the ball". Albeit clichés, vision and sports do go together given vision covers 80% of our sensory input. This does not, however, consist of just seeing 6/6 (20/20) on the Snellen visual acuity chart.

It has been reported that very few athletes undergo vision screening, with even fewer undergoing vision training.[1] Zeri et al investigated the attitude of athletes and support personnel towards vision correction in sport. The majority believed correction of a vision deficiency was important. However, there was a statistically significant decrease in support for contact lens use when recommended for sporting purposes. The authors attributed the decrease in support of contact lens use in sports to a perceived prejudice towards contact lenses and a lack of education and knowledge about them.[2]

Some athletes and teams are known to supplement their traditional training regimen with sports vision training to increase their performance and thus, have an advantage over competitors.[1,3,4] But what is sports vision? Sports vision can be defined as the clinical application of visual science for the improvement of visual function and performance in sport. The aims of sports vision are:

1) To enhance an athlete's vision and

2) To improve an athlete's performance through a variety of training techniques that target visual skills.

Sports vision encompasses a wide range of disciplines from optometry and vision science, psychology, physiology, sports and exercise science, strength and conditioning to name a few.[5]

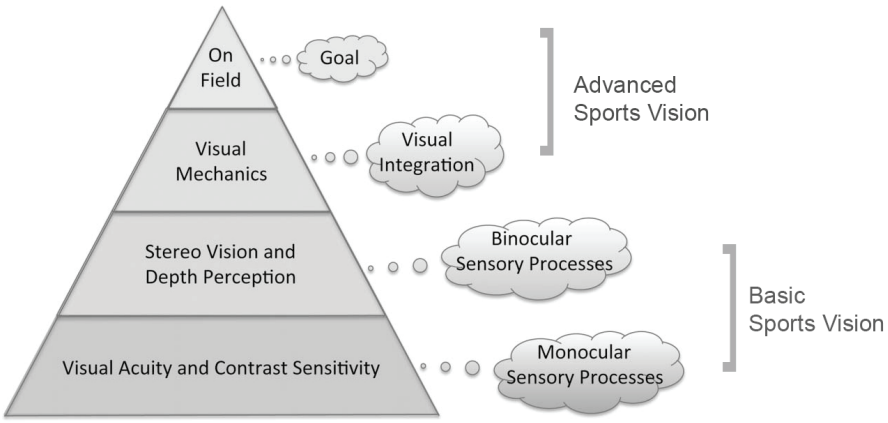

Figure 1: Sport Vision Pyramid. Modified from Kirschen and Laby [5]

The practice of sports vision is comprised of multiple levels; beginning with the basic, entry-level tier concentrating on fundamental visual skills. Kirschen and Laby expanded on this idea further in the 1990s and developed the concept of a Sports Vision Pyramid (Figure 1).[5] The pyramid provides a systematic approach to understanding the multiple components of sports vision. The pyramid is comprised of four tiers with the base foundation layer consisting of visual acuity and contrast sensitivity. The higher layers of the pyramid consist of stereo vision, visual mechanics with on-field performance as the top layer.[5]

Research in perceptual-cognitive skills have shown athletes have been shown to be faster (35%) and more accurate (31%) in making decisions compared to non-athletes.[6] This indicates that athletes can extract and interpret relevant visual information better than non-athletes potentially leading to better awareness, anticipation of movement and play and subsequently resulting in better performance.[6] Laby et al performed the largest study to date investigating the visual functions (visual acuity, stereoacuity and contrast sensitivity) of 387 professional baseball players.[7] Their study showed that professional athletes had better visual skills than non-athletes. However, it is still unclear whether these superior abilities are innate to the athlete or learned.[2]

Athletes have different visual abilities, and the requirements and demands placed on vision varies on the sport they play. Additionally, research has shown athletes have different visual abilities depending on which positions they play within the same sport.[6,8,9]

Sports vision screening

The bottom layer of the sports vision pyramid consists of visual acuity and

contrast sensitivity. These are considered the fundamental components of sports vision and are "the building blocks of effective sports vision".[5,10] These visual skills are often measured and examined by an optometrist and other eye care professionals in everyday practice. As such, these visual skills along with others are included in current sports vision screening protocols such as the Pacific Sports Visual Performance Profile (PSVPP) developed by Coffey and Reichow.[11] The objective of this profile was to standardise the way visual performance of Olympic-level and professional athletes are measured. These skills include: static visual acuity, dynamic visual acuity, contrast sensitivity, near point of convergence, fusion and eye alignment, accommodative-vergence facility, hand-eye co-ordination, motor reaction time, saccadic eye movement dynamics, stereopsis, span of recognition and peripheral awareness.[9,11,12] Correcting these visual components where one is weak can improve visual function, thus improve performance in sport. Performing a vision screening and correcting a visual deficiency is an easy addition to an athlete's training programme. This should be considered the first step in the practice/ application of sports vision to improve an athlete's performance.

Table 1 is an example of a sports vision screening assessment test and recording template. This has been used by the author on individual athletes, officials and professional teams undergoing a preseason medical assessment. As demonstrated in Table 1, it does not take too much time to complete and a lot of valuable information can be collected using the screening tool to help improve the athlete's performance.

Advanced sports vision

The next level following basic sports vision, is advanced sports vision. Advanced sports vision involves the use of vision training and eye exercises (such as perceptual, cognitive and oculomotor tasks) to enhance visual performance and which subsequently can be transferred to improved sporting performance.[6] This training may involve the use of vision exercises often prescribed by optometrists and eye care professionals to treat vision and binocularity anomalies. Additionally, with the recent advancements in digital technology, there has been an increase interest and use in specific sports vision training instruments.[6]

Research in advanced sports vision training, specifically perceptual learning has shown that improvements in visual abilities and visual discrimination a result of this training can last for months and even years.[6] Additionally, research has also shown that the benefits gained from perceptual learning can be transferred to new and previously untrained motor skills. [6]

As mentioned earlier, visual requirements and demands vary between sports. A sports vision training programme should be tailored specifically for the athlete's sport and position.

Examples of sports vision in sport

Cricket and golf provide two contrasting examples in sports vision due to their vastly different visual requirements. In cricket a batter has only about 225 milliseconds to look, think and decide on what do. Therefore, multiple aspects of the visual system including visual acuity, contrast sensitivity, binocular stereoscopic vision and higher functions of visual perception must be functioning properly for an athlete to be performing at their highest.

Elmurr conducted a systematic review analysing the relationship between vision and batting in cricket.[13] It has been shown that both saccadic eye movements and smooth pursuits are involved in cricket batting.[13,14] Batsmen monitor the release of the ball and produce an anticipatory saccade to the bounce of the ball and will follow it's trajectory for 100 to 200 milliseconds after the bounce.[13]

Table 1: Sports Vision Screening Recording Form Template.

Sports Vision Screening Template

Name: _____

Sport: _____ **Position:** _____

1. Do you wear glasses or contact lenses normally? Yes *Glasses/ Contacts (please circle)* No
If yes, do you wear them during training and matches? *Yes / No*

	Office Use
Static Unaided Visual Acuities: R _____ L _____	Pass ☐ Fail ☐
Static Aided Visual Acuities: R _____ L _____	Pass ☐ Fail ☐
Dynamic Unaided Visual Acuities: R _____ L _____	Pass ☐ Fail ☐
Dynamic Aided Visual Acuities: R _____ L _____	Pass ☐ Fail ☐
Visual Fields: Full ☐ Reduced: _____	Pass ☐ Fail ☐
Binocular Colour Vision: Normal / Fail	Pass ☐ Fail ☐
Stereopsis: _____ sec	Pass ☐ Fail ☐
Cover Test: Distance _____ Near _____	Pass ☐ Fail ☐
NPC (Break point) : _____ **Accommodation:** _____	Pass ☐ Fail ☐
Saccades: Full ☐ Reduced: _____	Pass ☐ Fail ☐
Brock String:	
Dis @6m: Normal / Over / Under	Pass ☐ Fail ☐
Int @1m: Normal / Over / Under	Pass ☐ Fail ☐

Comments: _____

_____

_____

It has also been shown that skilled batsmen also have a short latency when initiating their first saccade compared to those less skilled. In this review, Elmurr also reported on one of his studies where a group of non-athletes completed a vision training programme. The results showed that saccadic reaction times decreased with training. This indicates saccadic eye movements can be trainable and 're-programmed'.[13]

In comparison, in golf, seeing and making a split-second decision is less relevant but a golfer still requires accurate eye tracking and precise gaze direction. Research has shown that athletes typically have a longer duration of fixation before initiating a motor response. This has been called the quiet eye (QE) period.[15] The QE has been studied extensively and has shown to be trainable and can improve accuracy and performance in a golfer's putting.[15,16]

In a separate study, Dalton et al investigated the relationship between eye dominance and handedness in golfers.[17] This retrospective analysis consisting of 31 golfers of varying skill levels (including professionals to amateurs). The golfer's eye dominance was measured using a non-standardised dominance chart developed by one of the authors who reported it to be internally validated. Dominance was measured at both primary gaze and at the putting gaze with the dominance chart placed on the floor. The golfer's handedness was measured by asking the golfers to report their hand preference on a five-point scale. The results showed that eye dominance in the primary and putting gaze directions were not always equal. The magnitude of eye dominance at the putting gaze is significantly less than at primary gaze. Additionally, having an eye dominance may be associated with increased success in putting.[17]

In sports, often athletes who are performing well report the target or ball to be bigger. In one study, softball players who were hitting well, perceived the ball to be bigger than those who are performing poorly.[18] Witt et al tried to replicate this with golfers and recruited 46 golfers following a round of golf. They were asked to estimate the size of the hole they perceived to be seeing and additionally, they collected their score on their round, their usual handicap, how many putts they took on the 18th hole and how many strokes they took for that hole. Nine black circles of varying diameter were placed on a board and the participants were asked to select the circle which corresponded to the size of 18th hole on the golf course. The results showed the golfers who performed better perceived the hole to be bigger than those who performed worse. There was also no significant correlation between the handicap of the golfer (skill level) to the perceived hole size.[18]

SUMMARY

Before undergoing an advanced vision training programme to supplement their traditional regime, an athlete and team should undergo a vision screening. As mentioned earlier, few athletes undergo a vision screening. However, there is evidence that for an athlete to perform optimally, it is important, as a minimum, to screen and assess their visual performance and evaluate the visual demands placed on the individual athlete by their sport and the position they play in that sport.[9] This paper introduces the wider sports medicine audience to the concept of a sports vision screening. Table 1 shows the sports vision screening assessment tests and recording template used by the authors. The screening test encompasses majority of the visual skills described in the PSVPP and by other authors and can be adopted by the reader to incorporate into their everyday practice.

GLOSSARY

Modified from Meir.[1]

Accommodation: The ability to adjust the point of focus as objects (e.g. a ball) move (nearer) toward or (farther) away from the athlete,

Colour Vision: The ability to discriminate differences in colour (e.g., the ability to rapidly identify a teammate in the peripheral vision by uniform colour). Objects with low contrast against the background will be more difficult to see than are objects with a higher contrast.

Contrast sensitivity: The ability to see objects with variable background lighting conditions.

Depth perception (stereopsis): The ability of a person to accurately judge the distance between him-or herself and another object (e.g., a ball) in his or her surroundings.

Dominance: Dominance of one eye over the other. We all have a dominant eye, which processes and transmits information to the brain a few milliseconds faster than the subordinate eye. The dominant eye also guides the movement and fixation of the other eye.

Fixation: Without a conscious effort to attend to something, our eyes will constantly move throughout the visual field. Fixation occurs when an object attracts our visual attention and we focus both eyes on it.

Peripheral vision: The ability of a person to detect objects in his or her vision away from fixation. Due to anatomical limitations, peripheral vision cannot be trained. However, peripheral awareness can be trained, thereby increasing the speed and accuracy at which objects can be identified.

Saccades: The ability of the eyes to follow and track fast moving objects from one point to another by jumping of the eyes to maintain fixation.

Speed of recognition: The ability to rapidly process information from the environment and use it indecision making, movement preparation, and skill execution.

Tracking (smooth pursuit): The ability of the eyes to follow and track slow moving objects from one point to another.

Vergence: The ability to maintain fixation on objects as they move toward or away from the athlete. The eyes converge when viewing objects that are close and diverge when viewing more distant objects.

Visual acuity: The ability to discriminate and resolve fine detail in an object. Static visual acuity is the ability to see a certain level of detail in a stationary object and is typically measured by the Snellen acuity scale. If a person can read the 6/6 (20/20) line on the Snellen chart, he or she is considered to have normal visual acuity (i.e., good static visual acuity). Dynamic visual acuity is the ability to resolve detail in moving objects.

AUTHOR AFFILIATIONS

Robert J Ng MHSc (Hons) (Optometry), BOptom (Hons)
School of Optometry and Vision Science
The University of Auckland
Auckland
New Zealand
Sol Bae MBBS, BHSc (Hons)
Department of Emergency Medicine
Concord Repatriation General Hospital
Sydney, NSW
Australia

REFERENCES

1 Meir R. Conditioning the visual system: A practical perspective on visual conditioning in rugby football. Review. *Strength Cond J*. 2005;**27**(4):86-92. doi:http://dx.doi.org/10.1519/00126548-200508000-00015

2 Zeri F, Livi S, Maffioletti S. Attitudes towards

visual correction in sport: What coaches, physical education teachers and sports physicians think. Article. *Cont Lens Anterior* Eye. 2011;**34**(2):71-76. doi:http://doi.org/10.1016/j.clae.2010.08.006

3 Rees P. England's vision coach Sherylle Calder has World Cup glory in sight The Guardian. 28 January 2017. Accessed 7 May 2020. https://www.theguardian.com/sport/2017/jan/28/england-six-nations-sherylle-calder-world-cup

4 Mitroff SR, Friesen P, Bennett D, Yoo H, Reichow AW. Enhancing ice hockey skills through stroboscopic visual training: a pilot study. *Athl Train Sports Health Care.* 2013;**5**(6):261-264. doi:http://dx.doi.org/10.3928/19425864-20131030-02

5 Kirschen DG, Laby DL. The role of sports vision in eye care today. Eye Contact Lens. May 2011;37(3):127-30. doi:http://doi.org/10.1097/ICL.0b013e3182126a08

6 Appelbaum LG, Erickson G. Sports vision training: A review of the state-of-the-art in digital training techniques. *Int Rev Sport Exerc Psychol*. 2016:**1**-30. doi:http://doi.org/10.1080/1750984X.2016.1266376

7 Laby DM, Davidson JL, Rosenbaum LJ, et al. The Visual Function of Professional Baseball Players. *Am J Ophthalmol*. 1996/10/01/1996;**122**(4):476-485. doi:https://doi.org/10.1016/S0002-9394(14)72106-3

8 Ceyte H, Lion A, Caudron S, Perrin P, Gauchard GC. Visuo-oculomotor skills related to the visual demands of sporting environments. Article. *Exp Brain Res*. 2017;**235**(1):269-277. doi:http://doi.org/10.1007/s00221-016-4793-3

9. Hazel CA. The efficacy of sports vision practice and its role in clinical optometry*. *Clin Exp Optom*. 1995;**78**(3):98-105. doi:http://doi.org/10.1111/j.1444-0938.1995.tb00798.x

10 Zimmerman AB, Lust KL, Bullimore MA. Visual acuity and contrast sensitivity testing for sports vision. Review. *Eye Contact Lens*. May 2011;**37**(3):153-9. doi:https://dx.doi.org/10.1097/ICL.0b013e31820d12f4

11 Coffey B, Reichow A. Optometric evaluation of the elite athlete: the pacific sports visual performance profile. *Probl Optom*. 1990;**1**:32-58.

12 Erickson GB, Citek K, Cove M, et al. Reliability of a computer-based system for measuring visual performance skills. *J Am Optom Assoc*. 9// 2011;**82**(9):528-542. doi:http://dx.doi.org/10.1016/j.optm.2011.01.012

13 Elmurr P. The relationship of vision and skilled movement-a general review using cricket batting. Review. *Eye Contact Lens*. May 2011;**37**(3):164-6. doi:https://dx.doi.org/10.1097/ICL.0b013e318217cc09

14 Portus MR, Farrow D. Enhancing cricket batting skill: Implications for biomechanics and skill acquisition research and practice. Review. *Sports Biomech.* 2011;**10**(4):294-305. doi:http://doi.org/10.1080/14763141.2011.629674

15 Vickers JN. Visual Control When Aiming at a Far Target. Article. *J Exp Psychol Hum Percept Perform*. 1996;**22**(2):342-354. doi:http://dx.doi.org/10.1037/0096-1523.22.2.342

16 Vine S, Moore L, Wilson M. Quiet Eye Training Facilitates Competitive Putting Performance in Elite Golfers. Original Research. *Front Psychol.* 2011-January-28 2011;**2**(8)doi:http://doi.org/10.3389/fpsyg.2011.00008

17 Dalton K, Guillon M, Naroo SA. Ocular dominance and handedness in golf putting. Article. Optom Vis Sci. 2015;92(10):968-975. doi:http://dx.doi.org/10.1097/OPX.0000000000000690

18 Witt JK, Linkenauger SA, Bakdash JZ, Proffitt DR. Putting to a bigger hole: Golf performance relates to perceived size. Article. *Psychon Bull Rev.* 2008;**15**(3):581-585. doi:http://doi.org/10.3758/PBR.15.3.581

Oral iron supplementation: Is it time to review how we manage our iron-deficient non-anaemic (IDNA) athletes?

CARMEN CHAN

ABSTRACT

Iron is a key micronutrient important for erythropoiesis and energy metabolism. While it is well established that iron supplementation is indicated for the correction of iron deficiency anaemia, the benefit of supplementing iron deficient non-anaemic (IDNA) athletes is less clear. This review discusses the role of oral iron supplementation in IDNA athletes, and explores the influence of ferritin replacement and supplementation on performance outcomes. It is thought that there is no clear evidence that IDNA affects oxygen transport. However, IDNA may impair oxidative capacity, and potentially affect performance outcome measures at very low ferritin levels. Preventing serum ferritin declines during prolonged, intense competition or prior to altitude exposure may also improve rates of recovery, and enable maximal returns on hypoxia induced erythropoeisis.

Correspondence
Carmen Chan
Capital & Coast District Health Board
Wellington
New Zealand

INTRODUCTION

Iron is an essential micronutrient core to the effective functioning of the human body. Known to play a key role in the formation of haemoglobin, profound iron deficiency causes anaemia, and can detrimentally affect both performance and health through impaired oxygen carrying-capacity and energy production. Whilst the role of iron supplementation has been well established for the correction of anaemia, increasing debate has surrounded the role of correcting low ferritin stores while haemoglobin levels remain within normal limits. Termed 'iron deficiency non-anaemia' (IDNA), proponents argue that iron plays a role not only in haemoglobin related oxygen transport, but also in tissue oxidative capacity, immune and cognitive function.[1,2] Such factors are significant for the possibility of influencing the performance of all athletes who rely upon effective aerobic respiration and metabolism to achieve their performance goals.

Oral iron supplementation has been a longstanding ferritin replacement strategy. While iron occurs naturally in both animal and plant-based sources, these are often insufficient on their own for the requirements of athletes with pre-existing deficiencies.[3] The element itself is absorbed via the gut enterocyte, and mediated by the hormone hepcidin. Effects of iron supplementation on performance, dosing strategies for maximising iron absorption while mitigating common gut related side effects continues to be of ongoing salience.

This review aims to detail knowledge surrounding basic iron metabolism, discuss sources and strategies for augmenting iron uptake, explore dosing strategies for varying sporting scenarios and discuss the more recent findings on the effect of oral supplementation on the iron deficient non-anaemic endurance athlete.

Metabolism and physiology of iron

Iron is a transition metal that acts as the central metal atom in the haemoglobin protein of the red blood cell. Haemoglobin and myoglobin proteins play a role in binding oxygen in a porphyrin ring, and haemoglobin helps to carry oxygen from lungs to skeletal muscle where it is then bound by myoglobin prior to undergoing the process of aerobic respiration.

Iron is a key factor in the cytochromes and enzymes involved in electron transport in the energy-producing mitochondria and proponents have postulated that while IDNA might not impair haemoglobin oxygen carrying capacity, iron deficiency may still be detrimental to energy metabolism in both maximal and submaximal exercise performance if there are deficiencies to the components involved in aerobic respiration at the cellular level.[4,5]

Physiologically, iron is absorbed via the divalent metal transporter[1,6] in the gut enterocyte, and subsequently enters the bloodstream via the ferroportin transporter. It is then carried by the transferrin protein to the liver where it is either stored as ferritin or transported to iron consuming tissues.[7] The absorption of iron is mediated by hepcidin, a hepatic peptide hormone that acts on ferroportin. In states of iron overload or inflammation, hepcidin downregulates ferroportin and reduces iron absorptive capacity. Exercise has been found to upregulate hepcidin via an acute inflammatory response[1] and indeed inflammation is further exacerbated in states of low glycogen availability with increases in IL-6 induced hepcidin rises. This suggests that macronutrient availability may also impact upon iron metabolism and absorption.[8]

Natural sources of iron

For any athlete, nutritional counselling should always be combined with micronutrient supplementation to ensure sufficient energy intake, and appropriate fuelling to support recovery.[9] Iron can be obtained from food sources in heme form via animal products, and non-heme form via plant-based foods. Heme iron found in red meat has around 15-30% absorptive capacity while non-heme iron present in plant-based products can have variable absorption ranging from 2-20%.[3,10] Consuming 110-179g of meat with other iron enhancing foods can be effectively equal to taking a 50mg ferrous sulphate supplement at maintaining serum ferritin, and may be more effective at protecting iron states than iron supplements.[11] It is estimated that 100mg of heme iron a day can replenish iron deficient stores in over 2-3 months.[6] Foods with high levels of ascorbic acid such as citrus fruit, and tomatoes can enhance the absorption of iron when taken concurrently,[3,6] while foods high in phytates, polyphenols, calcium and magnesium may bind to or competitively inhibit enteric iron absorption.[1]

Iron regulation and dosing strategies

The presence of hepcidin presents unique challenges for maximising the uptake of iron during supplementation. Along with exercise, hepcidin levels increase in response

to oral iron supplementation.[12] Despite the attenuation of absorption, a six-fold increase in iron dosage (i.e. from 40 to 240mg) can still result in a three-fold increase in total iron absorbed due to absolute increases in consumed volume.[13,14] However, enteric side effects such as nausea, constipation, cramping and diarrhoea[1,15] from unabsorbed iron acts as a limiting factor for this strategy and is a common side effect of oral supplementation.

In New Zealand, oral iron supplementation can be found in both tablet and liquid formulations[9,16] and be fully cost subsided ($5) with prescription.[16,17] The available chemical forms include ferrous fumarate, ferrous sulfate, or iron polymaltose containing 65 to 100mg of elemental iron.[9] Ferrous sulfate is the most commonly studied and best tolerated oral iron supplement.[2,9] Varying dose regimes ranging from 40 to 150mg of elemental iron appear to be best tolerated for sufficient bioavailability and efficacy for maintenance and replacement strategies.[2,7]

On a practical level, authors have proposed prescribing 100mg of elemental iron once or twice daily along with nutrition counselling during training season for iron deficient athletes.[9,10,18] Enteric coated and extended release formulations may have fewer gut side effects, but worse absorption rates.[4] Formulations such as iron proteinsuccinylate[19] or novel formulations such as Lactobacillus plantarum with iron combinations[20] may enhance iron bioavailability and reduce gastrointestinal side effects.

Addressing potential side dffects of oral iron supplementation

For those experiencing enteric side effects, alternate day dosing may offer comparable benefits to daily dosing with reduced gastrointestinal side effects. Participants taking either alternate day or daily ferrous sulphate tablet both had a 60% increase in their ferritin levels over 8 weeks in a study performed by McCormick et al.[21] The same authors also found that morning iron supplementation is also more effective than afternoon dosing, hypothesising that hepcidin, typically peaking towards late afternoon, mitigates absorption.[22] Additionally, taking iron supplements away from a main meal may also improve absolute absorption.[1]

Despite having no means of excreting excess bodily iron,[6] the rate of absorption from the gut means that the risk of iron overload from excess oral intake is extremely low.[1] However, the risk of iron overload includes a secondary haemochromatosis, and long term iron in excess that is unbound by ferritin or transferrin poses the risk of causing unwanted oxidation - potentially resulting in organ damage, lipid perioxidation, cell damage and subsequently, carcinogenesis.[1,3,4] It is thus commonly advised that athletes with a normal iron status should not be routinely supplemented.[5,6]

Supplementation of non-iron deficient athletes to prevent IDNA?

However, there are specific scenarios where with appropriate monitoring of serum iron levels, that supplementing endurance athletes may pose performance benefits. A recent study by Córdova et al. found that oral iron supplementation of non iron deficient elite cyclists for the three week duration of their race cycle reduced levels of the stress hormone cortisol, and prevented a decline in iron stores compared to those that were unsupplemented. While there was no measurable differences in performance, these findings suggest that regulated iron supplementation could neverthless aid in a more rapid recovery.[19]

Similarly, oral iron supplementation has shown to be important in correcting and preventing iron deficiencies for athletes preparing for altitude training to enable the benefits from hypoxia-induced erythropoesis.[14,23] Indeed, athletes without iron supplementation over 2-4 weeks of altitude training were shown by Govus et al. to have a 33% decline in serum ferritin levels while those given a 105mg iron supplement still had a 14% ferritin decline. Those who received a 210mg daily iron supplement who had a 37% ferritin level increase and the greatest improvements in haemoglobin mass.[23] These findings suggest that oral iron supplementation may play an important role in maintaining a normal iron state in those both normal, and iron deficient states at altitude. It thus has been recently proposed by Okazuki et al. that athletes should be titrated to serum ferritin levels of 40-90ng/ml prior to, and while spending time at moderate altitude in order to experience performance benefits.[14]

Does correcting IDNA offer performance benefits?

The question remains surrounding whether correcting IDNA offers performance benefits given the role of iron in aerobic respiration at the cellular level. Dellavalle et al. found that supplementing IDNA collegiate rowers was statistically significant in improving rowing speed, and distance rowed.[18] A review by Rubeor et al. suggested that replacing ferriting levels <20µg/L may offer performance benefits, but that replacement above this level is unlikely to be of value.[2] Sim et al. similarly noted that despite lack of measurable evidence on performance compromise, caveats in IDNA could still include compromised immune function, lethargy and weakness related to impaired energy production and cellular function.

CONCLUSION

Ultimately, the nature of endurance sports places athletes at risk of iron deficiency due to increased exercise and energy demands, and increased iron turnover. Proper monitoring of iron and haemoglobin status is an important factor for maintaining an athlete's health and performance and screening frequency should be regulated based upon risk factors such as gender, history of deficiency, training loads, and symptoms.[5,6,9,10]

Serum iron should be primarily maintained through a balanced diet, but may also require oral supplementation to ensure adequate iron stores. Oral iron supplementation improves ferritin and transferrin parameters[24] and ferrous sulfate is the most commonly trialled form of oral iron supplement. Alternate day dosing may be a novel measure for mitigating common gastrointestinal side effects of oral supplementation, and concurrent consumption of enhancers such as ascorbic acid, and probiotics such as Lactobacillus plantarum may aid in increasing iron absorption.

Preventing serum ferritin declines during prolonged, intense competition or prior to altitude exposure may also improve rates of recovery, and enable maximal returns on hypoxia induced erythropoeisis. While there is no clear evidence that IDNA affects oxygen transport, there are clinical studies and reviews which propose that IDNA may impair oxidative capacity, and potentially affect performance outcome measures at very low ferritin levels. Furthermore, addressing IDNA may offer benefit in improving cognitive, and immune function and perceptions of lethargy – something which, for elite endurance athletes, may maximise their capacity to perform at optimal health and flourish in the sport of their choice.

REFERENCES

1 Pedlar CR, Brugnara C, Bruinvels G, Burden R. Iron balance and iron supplementation for the female athlete: A practical approach. *European Journal of Sport Science*. 2018;**18**(2):295-305.

2 Rubeor A, Goojha C, Manning J, White J. Does Iron Supplementation Improve Performance in Iron-Deficient Nonanemic Athletes? *Sports Health*. 2018;**10**(5):400-5.

3 Bass LJ, McClung JP. Iron Nutrition and the Female Athlete: Countermeasures for the Prevention of Poor Iron Status. *Journal of Evidence-Based Complementary & Alternative Medicine.* 2011;**16**(3):195-200.

4 Hinton PS. Iron and the endurance athlete. Applied physiology, nutrition, and metabolism = *Physiologie appliquee, nutrition et metabolisme*. 2014;**39**(9):1012-8.

5 DellaValle DM. Iron supplementation for female athletes: effects on iron status and performance outcomes. *Current sports medicine reports*. 2013;**12**(4):234-9.

6 Zourdos MC, Sanchez-Gonzalez MA, Mahoney SE. A brief review: the implications of iron supplementation for marathon runners on health and performance. *Journal of Strength and Conditioning Research*. 2015;**29**(2):559-65.

7 Clenin G, Cordes M, Huber A, Schumacher YO, Noack P, Scales J, et al. Iron deficiency in sports - definition, influence on performance and therapy. *Swiss Medical Weekly*. 2015;**145**:w14196.

8 Sim M, Dawson B, Landers G, Trinder D, Peeling P. Iron regulation in athletes: exploring the menstrual cycle and effects of different exercise modalities on hepcidin production. *International Journal of Sport Nutrition and Exercise Metabolism*. 2014;**24**(2):177-87.

9 Sim MG-LLCGGAMASTPP. Iron considerations for the athlete: a narrative review. *European Journal of Applied Physiology*. 2019;**119**(7):1463-78.

10 Rowland T. Iron Deficiency in Athletes: An Update. *American Journal of Lifestyle Medicine*. 2012;**6**(4):319-27.

11 Lyle RM, Weaver CM, Sedlock DA, Rajaram S, Martin B, Melby CL. Iron status in exercising women: the effect of oral iron therapy vs increased consumption of muscle foods. *The American Journal of Clinical Nutrition*. 1992;**56**(6):1049-55.

12 Ishibashi A, Maeda N, Kamei A, Goto K. Iron Supplementation during Three Consecutive Days of Endurance Training Augmented Hepcidin Levels. *Nutrients*. 2017;**9**(8).

13 Moretti D, Goede JS, Zeder C, Jiskra M, Chatzinakou V, Tjalsma H, et al. Oral iron supplements increase hepcidin and decrease iron absorption from daily or twice-daily doses in iron-depleted young women. *Blood*. 2015;**126**(17):1981-9.

14 Okazaki K, Stray-Gundersen J, Chapman RF, Levine BD. Iron insufficiency diminishes the erythropoietic response to moderate altitude exposure. *Journal of Applied Physiology*. 2019;**127**(6):1569-78.

15 Alaunyte I, Stojceska V, Plunkett A. Iron and the female athlete: a review of dietary treatment methods for improving iron status and exercise performance. *Journal of the International Society of Sports Nutrition*. 2015;**12**:38.

16 The New Zealand Formulary. Iron The New Zealand Formulary: The New Zealand Formulary; 2020 [Available from: https://nzf.org.nz/.

17 Ministry of Health. Prescription Charges: Ministry of Health; 2018 [Available from: https://www.health.govt.nz/your-health/conditions-and-treatments/treatments-and-surgery/medications/prescription-charges#:~:text=Many%20medicines%20in%20New%20Zealand,prescription%20medicine%20is%20usually%20%245.

18 DellaValle DM, Haas JD. Iron supplementation improves energetic efficiency in iron-depleted female rowers. *Medicine and Science in Sports and Exercise*. 2014;**46**(6):1204-15.

19 Cordova A, Mielgo-Ayuso J, Fernandez-Lazaro CI, Caballero-Garcia A, Roche E, Fernandez-Lazaro D. Effect of Iron Supplementation on the Modulation of Iron Metabolism, Muscle Damage Biomarkers and Cortisol in Professional Cyclists. *Nutrients*. 2019;**11**(3).

20 Axling U, Önning G, Combs MA, Bogale A, Högström M, Svensson M. The Effect of Lactobacillus plantarum 299v on Iron Status and Physical Performance in Female Iron-Deficient Athletes: A Randomized Controlled Trial. *Nutrients*. 2020;**12**(5).

21 McCormick R, Dreyer A, Dawson B, Sim M, Lester L, Goodman C, et al. The Effectiveness of Daily and Alternate Day Oral Iron Supplementation in Athletes With Suboptimal Iron Status (Part 2). *Int J Sport Nutr Exerc Metab*. 2020:1-6.

22 McCormick RMDMADALCMVRTDCGRZMBSMGCDBPP. The impact of Morning versus Afternoon Exercise on Iron Absorption in Athletes. *Medicine and Science in Sports and Exercise*. 2019; Ahead of print.

23 Govus AD, Garvican-Lewis LA, Abbiss CR, Peeling P, Gore CJ. Pre-Altitude Serum Ferritin Levels and Daily Oral Iron Supplement Dose Mediate Iron Parameter and Hemoglobin Mass Responses to Altitude Exposure. *PLoS One*. 2015;**10**(8):e0135120.

24 Burden RJ, Morton K, Richards T, Whyte GP, Pedlar CR. Is iron treatment beneficial in, iron-deficient but non-anaemic (IDNA) endurance athletes? A systematic review and meta-analysis. *British Journal of Sports Medicine*. 2015;**49**(21):1389.