NEW ZEALAND
Journal of Sports Medicine
SPORTS MEDICINE NEW ZEALAND INC
Vol 42 • No 2 • 2015
Official Journal of Sports Medicine New Zealand Inc.

PUBLISHER
SPORTS MEDICINE NEW ZEALAND
PO Box 6398, Dunedin
NEW ZEALAND
Tel: +64-3-477-7887
Fax: +64-3-477-7882
Email: smnznat@xtra.co.nz
Web: www.sportsmedicine.co.nz

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

CONTENTS

EDITORIAL
Beyond the Rule Book 38
B Hamilton
Modern Youth Sport - Too much? Too serious? Too organised? Too many injuries! 41
C Whatman

BEST OF BRITISH 42
C Milne

INTERVIEWS
Lynne Coleman 46
Jeni Pearce 48

ORIGINAL ARTICLES
Self-reported sun protection strategies among Australian surfers: Are they heeding the message? 50
R Meir, S Zhou, M Rolfe, W Gilleard, R Coutts
The effectiveness of preventative neuromuscular training on anterior cruciate ligament injury rates in female athletes: A systematic review 56
O Simpson, D Reid, R Ellis, S White
The effect of running demands and impacts on post-tournament markers of inflammation and haemolysis in women's rugby sevens 70
A Clarke, J Anson, D Pyne

CASE REPORTS
Beware the 'benign' bump: Pseudoaneurysm of the superficial temporal artery 77
T Marks
Take care of the steroid flare 78
B Hamilton, M Munro, J Pearson, J Salesa, L Johnson, D Exeter, C Milne

HOW I TREAT
Healthy Living
N Anglem 80
M Wood and N Harris 81

INVITED ARTICLE
Athletes with spinal cord injury: Musculoskeletal issues and remedies 82
M Munro, J Ralph, J Pearson

REPORT
Freeski and snowboard - Park and pipe injury rates, patterns and prevention 84
G Rutledge

CONFERENCE REPORTS
Bike Fit Myths: Reflections from the 2015 Medicine Cycling Conference 87
M Harris
Medicine on the Edge: High Altitude and Expedition Medicine Conference 2015 88
S Webb

CONTRIBUTORS

Nat Anglem
Nat Anglem is a sports physician in Christchurch. His aim is to use models of high performance sport to improve the health and well-being of his patients, as well as their athletic success. He works for High Performance Sport New Zealand within the Wintersport programme.

Judith Anson
Judith Anson is an adjunct associate professor at the University of Canberra Research Institute of Sport and Exercise. Previously, she was Dean of the Faculty of Health. Her research interests include applied sports physiology, proprioception in athlete and the general population, an falls risks in older people.

Anthea Clarke
Anthea Clarke is a current PhD student with Australian Rugby Union, the Australian Institute of Sport, and the University of Canberra. her topic focuses on increasing the understanding female rugby sevens players; how to appropriately monitor and manage players as well as understanding the current game and training demands from junior to elite level.

Rosanne Coutts
Rosanne Coutts is an accredited exercise physiologist at Southern Cross University. Her research interests focus on the behavioural aspects of sport and exercise, chronic fatigue syndrome, and muscle dysmorphia. Rosanne is currently the Director of Teaching and Learning with the School of Health and Human Sciences at Southern Cross University.

Richard Ellis
Richard is a senior lecturer in the Department of Physiotherapy at Auckland University of Technology (AUT) and also an associate head of research for the School of Clinical Sciences at AUT. Richard is a musculoskeletal physiotherapist who teaches on both the undergraduate and postgraduate musculoskeletal physiotherapy programmes at AUT. Richard leads the Musculoskeletal Imaging Unit within the Health and Rehabilitation Research Institute (AUT). His main areas of research interest include rehabilitative ultrasound imaging; manual and musculoskeletal physiotherapy; and the assessment and treatment of peripheral nervous system disorders. External to AUT, Richard is the President of the New Zealand Manipulative Physiotherapists Association (NZMPA).

Daniel Exeter
Dan Exeter is a sports and exercise medicine physician at Axis Sports Medicine Specialists. He is now Medical Director for Athletics New Zealand and will be part of the team assisting our athletes at the 2016 Rio Olympic Games. His most recent high performance post prior to this was with Hawthorn Football Club, a role which culminated in an AFL (Australian Rules) Premiership. Dan has interests in the areas of injury prevention, hamstring injury, tendon injury, and cardiac screening of athletes. He has recently submitted a masters research portfolio on ECG screening of athletes and is also a reviewer for Heart journal in this field. In addition to clinical work, Dan has a senior lecturer role with the University of Auckland.

Wendy Gilleard
Wendy Gilleard has focused her research interests in the field of biomechanics for 22 years and is currently based at Southern Cross University as an associate professor. She holds a PhD from the University of Sydney. Her primary research approach is the use of three dimensional motion analyses. She has supervised projects on a broad range of rehabilitation and sporting applications and reviews for a number of rehabilitation focused journals.

Mark Harris
Mark Harris is a physiotherapist working full time with High Performance Sport New Zealand and is currently based at the Avantidrome in Cambridge. His primary role is as part of the support team for New Zealand Cycling. He also does some teaching on the Masters of Sports Physiotherapy programme for the University of Bath, United Kingdom. He has previously worked with British Swimming and British Bob-Skeleton along with various rugby and football teams from club to international level within New Zealand.

Nigel Harris
Nigel Harris is a senior lecturer in exercise science at AUT University. Nigel's research activities with AUT's Human Potential Centre focus on the effects of resistance training and short duration, higher intensity intermittent exercise on general health.

Louise Johnson
Louise Johnson is a senior sports physiotherapist with High Performance Sport New Zealand. Currently lead physiotherpaist with Yachting New Zealand and Valerie Adams. Member of NZ medical team for four Olympic and two Commonwealth Games.

Thomas Marks
Thomas is a GPEP trainee with previous emergency medicine, general surgical and orthopaedic experience both in New Zealand and his native UK from where he emigrated aged 26. As a keen rugby player throughout school, university and now at club and weight-grade representative level in New Zealand his interest led to him looking after Bay of Plenty in two ITM Cup campaigns and he has recently completed a stint with Auckland. Thomas is aiming to combine more sports medicine work with general practice and skin cancer surgery in the future.

Rudi Meir
Rudi Meir is a senior lecturer at Southern Cross University and has extensive experience working as a specialist skills and conditioning coach in professional rugby league and rugby union. He has published widely on a range of topics related to sport science including the long-term consequences of sports injuries. His current research interests relate to the attitudes of adolescent athletes toward performance enhancing drugs (PEDs), determining fluid status in recreational surfers, and three dimensional analysis of various resistance training exercises.

Chris Milne
Chris Milne is a sports physician in private pradtice 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 of Sports Medicine New Zealand.

Megan Munro
Megan Munro, originally from Scotland, is very passionate about and has great experience in parasport. She worked as a physiotherapist for the British Military for a number of years, was physiotherapist at the London 2012 Olympic and Paralympic Games and was appointed Lead Physio with Paralympics New Zealand Swimming in August 2013. She has an MSc in Sports and Exercise Medicine where she wrote her thesis in amputee rehabilitation in a military setting. Megan's experience within elite para-sport is a great advantage to New Zealand as she understands athlete's needs and what it takes to succeed.

Jake Pearson
Jake Pearson is a sports physician based at Capital Sports Medicine in Wellington and in his training spent time at both UniSports in Auckland and the AIS in Canberra. He is the Medical Director for Paralympics NZ, doctor for the Wellington Phoenix Football Club and Medical Lead for the annual Wellington Rugby Sevens tournament.

David Pyne
David Pyne is a sports scientist in the Department of Physiology at the Australian Institute of Sport, Canberra, Australia. His primary interests are exercise and the immune system, environmental physiology, the applied physiology of swimming, and fitness and conditioning for team sports. He holds adjunct professor appointments at James Cook University, Cairns, Australia; the University of Canberra; and Griffith University, Southport, Australia. He was Foundation Editor of the International Journal of Sports Physiology and Performance from 2004-2009 and currently serves as an associate editor.

Justin Ralph
Justin Ralph is a physiotherapist at Sports Med Physiotherapy in Hamilton. He has completed his postgraduate diploma in musculoskeletal physiotherapy at AUT and is the lead physiotherapist for the NZ Paralympic Bike Team.

Duncan Reid
Duncan Reid is Associate Professor of Physiotherapy and Associate Dean of Health, Faculty of Health and Environmental Science, Auckland University of Technology. Duncan has had 32 years of clinical experience in musculoskeletal physiotherapy. His main areas of interest are in manual and manipulative therapy especially manipulation to the cervical spine.

Margret Rolfe
Margaret Rolfe is a biostatistician based in Lismore (Northern NSW) working in the University Centre for Rural Health - North Coast and is an adjunct research fellow at the University of Sydney. She has a PhD in Bayesian Statistics completed at QUT. Her research interests include chronic disease, Bayesian network models, application of multilevel models in sports science, longitudinal modelling, and health epidemiology.

Ginny Rutledge
Ginny Rutledge is prinicipal physiotherapist at Wanaka Physiotherapy. She is a provider for High Performance Sport NZ and is Physio/ MedicalCoordinator to the NZ Winter Performance Programme. She was lead physiotherapist to the Salt Lake 2002, Torino 2006, Vancouver 2010 and Sochi 2014 Winter Olympics. Her special interests involve minimising injury risk in winter sport athletes who participate in Alpine Ski Racing, FreeSki and Snowboarding.

Olivia Simpson
Olivia Simpson is a post-graduate qualified musculoskeletal physiotherapist based at Kowhai Physiotherapy and Hand Therapy Clinic in Warkworth. She is also an experienced strength and conditioning coach. As a sports physio Olivia has worked with a variety of athletes and teams, and particularly enjoys working with development-age athletes. This year she worked with the NZ Hockey Junior Black Sticks Women and NZ Hockey "A"s Women. She is involved in local and regional netball and is the assistant physiotherapist for the Netball NZ U21 team. She is passionate about helping her athletes to perform better and become more injury-resistant through movement screening and movement-based strength training. Olivia is a member of the Netball NZ ACL Injury Prevention Panel that is developing a netball-specific neuromuscular warm-up which will be launched nationwide in 2016.

Sandra Webb
Sandra Webb is a general practitioner and sports doctor based in Dunedin. She was team doctor for the Black Ferns from 2000-05, the 2002 Manchester Commonwealth Games and the Highlanders Super 15 rugby team from 2005 until 2011. A Fellow of SMNZ she also served as National Chairman from 2006-10. Her current interests include travel medicine and diving medicine.

Steve White
Steve is a senior lecturer at AUT University where he is the paper leader for both the undergraduate and postgraduate musculoskeletal papers within the Physiotherapy Department. His key areas of interest are diagnostics and clinical reasoning and how these relate to the diagnosis and management of musculoskeletal pain originating from the hip, lumbar, SIJ and shoulder. Steve is currently undertaking a PhD that aims to determine the diagnostic accuracy of the clinical examination of people with hip joint pain. Prior to pursuing a full-time academic career in 2005, Steve worked in his own private practice for 25 years.

Matt Wood
Matt Wood is a lecturer at the School of Sport and Recreation AUT University and manager of the AUT Human Potential Clinic that provides clinical exercise physiology services. Matt's current research interests involve the optimisation of exercise prescription for people living with chronic disease.

Shi Zhou
Shi Zhou is an exercise physiologist at Southern Cross University. He was originally educated in China and obtained his PhD at The University of Melbourne. He has broad research interests in neuromuscular responses and adaptations to exercise and training, exercise testing and interventions for selected populations, and nutritional supplements for performance and health.

Beyond the Rule Book

BRUCE HAMILTON

I recently stumbled across a copy of the June 23rd, 1969 issue of Sports Illustrated. Sports Illustrated (SI) is not usually considered an academic journal, although despite this, it is likely a truism that the annual swimsuit edition is carefully studied. First published (after a few failed attempts in the preceding years) in 1954, Sports Illustrated has become one of the world's most recognisable and successful sporting magazines with a circulation of over 3 million. As an athlete, you know you have made it when you star on the cover of Sports Illustrated, in the company of Michael Jordan and the LA Lakers as the most regularly featured athletes. While these regularly featured athletes clearly suffered no ill effects of being on the cover of Sports Illustrated, not all athletes were so lucky, with many suffering from the so-called "Sports Illustrated cover jinx". Likely (but possibly not) an urban myth, the cover jinx implies that subsequent to being featured on the cover of Sports Illustrated, athletes performances will be jinxed or suffer from bad luck. Indeed, as a case in point, two weeks before the particular issue that I discovered, defending US Open golf champion Lee Trevino was featured on the cover as part of the build up to the 1969 US Open, only to miss the cut in the Championship. Proof indeed. An alternative explanation for the observations this myth is founded on may be found in statistics, with athletes merely "regressing to the mean". Applying this explanation, after a series of outliers (exceptional performances, after which athletes are invariably featured on the SI cover), future performances will more likely reflect an individual athlete's typical or average performance, thereby giving the appearance of being "jinxed".

Unusually for Sports Illustrated, the cover of the June 23, 1969 issue did not feature an athlete, but rather a strikingly colourful array of pills and potions, and was headlined "Drugs: A Threat to Sport" (Figure 1). Ironically, the back cover contained an attractive full page advertisement for "menthol fresh, filter cigarettes", not so subtly implying that smoking that particular brand of death sticks is sexy, fresh and healthy. Notwithstanding what is now an obvious irony, the feature article inside highlighted doping issues that remain very relevant to 21st century sport.[1] However, even in 1969, the threat of drugs to the integrity of sport was not a new issue, as the use of drugs in sport had been anxiously discussed for 40 years or more.[2] For example, in 1928 the IAAF (then the "International Amateur Athletics Federation") published one of the first (and perhaps the last where there was a unanimous agreement amongst all attendees) formal position statements on doping in sport, stating that "Doping is the use of any stimulant not normally employed to increase the power of action in athletic competition above the average",[3] and in 1965 a comprehensive "International Symposium on Doping in Sport" had taken place in Belgium.[4] Of interest, but tangential to the principle purpose of this editorial (which I will get to eventually), the IAAF position in 1928 determined that identifying and penalising those found to be assisting athletes in doping, was as important as penalising the athletes themselves. Specifically, the IAAF identified that "Any person knowingly acting or assisting…. shall be excluded from any place where these rules are in force".[3] This feature of anti-doping has been resurrected in the 2015 WADA Code (albeit in a slightly more expansive manner than the two paragraphs dedicated to anti-doping in 1928), an evolution of the anti-doping code with which all those working in sport should be familiar.

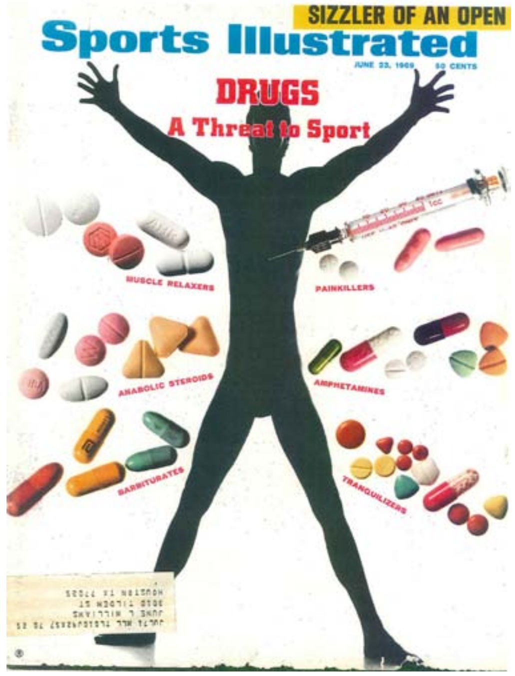


Figure 1: Front cover of Sports Illustrated Magazine, June 23 1969.

Forty-six years after the publication of the June 23rd 1969 Sports Illustrated, it is unfortunate for us all that doping in sport has not suffered from the "SI cover jinx". No indeed. Rather than the SI cover of 1969 representing a series of outliers or rare events with a subsequent moderation in anti-doping behaviours, in 2015 it seems that just about every paper you open, every magazine you pick up and every TV channel flick you make, you will find a 'doping', or 'anti-doping' story breaking. The public shaming of Lance Armstrong seems a distant memory, replaced by the grandiosely titled "Sport's Biggest Drug Scandal" referring to alleged doping infractions that occurred in the Australian Football League (I suspect that the title of this book from our Australian neighbours is a little misplaced given the history of doping around the world).[5] Recently, further challenging questions have been asked of the great American athlete-turned-coach Alberto Salazar, regarding his performance enhancement techniques (for more details on this topic see editorial NZJSM[6]).[7-9] In the immediate post-Armstrong cycling era, of 520 samples taken from cyclists during the 2014 Tour de France, the UCI formally announced that "there were no positive tests". However, at the same time, an independent investigation commissioned by the UCI into drug use in elite cycling concluded that "doping is still taking place", "a culture of doping in cycling continues to exist" and that "doctors play a key role in devising programmes that provide performance enhancement".[10] The World Anti-doping Agency (WADA) has (for the first time) published a summary of anti-doping rule violations (ADRVs), compiled from more than 200,000 athlete samples taken in 2013. From that immense sampling pool, 2540 athletes were initially reported as having adverse analytical findings, and 1687 (0.8%) were ultimately confirmed as ADRVs (the difference between these two numbers results from athletes either being found to have valid TUE's, categorised as "no case to answer", being exonerated or represent cases that are still pending).[11] Perusal of the IAAF website highlights that more than 350 international athletes are currently serving a suspension for drug related activities in track and field alone.[12] New Zealand's own anti-doping Tsar has suggested that in New Zealand, the anti-doping cause was "not helped by a culture of secrecy within some sports".[13] This brief rundown on recent anti-doping 'highlights', which merely scratches the surface of anti-doping incidents, makes for challenging reading for those involved, interested, or participating in all levels of sport.

I admit to a morbid fascination with this topic and there is abundant verbiage out there to feed that fascination, but reading the available mainstream literature (and therefore by definition probably not having any idea of what is or was actually going on) surrounding both the "Salazar"[7-9] and "Essendon"[5] saga's was at times a painful process. I was however, struck by an apparent similarity between underlying elements of the two sagas. Specifically, both episodes illustrate an apparent willingness from participants to apply the principle of "if it's not explicitly against the rules, then its fine to do" along with actively seeking any ambiguity in the rules as a reasonable justification to "push the envelope". It seems that in modern sport, an individual's responsibility for sportsman- (and woman-) ship, has been relinquished, with the moral compass of modern sports being determined by a rule book, umpires or even lawyers, rather than ones internal sporting and moral principles.[14] Brooding, ruminating or mulling over this is really beyond the scope of my medical skills, and I know that sport psychologists, sociologists, ethicists and others will likely be able to explain and rationalise this far more clearly than myself. However, when one considers the nature of elite sport in the modern world, it is clear that it faces challenges, and the abdication of moral responsibility is one of them. Traditionally, sport was considered a means to develop an individual's character, resilience and health. However, participation in modern elite sport is now a career, whose fundamental modus operandi remains grounded in the amateur ethos of fair play and sportsmanship, but which exists within a larger entertainment industry whose fundamental principles are based not around fair play, but revenue generation. While it is obvious that the imperatives of elite sport (ie, success) and the amateur ethos (fair play, comradery, sportsmanship) are not always well aligned, participants in modern sport must remember that it is the historical features of sport, that provide it with much of its validity and integrity. Pragmatically, in this world of conflicting imperatives, it seems that it's the willingness of athletes, coaches and support staff to abandon their individual responsibility for maintaining the integrity of their chosen sport, and rather to rely on others to determine and articulate the moral standards in the "rule-book", that justifies their search for illegitimate means of success.

That WADA address this issue in their rationale for inclusion of substances on the prohibited list is significant. By placing the "spirit of sport" on equal footing with "health" and "performance enhancement" when determining whether a substance or method should be on the Prohibited List, WADA have recognised the importance of protecting the underlying ethos and ethics of sport. Indeed, while the vague nature of the description of the spirit of sport in the WADA Code frustrates some,[15,16] I would contend that this is one of the most important and under-emphasised elements of the WADA Code. While elite sport is indeed entertainment for the masses, without an underlying and believable ethos of sportsmanship and fair play, the appeal of watching and engaging in elite sport (at least to me) is greatly reduced.

Englishman John Mill (1806-1873) was considered one of the most influential political philosophers of the nineteenth century. Mill had strong views on individual liberties, believing that an individual ought to be free to do as he wishes - unless that individual harms others. No matter how you look at it, utilising performance enhancing drugs in modern sport is not a victimless crime. As practitioners working in all fields of Sports Medicine, it is vital that we consider both the ethics of our chosen profession and the values of sport when working with athletes and coaches. Rather than being part of the doping problem, we have a key role in the prevention of doping, working with athletes, coaches, medical practitioners and all the other specialty areas that make modern sport work, to ensure the ethics and values of sport are recognised and applied. While WADA and the sporting federations provide an anti-doping framework and a rulebook for sport, this does not deflect responsibility from the individual to take a strong ethical position, in order to protect the underlying ethos of sport. We all have a role in protecting sport from the perils of doping, for as Mill said: "The only thing necessary for the triumph of evil is that good men [sic] do nothing". Let's all do something about protecting sport from dopes.

References

1 Gilbert B, Problems In A Turned-On World, in Sports Illustrated. 1969 p64-72.

2 Hoberman J, Amphetamine and the Four-Minute Mile. *Sport in History*, 2006. **26**(2): 289-304.

3 Edstrom J S and Kjellman H, Handbook of the International Amateur Athletics Federation 1927-1928. 1928, Vesteras, Sweden.

4 De Schaepdryver A and Hebbelinck H, Doping: Proceedings of an International Seminar. First ed. 1965, Oxford: Pergamon Press Ltd. 180.

5 Le Grand C, The Straight Dope: The Inside Story of Sport's Biggest Drug Scandal. 2015, Melbourne: Melbourne University Press.

6 Hamilton B, Redefining Normality in Sports Medicine: The Power of the Hormone. *New Zealand Journal of Sports Medicine*. **40**(2): 58-59.

7 Epstein D. Alberto Salazar Disputes Allegations - Some of Which Were Never Made. 2015 June 26, 2015; Available from: http://www.propublica.org/article/alberto-salazar-disputes-allegations-some-of-which-were-never-made.

8 Salazar A. Alberto Open Letter Part One. 2015 [cited 2015 June 26, 2015]; Available from: http://nikeoregonproject.com/blogs/news/35522561-alberto-open-letter-part-1.

9 Salazar A. Alberto Open Letter Part Two. 2015 [cited 2015 June 26 2015]; Available from: http://nikeoregonproject.com/blogs/news/35523713-alberto-open-letter-part-2.

10 Marty D, Nicholson P and Haas U, Cycling Independent Reform Commission Report to the President of the Union Cycliste Internationale. 2015, UCI: Lausanne. p227.

11 WADA, 2013 Anti-Doping Rule Violations (ADRVs) Report. 2015, World Anti-Doping Agency: Montreal. p66.

12 IAAF. Athletes currently suspended from all competitions in athletics following an Anti-Doping Rule Violation as at: 09.07.15. 2015 [cited 2015 July 19, 2015]; Available from: http://www.iaaf.org/about-iaaf/documents/anti-doping.

13 Davison I, Code of silence over drugs in NZ sport - anti-doping head, in New Zealand Herald. 2015: Auckland.

14 Morgan W J, K V Meier K V and Schneider A J, Ethics in Sport. 2001, Champaign, IL: Human Kinetics.

15 McNamee M J. The spirit of sport and anti doping policy: an ideal worth fighting for. 2013 [cited 2015 July 19]; Available from: https://www.wada-ama.org/en/media/news/2013-02/the-spirit-of-sport-and-anti-doping-policy-an-ideal-worth-fighting-for.

16 WADA, World Anti-Doping Code 2015. 2015, Montreal: WADA.

Modern youth sport: Too much? Too serious? Too organised? Too many injuries!

CHRIS WHATMAN

When did kids sport get so serious! Most of the kids I've met recently are playing multiple sports, training most days of the week and playing the rest. The good old days of playing one sport in winter and one in summer seem long gone and it all seems so serious! Boys as young as eight and nine point out "rep" players in the opposition that need targeting – I didn't even know they had reps at that age and I'm the coach!

Recently I read about the selection of an under 12 New Zealand baseball team, 30 odd kids selected to play in the World Series in America later this year. Call me old fashioned but an under 12 national side just seems strange and a world series for 12 year olds - really?! A quick look around other sports suggests that baseball is not alone and it seems your representative career can start very early these days. I recall when interviewing Laura Langman she mentioned that as a kid there was no "under 8's" and netball didn't really become serious for her until secondary school – sounds far more sensible to me. It seems sport has got so serious that even the lawyers are getting involved when parents think their children have been unfairly omitted from a team – seems like a slippery slope!

I have seen efforts by some sports to tone things down a bit – mostly trying to get parents to behave on the side line. Local clubs I visit have been displaying signs stating things like "This is not the world cup", "These are only kids", "The referees are volunteers" – good stuff in my view but maybe sports need to do more.

Why should this concern those in sports medicine? Fairly simple and certainly not news to anyone – too much early specialisation/exposure in sport has been linked to increased risk of overuse injury – repetitive load accumulates and can lead to tissue breakdown. This isn't a new concept, Scott Dye proposed the envelope of function for the knee in 1996 (the range of loads that can be applied without causing structural failure) theorising that even small magnitude loads if repeated enough would eventually cause problems.[1] The envelope of function describes a range of loading that is compatible with tissue homeostasis. Recent evidence suggests the best youth volleyball players are at greater risk of injury simply because they are involved in the game more and thus experience greater frequency of loading. How many of our young athletes are pushing beyond the bounds of their envelope of function? Do we really have a good understanding of what that envelope looks like and the consequences of pushing it too far? Physiotherapy colleagues have recently expressed concerns regarding young clients presenting with multiple overuse injuries due to excessive exposure to sport. Coaches have stories of teams playing and training on all days of the week leading into a national secondary school tournament. Irrespective of the increased injury risk my coaching colleagues in academia point out there is evidence this early exposure/specialisation in many sports isn't the best/only way to achieve sporting success!

Unsurprisingly there have been many reports over recent times pointing out that while sport has many benefits for youth the risk of injury is a significant concern. Some authors are suggesting that ankle and knee injuries in youth can be linked to increased risk of osteoarthritis in later life which is obviously associated with significant public and personal cost. Osteoarthritis is considered a major contributor to reduced activity in later life and the subsequent increased risk of associated diseases and reduced quality of life.

Adding to the serious nature of youth sport is the advent of 1st team rugby and netball televised live on Sky Sport – great for the overseas talent scouts but maybe not so good for the young talent? If a team mate messed up playing 1st XV for the mighty Wellington College back in the day it wasn't on display to the nation – different story today. What impact does this have around decisions to play a player who may or may not be fully fit? Recent evidence from America suggests significant numbers of youth athletes play down injuries so they can play on and many coaches report having been pressurised to play injured players – sounds like youth sport getting too serious to me.

So what to do? Seems the sports themselves have a responsibility to set up structures that allow children to undertake sport in a way that optimises player development and minimises the risk of injury. Educating parents would obviously also have to sit alongside this. Why not get rid of representative teams until secondary school at the earliest and encourage kids to play a variety of sports to develop a full range of movement skills? I don't know much about nutrition but my young boys tell me I should have lots of different colours on my plate to ensure a healthy diet! I'd suggest lots of "colours" in sports participation in youth could have the same merits and many would agree. Perhaps there also needs to be time/opportunities for kids who want to play but don't want to sign up to a structured competition? Maybe they just want a bit of fun in a "pick-up" game with their mates – no time for that in the serious training and playing schedule of many youngsters these days!

References

1 Dye S, The Knee as a Biologic Transmission With an Envelope of Function. *Clinical Orthopaedics and Related Research*, 1996. **323**:10-18.

BEST OF BRITISH - from the British Journal of Sports Medicine

CHRIS MILNE

There were two issues of BJSM in March. The first of these contained a number of articles from Physios in Sport (UK), the body responsible for compiling this issue of the journal. It included a provocative editorial by Jeremy Lewis, a New Zealand physiotherapist who has risen up the academic ranks in the UK and is based at the University of Hertfordshire, just north of London. Entitled 'Blood letting for pneumonia, prolonged bed rest for back pain, is subacromial decompression another clinical illusion', Lewis comments that there has been a huge increase in the number of surgical repairs of the rotator cuff performed in 2006 compared with a decade earlier.[1] In particular, there has been a six-fold increase in the number of repairs performed arthroscopically. He comments that many physiotherapists have embraced the subacromial impingement syndrome model, where a forward head posture is associated with an increase in the thoracic kyphosis and with an imbalance of the shoulder girdle muscles. There is secondary anterior tilt and downward rotation of the scapula which, in turn, provokes impingement and rotator cuff pathology. However, this dogma has recently been challenged and an alternative theory suggests that the symptoms result from intrinsic failure of the rotator cuff tendon. Whatever the genesis of the problem, surgical procedures do not seem to have a dramatically superior outcome to non-operative treatment for rotator cuff impingement. Clinicians therefore face the challenge of translating the available research into clinical practice, particularly when this research is often conducted in populations that are not representative of their own clinical practice. In essence, Lewis recommends an appropriately conducted exercise programme rather than resorting to surgical management, as often as we do.

Later in the same issue was an article by Irene Davis and colleagues of Harvard Medical School, entitled 'The foot core system: a new paradigm for understanding intrinsic foot muscle function'.[2] The authors propose that a concept of core stability, already well delineated for the lumbopelvic region, could equally well be applied to the arch of the foot. There are both local stabilisers, the four layers of plantar intrinsic muscles, and the global movers, which are those muscles which originate in the lower leg then insert on the foot. I heard the concept further expanded at the ACSM meeting in San Diego earlier this year and it certainly has some merit. I am sure you will hear more about this as time goes by.

Our own Bruce Hamilton and colleagues from various institutions, including those in Qatar and Spain, collaborated on a narrative review on the classification and grading of muscle injuries.[3] This is a good overview, but it should be noted that the full version is only available in the online edition of the journal. [Editors note: Its also available from the editor on request]

Later in the same issue was an article assessing the diagnostic accuracy of clinical tests for injury of the ankle syndesmosis.[4] Written by a group of Australian authors from Sydney, it evaluated the various tests and found that the inability to perform a single leg hop had the highest sensitivity at 89%, whereas specificity was highest for pain out of proportion to the apparent injury at 79%. Of the clinical tests, the squeeze test had the highest specificity at 88%, and the dorsiflexion external rotation stress test plus syndesmosis ligament tenderness had the highest sensitivity values. In essence, a combination of the sensitive and specific signs seems to provide the best diagnostic information to the clinician. This is a finding that has cropped up in frequent review articles relating to other body sites as well.

Issue 6, also published in March, had a range of articles put together by the Swiss Sports Physiotherapists Association. There was a thought provoking editorial by Adam Meakins entitled 'Soft tissue sore spots of an unknown origin'.[5] Generally known as trigger points, they were first described by Travell and Simons as tender, painful areas found in myofascial tissue when palpated.[6] This theory has had widespread acceptance despite limited evidence put up in support. Meakins proposes that when clinicians are palpating trigger points they are actually experiencing the phenomena of 'pareidolia'. This is defined as a vague and obscure stimulus that is perceived as something clear and distinct. Meakins ends by suggesting we should not be explaining trigger points as muscle knots, but rather as soft tissue sore spots of an unknown origin.

Eccentric training for prevention of hamstring injury has featured frequently in the sports medicine literature in recent years. It was a significant component of our 2014 annual conference, however there continues to be inconclusive evidence regarding eccentric strengthening from randomised control trials. These authors suggest that decreased compliance with the strengthening regime is a key reason for the inconclusive evidence.[7] They recommend exercise implementation should be applicable to the entire team so as to get 'buy in' from the players.

There are many physical examination tests for hip dysfunction, and Michael Reiman and colleagues have evaluated each of these in an excellent review article accompanied by illustrations.[8] Tests evaluated include Trendelenburg's sign, the Thomas test, flexion and internal rotation test, as well as various tests for gluteal tendinopathy, femoral fracture and adductor related pain. The authors found the bilateral adductor test, performed when the patient is supine with both legs extended, to be the most diagnostic of the tests for sports related chronic groin pain. This paper is well worth reading, particularly for those clinicians who see a lot of hip and groin injuries, and for those clinicians involved in any training and examinations at diploma or fellowship level.

High risk stress fractures in the lower leg include those affecting the anterior tibial cortex, navicular and base of the 5th metatarsal (the Jones fracture). Surgery is frequently recommended for these injuries, and authors from Amsterdam evaluated 18 studies including two for the anterior tibia, eight for the navicular and eight for the 5th metatarsal.[9] They found the quality of the evidence to be low and subjected to a high risk of bias. However, surgery for a navicular fracture provided an early return to sport, and for the 5th metatarsal surgery provided the best results.

Issue 7 was an IOC supported issue and included a survey of the sports injuries and illnesses in the Sochi 2014 Olympic Winter Games.[10] Overall, 12% of the athletes incurred at least one injury during the Games and 8% an illness. These data are similar to previous Olympic Games. Within individual disciplines there was significant variation, and athletes competing in aerial skiing comprised 49% of the athletes injured in Sochi compared with only 19% in Vancouver four years earlier.

The Relative Energy Deficiency in Sport document released in 2014 attracted widespread comment and some criticism.[11,12] In 2015 the authors have made some additions to the consensus statement and these are outlined in a four page article plus an appendix.[13,14] This is well worth reading for anybody who deals with athletes in sports where energy balance is disturbed.

Rugby is our national sport (some would say our national religion) and, hence, many New Zealanders have a vested interest in injuries relating to the rugby scrum. Trewartha and colleagues conducted a literature review of the injury and biomechanical perspectives on the rugby scrum.[15] They found that the incidence of acute injury associated with scrummaging is moderate but the risk per event is high. There is emerging acknowledgement of the potential for scrummaging to lead to premature chronic degenerative change in the cervical spine. Certainly, this is a frequent observation by clinicians such as myself who have spent several decades in the field.

Sport is frequently promoted these days for its health benefits. What is the evidence for different sport disciplines? Oja and colleagues, mainly from Finland, reviewed 69 eligible studies across 26 different sport disciplines.[16] They found moderately strong evidence that both running and football improve aerobic fitness and cardiovascular function, and that football reduced adiposity. There was conditional evidence that running benefited metabolic fitness, adiposity and postural balance, and that football improved metabolic fitness, muscular performance, postural balance and cardiac function. Evidence for health benefits from other sports disciplines was less conclusive, however I am sure that sports other than running and football can provide health benefits. Absence of evidence is not the same thing as evidence of absence of an effect, and non-academics should not be hoodwinked. We should remember Hills causality criteria,[17] and if something is biologically plausible this makes it much more likely to be true, even if we are still awaiting the statistical evidence for it.

Issue 8 could well be described as the concussion issue and contained many useful articles on that subject. Prominent among these was a systematic review of concussion in rugby league. The authors, mainly from Australia, found that in comparison to other collision sports, research evaluating concussion in rugby league is limited.[18] However, we see ample evidence of it occurring any week we care to watch televised NRL games. The ball carrier has been found to be at greater risk for concussion injury than tacklers. Not surprisingly, foul play was responsible for a significant proportion of concussion injuries (29% of all injuries, compared with 9% of injuries sustained in legal play).

Jonathan Patricios and Michael Makdissi, two of the leading thinkers in concussion, have written an excellent article entitled '50 Shades of Gray: concussion complexities and constructive conclusions'.[19] They recognise the clinical complexity and variation of the condition, but it is important to get simple messages across to the public; that of recognise, remove and refer is chief among them. The long term risks of concussion remain poorly defined and often speculative. This provides ample opportunity for scaremongers in the media to have a field day. We need to keep plugging away with the information we do have and explain that, like other injuries, there is a spectrum of pathology and therefore the advice will vary depending on the individual circumstances.

Dizziness is a frequent symptom after sports related concussion. Jennifer Reneker and Chad Cook, both from the US, provide useful guidance on possible treatment to hasten recovery from this symptom.[20] They describe the usefulness of vestibular rehabilitation techniques for the treatment of central and peripheral causes of dizziness in non-concussed patients. They believe that there is a case for extending this treatment to concussed athletes with prominent symptoms of dizziness. All those years ago in my undergraduate teaching, I recall that the complex and dense innervation of the upper cervical segment is an anatomical phenomenon. The sensory processing required to interpret head position and movement is not fully understood, and dysfunction of the cervical spine frequently accompanies head injury. Mismatched sensory information can result in an altered motor response and control, and dizziness ensues. These authors make a good case for active treatment of this symptom early in the course of recovery, allied with ongoing research. They promote the concept of 'cervicogenic dizziness' and recognise that there is a need for this message to penetrate the medical school curriculum, as well as continuing medical education sessions. As always, further research data is required and until this data emerges, it is quite likely that the rest paradigm will retain its position as the fall-back treatment of choice.

Issue 9 from May could be entitled the FIFA issue. It presents articles on football for health and describes 20 years of the FIFA Medical Assessment and Research Centre. Edited by Jiri Dvorak and Astrid Junge, it outlines the progress made by FIFA in promoting preventive strategies such as the FIFA 11 for Health, efforts made to improve cardiac screening, and reducing long term health issues such as posttraumatic arthritis.[21-23] Our own Tony Edwards and Mark Fulcher have had significant roles in promoting some of the good work FIFA has been doing over the past 20 years.

Football training may confer health benefits and Bangsbo and colleagues explore the possibility.[21] Currently the evidence suggests that recreational football training can lower systolic and diastolic blood pressure by 7-8mmHg and 5-7mmHg respectively, and improve both left and right ventricular function. It also lowers total body fat, cholesterol and LDL cholesterol plus increases leg muscle mass and bone mineral density. When these benefits are combined with the fun of kicking a ball around, it is hard to see why people would not like the game.

Non-steroidal anti-inflammatory drugs (NSAIDs) are widely used by athletes. An article by Tscholl and colleagues found a high prevalence of medication use in professional football tournaments between 2002 and 2014; 69% of adult male players reported using medication in the 72 hours prior to a football match, and up to one-third of all players used NSAIDs prior to every match regardless of whether they took the field or not.[24] Although this reported incidence may be alarming to some, as an old marathon runner I am familiar with the literature from endurance sport, and these figures are comparable with those competing in football. Despite the many theoretical risks, NSAIDs seem to result in serious outcomes only rarely. However they should not be prescribed with impunity, and it is important for clinicians to educate players as to their rational and appropriate use.

Issue 10 included an article entitled 'Load me up Scotty: mechanotherapy for plantar fasciopathy'. Rathleff and colleagues used exercise and load (mechanotransduction) to treat the injured plantar fascia.[25] This study was an RCT with 12 month follow up and consisted of slow, low load strength training using heel raises with a towel underneath the toes to increase dorsiflexion of the MTP joint. In essence, it is similar to what we have been doing for years for Achilles tendons. I have long thought of the plantar fascia as an extension of the Achilles tendon, with the calcaneus merely being interposed between these two structures. Therefore, I feel somewhat vindicated when such luminaries as Rathleff and Kristian Thorborg, who has spoken out in New Zealand in the past, have advocated such therapy.

Clinicians are always on the lookout for physical performance tests that provide good data and may be relevant in assessing injuries. Eric Hegedus and colleagues looked at 29 articles detailing 19 physical performance tests, of which six were compiled in a best evidence synthesis.[26-28] These authors found conflicting evidence regarding the validity of the hop test and moderate evidence that this test was responsive to changes during rehabilitation. They found no test that predicted knee injury in athletes and commented that there is great opportunity for further study of these tests and the measurement properties of them in athletes.

Later in the same issue, a second article by Hegedus and colleagues looked at tests for the hip, thigh, foot and ankle and found that only the star excursion balance test performed in three directions (anterior, posteromedial and posterolateral) was associated with increased injury risk. There is moderate evidence that the one leg hop test for distance and hexagon hop can distinguish between normal and unstable ankles. Once again they recommend further research, and this is no surprise.

Finally in this issue, there was a summary of republished research from the British Medical Journal. The article was entitled 'Treatment for ACL tear: five year outcome of randomised trial'.[29] The authors found that at five years, patients assigned to rehabilitation plus early ACL reconstruction did not differ significantly in clinical or radiographic outcomes from those assigned to initial rehabilitation, with the option of having a later reconstruction if needed. This is somewhat different from the traditional dogma, but is hardly surprising. The main thing is to bear in mind that each episode of instability can potentially be associated with a meniscal tear, and it is the meniscal tears that can then lead on to a greater risk of posttraumatic arthritis. Also, young clinicians should bear in mind that the forces required to rupture an ACL are significant and, whatever is done, one cannot guarantee a perfect outcome. Often players never hear this message. Nevertheless, we should not shy away from plugging on and trying to do our best for each person that comes through our consulting rooms with this injury.

Issue 11 was put together by influential Norwegian clinicians and researchers. The Scandinavians aare at the forefront of sports medicine research, particularly with regard to exercise and cardiac dysfunction. Therefore, it is no surprise to see an article in this issue entitled 'The right ventricle following prolonged endurance exercise: are we looking at the more important side of the heart?'[30] Adrian Elliott and Andre la Gerche performed a meta analysis of 14 studies with 329 participants. They found that intense, prolonged exercise is associated with a measurable reduction in right ventricular function, whilst left ventricular function is relatively unaffected. They comment that the short term consequences of transient relative right ventricular dysfunction require assessment. Transient right ventricular impairment could impact on cardiac performance during repeated exercise bouts.

The final issue I analysed for this journal issue could well be called the groin pain issue. It included a summary of the Doha Agreement Meeting on terminology and definitions on groin pain in athletes.[31] This consensus statement brought together leading thinkers from around the world and a significant proportion of these people have spoken at our annual conference in days gone by. They agreed on three major subheadings of groin pain in athletes: these include 'muscle', e.g. adductor related, iliopsoas related, inguinal related and pubic related, as opposed to 'hip joint related', the second subheading. Causes that do not fit into either of these two major categories were listed in a third category entitled 'other'. The definitions and terminology are based on history and physical examination, making it simple and suitable for both clinical practice and research. The article provides an excellent table, with headings familiar to those who regularly consult Brukner and Khan's textbook, i.e. 'common', 'other musculoskeletal causes' and 'not to be missed causes'.

In the same issue there was an article entitled 'Minimum reporting standards for clinical research on groin pain in athletes' and this is essential reading for any would-be researchers in the area.[32]

Later in the same issue there was an interesting article entitled 'Femoroacetabular impingement surgery: are we moving too fast and too far beyond the evidence'.[33] Michael Reiman and Kristian Thorborg argue that whilst there has been an exponential rise in surgery for FAI in the past 10 years, there has been no such exponential rise in the strength of evidence supporting such treatment. They contend that FAI morphology does not equal pathology and recommend greater scrutiny on reported outcomes for each method of treatment. As a non-surgeon who reads reports from this side and the other side of the Tasman, I tend to think that there are more than a few people on the western side of the ditch who are being managed by a knife that may not need that management. Only time will tell. This article wins my vote for the most influential article in the last few months as it challenges our traditional thinking, and this is an essential feature of professional practice. All clinicians that treat patients with hip pain should read it and draw their own conclusions.

References

1 Lewis J, Bloodletting for pneumonia, prolonged bed rest for low back pain, is subacromial decompression another clinical illusion? *Br J Sports Med*, 2015. **49**(5):280-1.

2 McKeonn P O, et al, The foot core system: a new paradigm for understanding intrinsic foot muscle function. *Br J Sports Med*, 2015. **49**(5):290.

3 Hamilton B, et al, Classification and grading of muscle injuries: a narrative review. *Br J Sports Med*, 2015. **49**(5):306.

4 Sman A D, et al, Diagnostic accuracy of clinical tests for ankle syndesmosis injury. *Br J Sports Med*, 2015. **49**(5):323-9.

5 Meakins A, Soft tissue sore spots of an unknown origin. *Br J Sports Med*, 2015. **49**(6):348.

6 Travell J and Simons Myofascial Pain and Dysfunction. The Trigger Point Manual. Vol. 1. 1983.

7 Goode A P, et al, Eccentric training for prevention of hamstring injuries may depend on intervention compliance: a systematic review and meta-analysis. *Br J Sports Med*, 2015. **49**(6):349-56.

8 Reiman M P, Mather R C 3rd, and Cook C E, Physical examination tests for hip dysfunction and injury. *Br J Sports Med*, 2015. **49**(6):357-61.

9 Mallee W H, et al, Surgical versus conservative treatment for high-risk stress fractures of the lower leg (anterior tibial cortex, navicular and fifth metatarsal base): a systematic review. *Br J Sports Med*, 2015. **49**(6):370-6.

10 Soligard T, et al, Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games. *Br J Sports Med*, 2015. **49**(7):441-7.

11 De Souza M J, et al, Misunderstanding the female athlete triad: refuting the IOC consensus statement on Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med*, 2014. **48**(20):1461-5.

12 Mountjoy M, et al, The IOC consensus statement: beyond the Female Athlete Triad--Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med*, 2014. **48**(7):491-7.

13 Mountjoy M, et al, Authors' 2015 additions to the IOC consensus statement: Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med*, 2015. **49**(7):417-20.

14 Mountjoy M, et al, RED-S CAT. Relative Energy Deficiency in Sport (RED-S) Clinical Assessment Tool (CAT). *Br J Sports Med*, 2015. **49**(7):421-3.

15 Trewartha G, et al, Injury and biomechanical perspectives on the rugby scrum: a review of the literature. *Br J Sports Med*, 2015. **49**(7):425-33.

16 Oja P, et al, Health benefits of different sport disciplines for adults: systematic review of observational and intervention studies with meta-analysis. *Br J Sports Med*, 2015. **49**(7):434-40.

17 Lucas R M and McMichael A J, Association or confusion: evaluating links between "environment and disease". *Bulletin of the World Health Organisation*, 2005. **83**(10):792-795.

18 Kirkwood G, et al, Concussion in youth rugby union and rugby league: a systematic review. *Br J Sports Med*, 2015. **49**(8):506-10.

19 Patricios J and Makdissi M, Fifty shades of grey: concussion complexities and constructive conclusions. *Br J Sports Med*, 2015. **49**(8):492-3.

20 Reneker J C and Cook C E, Dizziness after sports-related concussion: can physiotherapists offer better treatment than just 'physical and cognitive rest'? *Br J Sports Med*, 2015. **49**(8):491-2.

21 Bangsbo J, et al, Recreational football for disease prevention and treatment in untrained men: a narrative review examining cardiovascular health, lipid profile, body composition, muscle strength and functional capacity. *Br J Sports Med*, 2015. **49**(9):568-76.

22 Bizzini M and 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**(9):577-9.

23 Dvorak J and Junge A, Twenty years of the FIFA Medical Assessment and Research Centre: from 'medicine for football' to 'football for health'. Br J Sports Med, 2015. 49(9): p. 561-3.

24 Tscholl P M, et al, High prevalence of medication use in professional football tournaments including the World Cups between 2002 and 2014: a narrative review with a focus on NSAIDs. *Br J Sports Med*, 2015. **49**(9):580-2.

25 Rathleff M S and Thorborg K, 'Load me up, Scotty': mechanotherapy for plantar fasciopathy (formerly known as plantar fasciitis). *Br J Sports Med*, 2015. **49**(10):638-9.

26 Hegedus E J and Cook C E, Return to play and physical performance tests: evidence-based, rough guess or charade? *Br J Sports Med*, 2015.

27 Hegedus E J, et al, Clinician-friendly lower extremity physical performance measures in athletes: a systematic review of measurement properties and correlation with injury, part 1. The tests for knee function including the hop tests. *Br J Sports Med*, 2015. **49**(10):642-8.

28 Hegedus E J, et al, Clinician-friendly lower extremity physical performance tests in athletes: a systematic review of measurement properties and correlation with injury. Part 2--the tests for the hip, thigh, foot and ankle including the star excursion balance test. *Br J Sports Med*, 2015. **49**(10):649-56.

29 Frobell R B, et al, Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial. *Br J Sports Med*, 2015. **49**(10):700.

30 Elliott A D and La Gerche A, The right ventricle following prolonged endurance exercise: are we overlooking the more important side of the heart? A meta-analysis. *Br J Sports Med*, 2015. **49**(11):724-9.

31 Weir A, et al, Doha agreement meeting on terminology and definitions in groin pain in athletes. *Br J Sports Med*, 2015. **49**(12):768-74.

32 Delahunt E, et al, Minimum reporting standards for clinical research on groin pain in athletes. *Br J Sports Med*, 2015. **49**(12):775-81.

33 Reiman M P and Thorborg K, Femoroacetabular impingement surgery: are we moving too fast and too far beyond the evidence? *Br J Sports Med*, 2015. **49**(12):782-4.

An Interview with Dr Lynne Coleman

Sports Doctor

Member of the New Zealand Order of Merit - 29 June 2015

BRUCE HAMILTON

INTRODUCTION

As part of the 2015 Queen's Birthday Honours List, Dr Lynne Coleman was recently made a "Member of the New Zealand Order of Merit" for her services as a Sports Doctor.

This is an incredible achievement for Lynne, and is fantastic for a Sports Doctor in NZ to be acknowledged in this way.

Lynne has made an immense contribution to Sports Medicine in NZ as was summarised as part of her Citation:

Dr Lynne Coleman is a sports doctor for high performance athletes in New Zealand.

Dr Coleman gained her medical degree in 1984 and a Postgraduate Diploma in Sports Medicine (Otago) in 2001 while working full-time as a General Practitioner. Since 2004 she has been involved in, and led the medical team for the New Zealand Olympic and Commonwealth Games teams. At the same time, she has also served as medical director for Swimming New Zealand, Athletics New Zealand and Basketball New Zealand and as team doctor for a number of our national men's and women's sports teams including New Zealand Rugby Union teams. She has been a Member of the Sports Tribunal of New Zealand since 2008, a body which considers disputes and disciplinary matters in sport, including anti-doping violations; was an elected member of the Waitemata District Health Board from 2001 to 2010; and has volunteered her time to the regional sports Trust on the North Shore (Harbour Sport) since 2006. Dr Coleman is widely regarded and respected within the sector for her long-standing commitment to New Zealand high-performance sport through her work as a sports physician.

Source: http://www.dpmc.govt.nz/honours/lists/qb2015-mnzm

Accessed July 1 2015

Qualifications:

- BHB
- MBChB
- DipObst
- FRNZCGP
- PGDipSportsMed
- PGDipBus
- MRNZCUC

Major Sporting Events / Roles:

- Olympic Games 2004,2008,2012
- Commonwealth Games 2006, 2010, 2014
- NZOC Health Team Leader 2006-2012
- Medical Director Swimming (current), Basketball, Athletics
- World University Games Bangkok
- Chef de Mission World University Games Belgrade 2009.
- NZRU Team Doctor – BlackFerns / U20s.

I have been lucky enough to have the opportunity to speak with Lynne about elements of her career in Sports Medicine.

When you were studying as an undergraduate, did you see yourself working in sports medicine?

Not as an undergraduate. Sports medicine was not a realistic option for me then, as at the time you needed to travel to the UK to get any type of qualification, and as I was newly married and ready to embark on starting a family this was not an option.

What inspired you to work in sports medicine?

I have always loved sport. I was brought up in a very sporting family, played tennis and netball at a reasonable level and continued to participate through medical school in teams until I was a Trainee Intern.

I decided to move into sports medicine after moving out of my obstetric career. I began working with my local rugby club and loved the work. I also helped with my children's various sports teams and found myself assisting with injuries and advising parents and children alike. I decided I wanted to work in an area with relatively healthly people striving to live healthily and keen to test themselves in the sporting arena. I also fundamentally believe in the benefits of healthy eating and healthy living and the benefits of exercise participation for both physical health and mental wellbeing.

What are some of your highlights from working in sports medicine?

There are so many that come to mind really. I feel incredibly honoured to have led the NZ Health Team and worked with people such as Dave Currie (CDM) to build a sense of team around our elite athletes. It has been very inspiring. I have also enjoyed being part of World Championship winning campaigns with Women's Rugby in 2006 and the U20 mens team this year.

I took special enjoyment in Moss Burmester winning gold in Melbourne 2006 in 200 m butterfly – as I had worked with him for a long time and this was just reward to his endeavour. Watching Sarah Ulmer and her gold medal performance in Athens 2004 – another stand out performance by a very special athlete. I have been incredibly lucky to have witnessed some phenomenal sporting triumphs.

What have been the low lights of working in sports medicine?

Low lights ... fortunately few and far beyond. I guess the disappointment for Mahe Drysdale in Beijing when he got sick and was not able to participate in his event to the best of his undoubted ability. Whilst it was a low light, the very fact he did in fact compete at all was a credit to him and the multi-disciplinary support team around him. The only other aspect I would like to acknowledge is the time my family has had to have without me, and me them. I love being involved, but it does come with personal sacrifice and I could not have done it all without their loving support of me.

What do you see as your strengths working in sports medicine, and what are your areas of particular expertise/interest?

I believe my strengths draw from my generalist training and experience. The way I investigate and work through issues with my athletes, I try and take a truly holisitic approach. I believe the years of experience in general practice grounds me with exposure to many different conditions and issues, and diagnostic ability is honed through these years - I bring all this to my sports medicine. I have a particular interest and strength in women's and adolescent health, and am very interested in the psychological stressors within elite high performance sport. I believe my generalist background assists me in working in team with my other multi-disciplinary colleagues.

How do you see the relationship between and relative roles of sports physicians and sports doctors/general practitioners with an interest?

I believe they are complementary on many levels. True, there is overlap, but I believe the athletes all benefit by having both types of practitioner available to them. It is not unlike midwives and GP obstetricians, both are very capable but the two skill sets together cover so much more. I would be sorry to see the loss of generalist skills to the wider sports medicine community, so I hope my journey inspires new interest amongst my generalist colleagues.

What do you consider to be key areas in exercise and health that sports medicine practitioners should be influencing both with individual patients and in national/regional policy?

Living an active lifestyle must be a national policy. We know the undoubted benefits of this and whilst we cannot all be elite athletes, we can be inspired to be healthy by these people and reap many of the physcial and mental health benefits of exercise and healthy eating. This is another reason I would encourage young generalist doctors to perform postgraduate training in sports medicine. The fundamental principles taught in Sports Medicine add to your skill set in primary care setting, regardless of whether you work formally in a sport or with a team.

What would you like to see more of in undergraduate medical training?

Exposure to multidisciplinary teams and how the roles of nutrition, physical therapy, sports and exercise science and other paramedical disciplines can assist clinicians in our role of promoting health and wellness.

I believe we have a responsibility to preventative medicine, as well has diagnosis and treament. I believe we need to be emphasising wellness and maintenance of wellness, rather than being 'ambulances at the bottom of the cliff'. Taking this approach will be the main modifier of illness and disease in the future.

What advice would you give to an undergraduate or junior doctor with an interest in sports medicine?

I would encourage them to get as much experience in a generalist sense as possible rather than focus into Sport Medicine at too early a stage. I would encourage them to get involved in their local sports clubs/teams as a junior doctor and to learn and understand the role of medicine in sport at the grassroots level. Being involved at all levels of sport makes you appreciate the 'power and influence' sport has in a Nation such as NZ. I have some concerns that there will not be enough full time roles for pure Sports Medicine doctors here in NZ, hence my comments around considering Sports Medicine as an adjunct to your medicial career path.

What do you see as critical elements of a success when working in sports medicine?

Athletes validating the work you do with them. In the end it is always about them. If they appreciate your work, as well as the wider support team – coaching staff, performance staff – appreciate your timely intervention and thus hopefully the optimal return to play and availability of players for team selection– then we are definitely doing our job.

First and foremost 'do not harm' is really relevant too. Timely non-intervention is also a skill, and being able to step back from the emotional 'heat' of a situation and do the 'right' thing is critical. Often it is about the relationships you have with people and mutual respect for everyone's position in any given situation, and ultimately everyone doing the very best you can in any given situation.

I do believe we have a role in investigating and researching diagnostic tools and treatments, to ensure we are offering the most cutting edge treatment and advice – we should be always striving for excellence in all that we do and validation of our approach is vital for this.

If you were not working as a doctor, what would you like to do?

Interesting question. I am quite a creative person, and I have often wondered if Architecture would have been good fit for me. That said, with my fascination for the human body and mind, in the end I do feel my career choice has been the right one for me.

An Interview with Jeni Pearce

Performance Nutritionist
Member of the New Zealand Order of Merit - 29 June 2015

BRUCE HAMILTON

INTRODUCTION

As part of the 2015 Queen's Birthday Honours List, HPSNZ Lead Performance Nutritionist Jeni Pearce was recently made a "Member of the New Zealand Order of Merit" for services to Sports Nutrition.

This is an incredible achievement for Jeni, and is great that her contribution to Sports Nutrition in NZ can be acknowledged in this way.

Jeni has made an immense contribution to Sports Nutrition in NZ and around the world, as was summarised as part of her Citation:

Ms Jeni Pearce has contributed to sports nutrition for 30 years and is a recognised pioneer and world leader in the field.

Ms Pearce ran her own private clinics for more than 22 years, during which time she was the nutrition representative for the Sports Medicine New Zealand Conference Scientific Committee and other sports nutrition bodies. She has worked pro bono with high performance athletes and teams including for the Olympic and Commonwealth Games since 1985, and as a consultant for international events, teams and athletes and the New Zealand Defence Department. From 2010 to 2012 she was head of performance nutrition for the English Institute of Sport and British Olympic Medical Institute Intensive Rehabilitation Unit and is currently Performance Nutrition Lead at High Performance Sport New Zealand. She has supported the development of sports nutrition diplomas and degree courses at New Zealand universities. She is currently President of the international 'Professionals in nutrition and exercise for sport' and was previously co-chair of the American College of Sports Medicine. Ms Pearce has published papers and books on health and sports nutrition, has been a media commentator on nutrition issues and presented key note addresses at many national and international nutrition and sports medicine conferences

Source: http://www.dpmc.govt.nz/honours/lists/qb2015-mnzm

Accessed July 1 2015

Having worked alongside Jeni for many years, I have managed to cajole her into this interview and talking about her career in sports nutrition.

How did you get into sports nutrition at a time that sports nutrition barely existed and what inspired you?

I was always keen on a range of sports at secondary school and made a number of local and regional teams for basketball and cricket as well as running. At the same time I was interested in food, nutrition and science, especially biology and chemistry. All I knew on entering Otago University was I wanted to work with food and people and did not wish to become a chef or laboratory scientist. At the end of my first year I asked to combine my 'Home Science' degree with the physical education programme and was told I would have to stay another 3 years despite many of our classes being the same. Playing sport in Dunedin at Otago University established a link for me between exercise and nutrition. My time as clinical dietitian at Tauranga hospital forged the move to sports nutrition. At the time I was performing an enormous amount of training, typically running 5-8 km in the morning, swimming at lunch, gym workouts after work, while biking to and back to the hospital each day and doing long runs on the weekends around the beaches. I was also trying to experiment with weight lifting and body building. As a result, I was tired all the time but also realised that the hospital environment was not for me, as I felt the loss of patients terribly, especially the children I worked with suffering from terminal diseases. This was when I applied to Iowa State University, on a scholarship with Otago University to study nutrition education/sports nutrition.

Qualifications:

- Dip HSc (Otago)
- Dip Sec Tech (Auckland)
- MSc Nutrition and Nutrition Education (Iowa, USA)
- Registered Dietitian (NZ 1980)
- SMA Sports Dietitian (Australia 1994)
- Fellow SMNZ
- IOC Diploma in Sports Nutrition
- Life Member NZ Nutrition Foundation

Major Sporting Events / Roles:

- America's Cup and Several Whitbread races
- English Institute Sport (EIS) Performance Nutrition Lead
- eam GB Performance Nutritionist 2008 (Beijing), 2010 (London)
- Mclaren F1 Performance Nutritionist
- HPSNZ Performance Nutrition Lead
- Glasgow Commonwealth Games Recovery Manager
- President PINES (Professionals in Nutrition for Exercise and Sports)
- Secretary SMNZ Waikato Branch & Conference support
- ACSM Nutrition Interest Group Co Chair

What was it like trying to get started in sports nutrition?

After completing my undergraduate degree at Otago, I was accepted into the Auckland secondary teaching programme and trained as a secondary teacher for chemistry, biology, physical education and home economics, which taught me about communication and knowledge sharing, but more importantly that working full time in educational institutions was not the ideal environment for me. Fortunately, I was then accepted into the dietetics programme at Christchurch hospital (an intensive one year internship and exams) at a time when having two career paths was uncommon and responded to the many challenges to graduated prior to starting work in a provincial hospital.

Jumping in feet first, after a quick look and scoping out obstacles, is part of my life philosophy - how bad can it be, and what's the worst that would happen? And if it does work out what would the rewards look like?

Applying for the ISU scholarship in the USA was based along this line of thinking; At least they will know I am interested in further study at a time when dietitians with postgraduate degrees were uncommon. Living and studying in the USA gave me the confidence, courage and conviction to start private practice in NZ on my return, but it took three years for two nutrition concepts to come together: A self-sustaining business in private practice as a dietitian (where people would actually pay to come and seek my advice and support) and the specialist area of private practice (athletes, coaches and teams would seek out and pay for my advice). I was told on a number of occasions I would go broke in a week or a month. Fortunately, at the time some key members of SMNZ were incredibly supportive and invited me to join their organisation: Dr Noel Roydhouse, Dr Matt Marshall, Dr David Gerrard and Dr Chris Milne. These mentors continued to encourage and support my burgeoning career pathway, as well as send their athletes to seek support in sports nutrition.

Is it true that you have written recipe books?

I have written 12 books to date, of which the 7 books were recipes only (practical and healthy with a focus on sport and making the theory real) and including "The Active Kids Cookbook". All have focused on the positive aspects of what can be done to change or improve nutritional intake for the active person. Eat to Compete, released in 1990, was the first and took 2 years to write!

I have also had recipes published in several other books (mostly for charity publications) and made contributions to sports nutrition textbooks in the area of Gut health and supplements. Due to my role at HPSNZ there is currently little time for book writing however there may be one last publication before I retire.

Editor Note: Jeni's books have sold over 150,000 copies, with "Eat to Compete" having 7 reprints.

How has nutrition evolved over the last 20 years?

I have witnessed decades of trends and progression in sports nutrition science including:

- The move from sports drinks and CHO loading in the 1970-80's
- high fibre eating and the low CHO high protein diets in the 1990's (complete with the development of protein drinks such as Complan and Sustagen)
- 21st century periodised nutrition and critical review of CHO intake based on training and performance
- the rise of creatine and supplementation (creatine, omega 3)
- the more recent evolution of whey protein and chocolate milk and a strong food focus and
- the influence of the microbiome (complete with faecal transplants) and the role and use of probiotics.

Sports and performance nutrition will constantly be evolving as the depth and breadth of knowledge is increasing and developments in research fine tunes our knowledge.

You have led the way in trying to refine the title of nutritionists working with elite athletes to "Performance Nutrition" – why is that?

The term 'sports nutrition' has been used to cover a range of activities including the very general eating of health and activity practices right through to the elite athlete. There has been a concern that some nutrition messages that are designed for specific situations/ environments and sports have been translated directly into the gym or recreational areas, where they are not relevant or appropriate. The use and abuse of supplements (particularly whey protein and creatine) and sports drinks would fit into this category. The term 'Performance Nutritionist' or 'Sports Performance Dietitian' has been used to more clearly define working at the elite end of sport. As such, at times the work is not necessarily about health and is very focused on performance outcome (weight making in sports such as light weight rowing, and other weight class sports are key examples where the athlete cannot compete unless they meet the weight criteria). A performance nutritionist has 6 key skill areas including:

1. strong knowledge of evidence based sports and exercise science
2. clinical nutrition skill set,
3. catering expertise
4. in depth background in food science
5. high level communication and behavioural skills
6. an ability to be applied and practical

Do you see a conflict between health and elite performance, when it comes to nutrition advice?

Yes, but only for short or specific periods of time. For example, there is a real concern around energy availability, RED-S (Relative Energy Deficient in Sport) and performance. If athletes are required to alter body composition to extreme levels for performance this should be done for the shortest time possible and with careful follow up and multidisciplinary support. Athletes should then return to a more desirable body composition for health and training as soon as possible. At HPSNZ and with most institute programmes we are privileged to work in teams. In Performance Nutrition we are privileged to work on an individual level with the coach, the athlete and the supporting sports science and medical teams. This is often not the case in many other environments outside of institutes and professional sport.

What are some of your highlights from working in Sports Nutrition?

Formula 1 motor racing (being an accredited pit crew member for a week), Americas Cup (watching the start of the race 800 m above the start line in a helicopter), travelling the world with the Whitbred Sailing races and developing an international expertise in freeze dried food and packaging, working with young players and athletes and seeing their careers become dynamic and highly successful, seeing seasoned athletes reach their goals and wining Olympic Medals, the incredible coaches and thoughtful athletes over the years who have expanded my knowledge and application of the science, and those who continue to challenge and seek nutrition to benefit and impact performance. Each sport has its own unique highlights and it's also the experts you work along the way (boat builders, sail makers, researchers, food scientists) with whom you get to expand your knowledge and appreciation of the privileged environment we work in. Being involved in developing and growing the discipline of Performance Nutrition both locally and internationally and having Sports Nutrition acknowledged as a sustainable career path, has been a real highlight.

If you were not working as a Performance Nutritionist, what would you like to do?

Be a food and travel critic and reporter travelling the world with a Christmas shop on the side.

Thanks!

Self-reported sun protection strategies among Australian surfers: Are they heeding the message?

RUDI A MEIR, SHI ZHOU, MARGARET I ROLFE, WENDY L GILLEARD, ROSANNE A COUTTS

See end of article for author affiliations.

Correspondence
Rudi Meir
School of Health and Human Sciences
Southern Cross University
PO Box 157, Lismore 2480
AUSTRALIA
Tel: +61 2 6620 3767
Fax: +61 2 6620 3880
Email: rudi.meir@scu.edu.au

ABSTRACT

Aim

To establish the current sun protection strategies of Australian surfers and the incidence of medically diagnosed skin cancer in the 12 month period preceding data collection.

Study Design

Diagnosed skin cancer and skin lesions were recorded via online questionnaire.

Participants: 685 self-selected surfers (mean 31.7 ±12.9 yr) participated in this research.

Methods

This research involved a retrospective survey of self-selected surfers completing an online survey that had specific questions related to sun protection strategies while surfing and whether respondents had been treated by a medical practitioner for a skin cancer or lesion and the site on the body where this was located.

Results

19.1% of respondents reported "never" using sunscreen/zinc on any sun exposed areas of the skin during the summer months with this figure rising to 46.8% in the winter months. Less than 4% reported wearing a surf cap in summer or winter. A total of 224 separate skin cancers/lesions were reported. 50% of all reported skin cancers/lesions were identified on the upper body with the face being the most common location overall (21.9%). This equates to a mean rate of occurrence of 9.1 skin cancers/lesions per 1000 hours surfed.

Conclusion

In spite of the significant investment and effort devoted to promoting appropriate forms of sun protection, survey responses indicate that surfers do not appear to be embracing the public health strategies related to sun protection.

Keywords

Ultraviolet radiation, skin cancer, surfing

INTRODUCTION

Surfing is a sport enjoyed by millions of participants around the world with countries such as Australia and New Zealand having global reputations as surf meccas. As an activity surfing challenges the body in a number of ways that place demands on a participant's balance, coordination, cardiovascular fitness, muscular endurance, strength and power.[11,12] Recent unpublished research has reported that surfers can typically spend between 1-2.5 hours in the water on each occasion they surf, with sessions lasting longer than 3 hours not unusual.[9] Surf participation can result in a wide range of injuries caused by the equipment used (eg, being struck by a surfboard), striking the sea floor (eg, reefs, rocks, sand), impacting with the water (eg, wiping out and landing awkwardly) or resulting from the physical movements utilised while riding a wave (eg, placing the knee under excessive valgus/medial stress when landing).[14] In addition to injuries associated directly from participation in surfing there is also the constant presence of potential marine based hazards (eg, being stung and bitten) and possible death from drowning or shark attack.

While there has been published research on the types of injuries sustained during surfing[2,10,23] and associated injury rates[1,14,17] little attention has been focused on the possible consequences of the long hours of sun exposure while participating in this activity. Excessive sun exposure is considered a major factor that relates to skin cancer rates.[13] The Australian Cancer Council estimates that annually approximately 1 million Australians are diagnosed with non-melanoma skin cancers with over 434,000 of these treated for one or more non-melanoma skin cancers with 95-99% of these caused by sun exposure. Risk factors associated with skin cancer include genetics and immunity but the most important risk factor, for both non-melanoma and melanoma skin cancer, is UV radiation (UVR).[3,13] Melanoma is the third most common cancer in Australia with mortality rates increasing with proximity to the equator.[21] The World Health Organisation estimates that each year more than 2 million skin cancers are diagnosed and while there are numerous types of skin cancer the three most common forms are basal cell carcinoma (BCC), squamous cell carcinoma (SCC) and melanoma.[20]

According to Moehrle[13] outdoor athletes exposed to UVR are probably at higher risk of skin cancer with repeated UV-A exposure leading to photodamage, which potentiates the effects of UV-B on skin cancer formation. Research by Rosso et al.[18] has suggested SCC risk is significantly associated with sun exposure during outdoor work, with BCC more likely linked with recreational sun exposure. Outdoor work exposes the individual to a more constant type of sun exposure throughout the year, with varying levels of solar irradiation, while recreational exposure is more intermittent. The former allows for some natural skin protection to develop through tanning and thickening of the external skin layers while the latter does not provide the opportunity for this same degree of natural skin protection to build up.[18]

Research[18,19] has concluded that relatively low levels of sun exposure are enough to develop BCC whereas SCC is more likely to develop in those exposed to higher doses of solar irradiation over an extended period of time, ie, chronic UV exposure. Further, exposure to UV radiation at a young age plays a role in the development of both BCC and melanoma later in life, with the risk increasing if there has been a history of one or more sunburns in childhood or adolescence.[19] Skin colour and ethnicity is also a significant factor with those of light colour being 80 times more likely to develop BCC and SCC, and 20 times more likely to develop melanoma than those of African American decent.[19]

Since 1980 Australians have been exposed to a range of public health campaigns designed to encourage behaviour change, increase awareness of skin cancer prevention and associated strategies. These strategies have included the use of mass media communications and intervention/education campaigns targeting schools, the workplace and community and leisure centres.[22] These campaigns initially revolved around the slogan "Slip! Slop! Slap!" and while state based were soon to evolve into a national campaign under the SunSmart branding of Cancer Council Australia (www.sunsmart.com.au). While there is evidence that Australians across all age groups are using sunscreen as a sun protection strategy it is not forming part of a multi-faceted protection strategy (ie, seeking shade, avoiding the sun, particularly in the hotter times of the day, wearing protective clothing and eyewear, and using sunscreen for exposed areas of the skin) as recommended by health authorities.[24]

There is evidence that mortality from melanoma has stabilised in recent years in Australia, despite a rise in detection rates, and this might be attributed to a combination of early detection and treatment.[24] Further, the SunSmart programme and its associated strategies appear to have improved sun protection behaviours and reduced sunburn up until the late 1990s. However, these improvements experienced a lapse from the late 1990s until 2003-2004 but have now returned to more favourable peak levels reported in 1994-1995.[7]

Given the above, information on the current sun protection practices of Australian surfers and their self-reported rates of skin cancer may help to shed light on the current skin protection strategies being adopted by this at risk group. To this end this study investigated the current sun protection practices of surfers and their self-reported rates of skin cancer and treatment by a medical practitioner in the twelve months immediately preceding this study.

METHODS

Study Design and Participants

This research used a retrospective, self-reporting web-based (online) questionnaire administered to a self-selected sample of surfers residing in Australia. The questions relating to sun protection strategies and reported skin cancer formed part of a larger survey instrument that was used to assess the prevalence and types of injuries sustained by surfers, the results of which have been reported separately.[9] Potential respondents to this survey were advised of its availability via a range of online surf industry sources. However, the principal source of these was the project's industry partner, Surfing Australia, who, in addition to distributing notification directly to its membership by email, also provided a "news" story and link on the homepage of its corporate web site. Additional media releases were distributed to general electronic and print media outlets and surf specific publications promoting this research and inviting interested surfers to consider participating.

The survey used a combination of "yes/no", checklist and simple open response questions. The first 4 pages presented information related to the rationale for the research, ethics approval (institutional ethics approval number ECN-09-148) and consent, and tips on how to complete and submit the survey. The remaining 10 pages of the survey contained a number of categories of questions but the ones directly related to this current analysis were related to:

i Average time spent in the water when surfing – categories were broken down to identify time of year, ie, winter or summer

ii The sun protection strategies used by respondents when surfing – these were use of sunscreen/zinc, wearing a rash vest (or wetsuit) or surf cap

iii The sun protection strategies used when outdoors but not surfing, and their daily occupation/activity – these were wearing a singlet or shirt/t-shirt, wearing a wide brimmed hat, seeking shade, wearing sunglasses; whether they were predominantly indoors or outdoors

iv Whether respondents have been treated by a medical practitioner in the past 12 months for a skin cancer or lesion and the site on the body where this was located

A descriptive analysis was employed to summarise and present the results of each question utilising SPSS (IBM SPSS Statistics, ver. 18.0). Categorical data was summarised with numbers and percentages, and continuous data with means, medians and standard deviations. Where appropriate chi-squared was utilised to test association and student t-tests were used to examine bivariate relationships of categorical and continuous variables respectively, particularly in examining gender differences. Logistic regression was used to examine the relationship of having skin cancers (Yes/No) with surf craft type before and after adjusting for age and years surfed. An alpha level of $p \leq 0.05$ (95% test of significance) was used for all statistical comparisons. All data were summarised using descriptive statistics (mean [±SD]), frequencies and percentages.

RESULTS

A total of 772 persons participated in the survey. However, some respondents did not complete all questions. For a total of 87 participants, the amount of missing data was significant and therefore not included. On this basis descriptive analyses were based on 685 respondents who completed the survey fully. Table 1 provides a summary of respondents by age category and gender. The overall mean (±SD) age of respondents was 31.7 ± 12.9 (range = 12-67) years, with a median of 30 years. The age of the male and female participants were very similar, with a mean age 31.9 ± 12.9 and 29.7 ± 12.2 years respectively. The majority of respondents (71.5%) typically described themselves as "recreational" surfers. Unsurprisingly the majority (71.3%) lived along the eastern seaboard of Australia with the remainder (28.7%) being distributed throughout all other states and territories.

The average number of hours per week surfed by respondents in summer was 10.9 ± 8.50 and in winter was 8.3 ± 6.98. Respondents indicated that they typically surfed for between 1 to 2.5 hours on each occasion. However, a number of respondents (19.6%) indicated that they typically surfed for longer than this with sessions lasting a minimum of 2.5 hours.

Respondents were asked about their occupation and how they would describe their work environment (e.g. indoors or outdoors). A total of 617 surfers responded to this question with 277 (44.9%), 72 (11.7%) and 268 (43.4%) indicating that they would generally describe their occupation/daily activity as being one that involved them being "indoors", "outdoors" or a combination of both respectively.

Table 2 provides details of the types of sun protection strategies being employed in the warmer (October to March) and cooler months (April to September) by respondents when surfing. From these results we can see that 64% (n = 395 of 617) of respondents "always" or "most of the time" applied sunscreen/zinc to their nose when surfing during the warmer months, while a total of 54% (n = 333 of 617) applied sunscreen to all exposed areas of skin when surfing in the warmer months with 19.1% (n = 118 of 617) reporting that they used no sunscreen at all in the warmer months. Similarly, the use of strategies such as the wearing of rash vests (short or long sleeved) and surf caps was less popular among respondents in the warmer months. The rates of sunscreen/zinc use on the nose, face and neck, and for all exposed areas of the skin in the cooler months was approximately half of that reported in the warmer months.

Table 1: Age of respondents by gender and 10 year age category distribution (N=685)

Age Categories	Males	%	Females	%	All*	%
12-19	126	21.5	23	24.0	149	21.8
20-29	154	26.3	31	32.3	186	27.1
30-39	146	25.0	19	19.8	166	24.2
40-49	84	14.4	13	13.5	98	14.3
50-59	64	10.9	10	10.4	74	10.8
60 and over	11	1.9	0	0.0	12	1.8
Total	585	100.0	96	100.0	685	100.0

*Four respondents identified as being transgender but were included in the "All" category and not identified elsewhere in any gender category analysis for confidentiality reasons.

When not surfing but outdoors working or for some other form of recreational/relaxation activity during the daytime, the most popular forms of sun protection reported by respondents were wearing a shirt ("most of the time" or "always" = 481 of 617; 77.9%) and/or sunglasses ("most of the time" or "always" = 455 of 617; 73.7%). The option of wearing a wide brimmed hat was the least popular, with 77.5% (n = 478 of 617) of respondents indicating that they either "never" or only "sometimes" used this strategy.

A total of 90 respondents (14.6%) of the 617 answering this question reported that they had been treated by a medical practitioner for a skin cancer or lesion in the 12 months immediately prior to completing the survey. Of these, 3 respondents were diagnosed with melanoma and 6 as having a BCC. A total of 224 separate skin cancers/lesions were reported, indicating that some respondents had more than one for the period. Table 3 provides a summary of these by age and frequency. The most common site category was the upper body (from below the neck to above hips) with 50% (n = 112) of all reported skin cancers/lesions. However, the most common location for skin cancers/lesions was the face with 21.9% (n = 49 of 224 report skin cancers/lesions) of all reported skin cancers/lesions (see Table 4). This equates to a mean rate of occurrence across all respondents answering "yes" to this question of 9.1 (median = 4.8) skin cancers/lesions per 1000 hours surfed in the 12 month reporting period.

Table 2: Sun protection strategies reported by respondents (n = 617).

Period	Strategy		Never	Sometimes	Mostly	Always
Warmer months	Sunscreen/zinc nose	n	138	84	147	248
		%	22.4%	13.6%	23.8%	40.2%
	Sunscreen/zinc face neck	n	63	96	187	271
		%	10.2%	15.6%	30.3%	43.9%
	Sunscreen all exposed skin	n	118	166	151	182
		%	19.1%	26.9%	24.5%	29.5%
	Short sleeve rash vest (or wetsuit)	n	153	188	144	132
		%	24.8%	30.5%	23.3%	21.4%
	Long sleeve rash vest (or wetsuit)	n	200	178	113	126
		%	32.4%	28.8%	18.3%	20.4%
	Surf cap	n	501	71	21	24
		%	81.2%	11.5%	3.4%	3.9%
Cooler months	Sunscreen/zinc nose	n	227	175	90	125
		%	36.8%	28.4%	14.6%	20.3%
	Sunscreen/zinc face neck	n	174	200	106	137
		%	28.2%	32.4%	17.2%	22.2%
	Sunscreen all exposed skin	n	289	161	75	92
		%	46.8%	26.1%	12.2%	14.9%
	Short sleeve rash vest (or wetsuit)	n	315	140	57	105
		%	51.1%	22.7%	9.2%	17.0%
	Long sleeve rash vest (or wetsuit)	n	116	73	127	301
		%	18.8%	11.8%	20.6%	48.8%
	Surf cap	n	529	49	20	19
		%	85.7%	7.9%	3.2%	3.1%

Statistically ($p < 0.05$) chi-squared established that there were no differences between the reported frequency of skin cancers between males and females ($p = 0.87$). Similarly, t-test established that there were no differences between males and females with respect to the hours spent surfing per week (warmer months $p = 0.17$; cooler months $p = 0.97$). However, when all respondents were combined, chi-squared analysis established that there was a significant effect of age ($p < 0.01$), with a higher rate of skin cancer reported within the identified age categories with advancing years (i.e. 12-19 yrs = 3.3%; 20-29 yrs = 4.8%; 30-39 yrs = 12.4%; 40-49 yrs = 29.8%; and 50 yrs and over = 39.2%).

Table 3: Frequency of reported skin cancer/lesions by age category (n = 90)

	Number of skin cancers reported per person									Group Total	Number of Age Group Respondents*
Age group	1	2	3	4	5	6	7	8	17		
12-19	2	-	-	1	-	-	-	-	-	6	3
20-29	2	2	1	-	-	-	-	-	-	9	5
30-39	11	3	1	-	-	-	1	1	1	52	18
40-49	13	3	6	1	2	-	-	-	-	51	25
50 and over	9	6	1	2	4	2	6	-	-	106	30
Total	37	28	27	16	30	12	49	8	17	224	81*

*Note: 9 respondents indicated that they had been diagnosed with a skin cancer or lesion but did not indicate the number

Table 4: Skin cancer/lesion site and number reported by surfers (n = 90).

General Area of Body	Reported Location	f	%	Rank
Neck and above	Head	7	3.1	10
(f = 92; 41.1%)	Ear	10	4.5	7
	Face	49	21.9	1
	Nose	5	2.2	11
	Mouth/lip	5	2.2	11
	Forehead	13	5.8	5
	Neck	3	1.3	12
Upper body (below neck to above hips)	Shoulder	9	4.0	8
(f = 112; 50.0%)	Chest	10	4.5	7
	Back (general)	11	4.9	6
	Upper back	16	7.1	4
	Abdomen	1	0.4	14
	Lower back	3	1.3	12
	Upper arm	9	4.0	8
	Forearm	22	9.8	3
	Hand	31	13.8	2
Lower body (buttocks and below)	Buttocks	1	0.4	14
(f = 12; 5.4%)	Knee	2	0.9	13
	Lower leg (incl' foot)	9	4.0	8
Unspecified (f = 8; 3.5%)		8	3.6	9
	Total	224	100.0	

f = frequency by anatomical location.

There was a significant association (Chi-square test) between total years surfed and higher rates of reported skin cancer ($p < 0.01$) among respondents who had been surfing for more years (< 10 years = 6.4%; 10-20 years = 10.1%, 21-30 years = 9.9% and > 30 years = 36%) compared with those who did not report a skin cancer and on average had less total years surfing (mean = 6.5 yrs, ±12.3 compared with 28 yrs, ±14.0).

Chi-square test of association indicated that type of craft surfed ($p < 0.01$) was also associated to a higher percentage rate of reported skin cancers. In the 12 month period immediately prior to the survey, Bodyboard riders reported the lowest incidence of skin cancer (8.3%), followed by short board riders (12.6%), with Malibu riders reporting the highest rates (28.0%) of skin cancer. However, this was mitigated when adjusted for the number of years surfed (using logistic regression) indicating no difference in type of craft.

DISCUSSION

The sun protection strategies and self-reported rates of skin cancer leading to medical intervention among Australian surfers have not been previously documented. In this study a total of 90 (14.7%; n = 617) respondents had been treated by their doctor for a skin cancer or lesion in the 12 months immediately preceding participation in the survey; this equated to approximately 1 in 7 surfers being diagnosed in the 12 month reporting period. The face was the most common (21.9%; n = 49) location for these skin cancers/lesions.

Age was a significant contributor to the reported rates of skin cancer, indicating the link between total exposure and the likelihood of sun cancer developing that requires treatment with advancing years.[13,18] This is also supported by evidence that the total years surfed leads to higher rates of reported skin cancer. Previous research[16] involving Australian cricketers has suggested that as cricketers age they are more likely to have had a skin cancer. However, as with the current study involving surfers, it is not clear whether the self-reported rates of skin cancer are higher than that reported within the general population.

The use of sun protection strategies in the summer months varied among respondents. A significant number of surfers (19.1%) indicated that they did not use sunscreen at all on any exposed areas of skin in the warmer months, with this number increasing (46.8%) in the cooler months. The majority of respondents to the survey lived in New South Wales (53.9%), where the average annual ambient temperature for the period 2000-2008 was 24.9oC (ABS, 2010). Further, the average annual UV rating ranges from 6-7 (UV rating of High) for the region south of Sydney and north to Coffs Harbour, to 8-11 (UV rating of Very High) for Coffs Harbour to the Sunshine Coast in South East Queensland respectively (BOM, 2013). As a result, the lack of sun protection while surfing is a significant issue for surfers.

The Bureau of Meteorology (BOM) and Cancer Council Australia advise that a UV rating of 3 or above should prompt Australians to take 5 steps to protect themselves from the harmful effects of sun damage. These are:

- "Slip" on some sun-protective clothing - that covers as much skin as possible
- "Slop" on SPF30+ sunscreen - make sure it is broad spectrum and water resistant. Put it on 20 minutes before going outdoors and every two hours afterwards. Sunscreen should never be used to extend the time spent in the sun
- "Slap" on a hat - that protects the face, head, neck and ears
- "Seek" shade
- "Slide" on some sunglasses - making sure they meet Australian Standards

This is an area for concern given the enormous amount of resources devoted to educating the general population about the importance of sun protection by organisations such as Cancer Council Australia. It would appear that the "Slip-slop-slap-seek-slide" message is having little impact on significant numbers of surfers. In contrast, when outdoors participating in some other form of activity (eg, work or recreation) almost 80% of respondents indicated that "most of the time" or "always" they wore a shirt to protect themselves from the sun and almost 75% indicated that they wore sunglasses "most of the time" or "always". One possible strategy to increase the use of sun protection strategies among high-risk populations (i.e. those experiencing increased UV exposure), such as surfers, could be more targeted education campaigns.[4,6,8] Further, primary care providers should consider screening patients that are known to surf (or participate in outdoor vocational and recreational activities) when they attend clinics for other unrelated medical reasons.[4,5]

This study has several limitations that should be acknowledged and considered when interpreting the results. Not everyone has access to the Internet and it may also be that those who respond via this medium may or may not differ from those who did not have access to the survey via the Internet. In addition, as with all retrospective research involving the self-reporting of information, the authors were relying on the honesty and ability of respondents to recall their information accurately in the preceding 12 month period. It also assumed that all respondents had the requisite literacy skills to understand and comprehend what was being asked in the survey.

CONCLUSION

Surfing is a popular sport in both Australia and New Zealand. By its very nature the sport has numerous inherent dangers associated with participation. Not least of these, as this study demonstrates, is that surfers are an at risk population when it comes to the harmful effects of sun exposure. This is not unexpected given the nature of the sport and its environment. Further, this study indicates that using a fragmented approach to sun protection while surfing is likely to see this population continue to be at risk of sun damage, resulting in an increasing incidence of skin cancer with age and years surfed. Medical practitioners can play an important education and prevention role by screening those patients that are known to surf and/or participate in outdoor vocational and recreational activities. In addition, a more targeted approach (eg, through sport specific publications and media campaigns) to education and increasing awareness may also help to improve the adherence to a multi-faceted protection strategy that better protects participants of this sport from the harmful effects of the sun.

What this study adds?

- Australian surfers spend approximately 11 hours per week surfing in summer with the time spent in the water per surf session typically ranging from 1-2.5 hours. However, during the warmer months of the year only 74.2% of surfers appear to be applying sunscreen or zinc to their face and neck, with 54% applying sunscreen to all exposed areas of skin and just 7.3% wearing a surf cap to protect the head, nose and ears. These percentages drop significantly in the cooler months.
- In a single 12 month period almost 15% of surfers reported being treated for skin cancer/lesion by a medical practitioner; these included melanoma and basal cell carcinoma. Some surfers will have more than one skin cancer/lesion identified in this period. This equates to a mean rate of occurrence of 9.1 skin cancer/lesions per 1000 hours surfed.
- The three most common sites for skin cancer/lesion are the face, hand and forearm.

ACKNOWLEDGEMENT

The authors wish to acknowledge the financial assistance of the New South Wales Sporting Injuries Committee who provided funding for this project through the New South Wales Sporting Injuries Insurance Scheme. Industry partner, Surfing Australia, actively supported this project by promoting participation to its members and assisting with the distribution of the online survey via its corporate web site.

AUTHOR AFFILIATIONS

Rudi A Meir PhD CSCS

Shi Zhou PhD

Margaret I Rolfe PhD

Wendy L Gilleard PhD

Rosanne A Coutts PhD

School of Health and Human Sciences

Southern Cross University

Lismore, New South Wales

Australia

REFERENCES

1 Avilés-Hernández I, Garcia-Zozaya I, DeVillasante J. Nontraumatic myelopathy associated with surfing. *J Spinal Cord Med* 2007; **30**(3):288-93.

2 Bentley T, Macky K, Edwards J. Injuries to New Zealanders participating in adventure tourism and adventure sports: An analysis of Accident Compensation Corporation (ACC) claims. *NZ Med J* 2006; **119**(1247):U2359.

3 De Luca JF, Adams BB, Yosipovitch G. Skin manifestations of athletes competing in summer Olympics: What a sports medicine physician should know. *Sports Medicine* 2012; **42**(5):399-413.

4 Dozier S, Wagner R Jr, Black SA, Terracina J. Beachfront screening for skin cancer in Texas Gulf coast surfers. *South Med J* 1997; **90**(1):55-58.

5 Helfand M, Mahon SM, Eden KB, Frame PS, Orleans CT. Screening for skin cancer. *Am J Prev Med* 2001; **20**(3-Suppl 3):47-58.

6 Lower T, Girgis A, Sanson-Fisher R. The prevalence and predictors of solar protection use among adolescents. *Prev Med* 1998; **27**(3):391-399.

7 Makin JK, Warne CD, Dobbinson SJ, Wakefield MA Hill DJ. Population and age-group trends in weekend sun protection and sunburn over two decades of the SunSmart programme in Melbourne. Australia. *Brit J Dermatol* 2013; **168**(1):154-161.

8 Martin RH. Relationship between risk factors, knowledge and preventive behaviour relevant to skin cancer in general practice patients in South Australia. *Brit J Gen Pract* 1995; **45**(396):365-367.

9 Meir R, Zhou S, Gilleard W, Coutts R. An investigation of surf participation and injury prevalence in Australian Surfers: A self-reported retrospective analysis. A report to the New South Wales Sporting Injuries Committee, May, 2011.

10. Meir R, Zhou S, Rolfe M, Gilleard W, Coutts R. An investigation of surf injury prevalence in Australian surfers: A self-reported retrospective analysis. *NZ J Sports Med* 2012; **39**(2):52-58.

11 Meir RA, Lowdon BJ, Davie AJ. Heart rates and estimated energy expenditure during recreational surfing. *Aust J Sci Med Sport* 1991; **23**(3):70-74.

12 Mendez-Villanueva A, Bishop D. Physiological aspects of surfboard riding performance. *Sports Med* 2005; **35**(1):55-70.

13 Moehrle M. Outdoor sports and skin cancer. *Clin Dermatol* 2008; **26**(1):12-15.

14 Nathanson A, Bird S, Dao L, Tam-Sing K. Competitive surfing injuries: a prospective study of surfing-related injuries among contest surfers. *Am J Sports Med* 2007; **35**(1):113-117.

15 Nathanson A, Haynes P, Galanis D. Surfing injuries. *Am J Emerg Med* 2002; **20**(3):155-160.

16 Noble-Jerks J, Weatherby RP, Meir R. Self-reported skin cancer protection strategies and location of skin cancer in retired cricketers: A case study from the membership of the Emu Cricket Club. *J Sci Med Sport* 2006; **9**(6):441-445.

17 Roger P, Llyod B. Surfboard injuries: A study over time. *Sport Health* 2006; **24**(3):21-23.

18 Rosso S, Zanetti R, Martinez C, Tormo MJ, Schraub S, Sancho-Garnier H, Franceschi S, Gafà L, Perea E, Navarro C, Laurent R, Schrameck C, Talamini R, Tumino R, Wechsler J . The multicentre south European study 'Helios' II: different sun exposure patterns in the aetiology of basal cell and squamous cell carcinomas of the skin. *Bri J Cancer* 1996; **73**(11):1447-1454.

19 Saraiya M, Glanz K, Briss PA, Nichols P, White C, Das D, Smith SJ, Tannor B, Hutchinson AB, Wilson KM, Gandhi N, Lee NC, Rimer B, Coates RC, Kerner JF, Hiatt RA, Buffler P, Rochester P. Interventions to prevent skin cancer by reducing exposure to ultraviolet radiation: A systematic review. *Am J Prev Med* 2004; **27**(5):422-466.

20 Šitum M, Živković MV, Dediol I, Zeljko Penavić J, Simić D. Knowledge and attitudes towards sun protection in Croatia. *Collegium Antropol* 2010; **34**(Suppl 1):141-146.

21 Sladden MJ, Ward JE, Del Mar C, Lowe JB. Skin cancer screening by Australian family physicians: Variation with physician beliefs and geographic locality. *Am J Prev Med* 1999; **17**(2):42-146.

22 Stanaton WR, Janda M, Baade PD, Anderson P. Primary prevention of skin cancer: A review of sun protection in Australia and internationally. *Health Promot Int* 2004; **19**(3):369-378.

23 Taylor DM, Bennett D, Carter M, Garewal D. Finch CF. Acute injury and chronic disability resulting from surfboard riding. *J Sci Med Sport* 2004; **7**(4):429-437.

24 Youl PH, Janda M, Elwood M, Lowe JB, Ring IT, Aitken JF. Who attends skin cancer clinics within a randomized melanoma screening program? *Cancer Detect Prev* 2006; **30**(1):44-51.

The effectiveness of preventative neuromuscular training on anterior cruciate ligament injury rates in female athletes: A systematic review

OLIVIA SIMPSON, DUNCAN REID, RICHARD ELLIS, STEVE WHITE

ABSTRACT

Aim

To evaluate the evidence of the effectiveness of controlled trials of neuromuscular (NM) training interventions aimed at preventing anterior cruciate ligament (ACL) injuries on the number of ACL injuries sustained by female athletes.

Data Sources

PubMED, CINAHL, MEDLINE, EBSCO and cross-referencing (Dates searched: 1995 to Dec 1, 2014)

Study Selection

Studies were included if they were: 1) prospective controlled trials; 2) a neuromuscular training intervention was conducted; 3) female athletes were participants; and 4) the number of ACL injuries were recorded. Thirteen relevant studies were identified.

Data Extraction

Extracted data included: 1) study design; 2) participant sport and competition level; 3) participant age; 4) profession of person(s) who implemented the intervention; 5) nature of intervention; 6) timing of intervention; 7) intervention frequency; 8) duration of intervention sessions; 9) intervention compliance; 10) dropout rates; 11) number of ACL injuries incurred; 12) ACL injury mechanism (contact or non-contact); 13) incidence of ACL injury per 100 sporting hours

Data Synthesis

The mean modified Downs and Black score of all reviewed studies was 18.5/28 (range 13 to 26). The mean modified Downs and Black score for studies that employed a NM warm-up intervention was 21.4/28. Quality Index score calculation showed that four studies had strong methodological quality; eight had moderate methodological quality; and one had limited methodological quality. Across all studies, control group athletes sustained 170 ACL injuries, as compared to 83 ACL injuries sustained by intervention group athletes. For control group athletes, mean injury incidence was 0.15 (range 0.03 to 0.24) ACL injuries and 0.11 (range 0.03 to 0.23) non-contact ACL injuries per 1000 sporting hours. For intervention group athletes, mean injury incidence was 0.08 (range 0.00 to 0.19) ACL injuries and 0.04 (range 0.00 to 0.09) non-contact ACL injuries per 1000 sporting hours. Overall, female control group athletes were more likely to sustain an ACL injury and much more likely to sustain a non-contact ACL injury.

Conclusions

Studies varied widely by sport intervention-type, participant characteristics and study design characteristics. Studies that employed an NM warm-up were of higher methodological quality and were relatively more effective than other types of interventions. Due to lack of heterogeneity of studies, more research is required. Overall, there is a moderate level of evidence for the efficacy of neuromuscular interventions in preventing ACL injuries in female athletes.

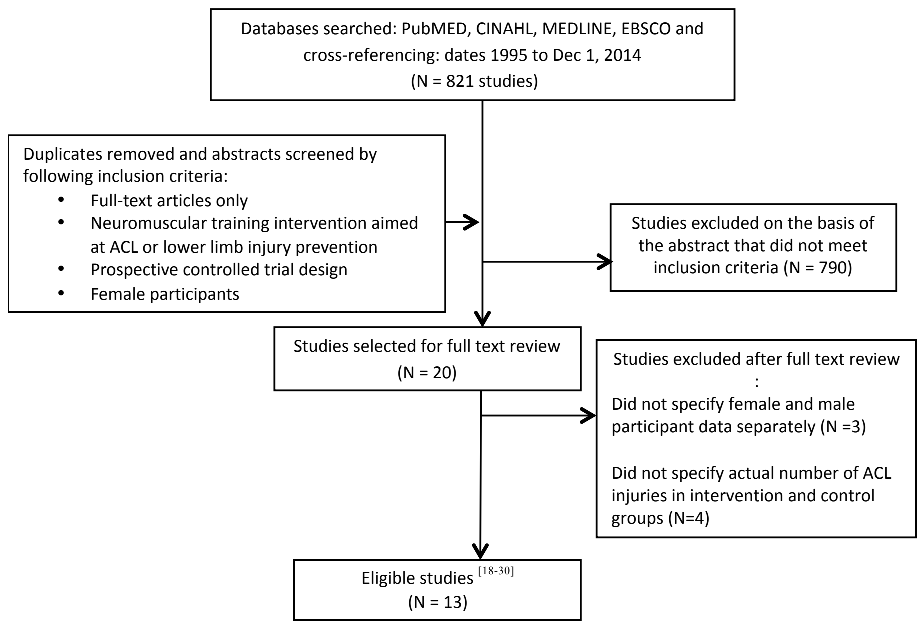
See end of article for author affiliations.

Correspondence
Olivia E J Simpson
Kowhai Physiotherapy and Hand Therapy Clinic
10 Percy Street
Warkworth, 0920
New Zealand
Phone 0064 (9) 425 9150
Fax 0064 (9) 425 9763
Email olivia@kowhaiphysio.co.nz

INTRODUCTION

An anterior cruciate ligament (ACL) injury can be devastating for an athlete. For female soccer and handball players, who sustain an ACL injury, it has been shown that 20% to 55% never return to the same level of sport, and players who return have at least a 20% risk of ACL re-injury.[1,2] Research shows a strong link between ACL injury and the early development of symptomatic knee osteoarthritis.[1,2] A recent systematic review calculated that 10 years after ACL injury, the prevalence of developing knee osteoarthritis was as high as 13% for isolated ACL injury and 48% for combined ACL and meniscal and/or medial collateral ligament (MCL) injuries.[3] In New Zealand, from 2000 to 2005 the average treatment cost to the Accident Compensation Corporation (ACC) for an ACL reconstruction, including imaging, surgery, rehabilitation and income replacement, was $11,157 NZD (New Zealand dollars).[4] ACL injuries are particularly prevalent in high impact pivoting and jump-landing sports.[1,2] Under an official Information Act request, ACC provided 2012/2013 figures showing that in New Zealand the three sports with the highest number of ACL injuries leading to reconstruction surgery were: rugby union (411), netball (406) and soccer (395) (Mr. B. Tietjens, personal communication with ACC, 17 November 2014). When stratified by gender, the sport in which female athletes sustained by far the most ACL injuries leading to reconstruction was netball (364), with the second highest amount occurring in soccer (82) (Mr B Tietjens, personal communication with ACC, 17 November 2014). These figures also showed that the number of ACL ruptures for New Zealand female netball players increased every year over five years, with 34% more ACL reconstructions performed on female netball players in 2012/13 as compared to 2008/09 (Mr B Tietjens, personal communication with ACC, 17 November 2014). ACL injuries in female New Zealand netball players are certainly a costly and growing problem. Adolescent and young adult female athletes have been shown to have a three- to eight-times higher incidence of ACL injury as compared with male athletes, with approximately 80% of female ACL injuries occurring in non-contact situations.[5-8] The ACL is stressed by anterior-shear forces applied to the tibia, such as when full body weight is moving forward on a planted foot, or with the contraction of the quadriceps muscles near full knee extension.[9,10] During landing and cutting tasks, female athletes exhibit greater knee valgus torque, less knee flexion and increased ground reaction forces on landing compared to male athletes[11,12] A prospective cohort study found that female athletes who landed with increased knee valgus angle and increased external knee valgus moments during a jump-land task were significantly more likely to sustain an ACL injury compared to females who landed with more neutral alignment.[13,14] However, landing and cutting mechanics of female athletes have been shown to improve after participating in targeted training interventions.[15,16,17]
Several prospective studies have employed a variety of training interventions with female athletes in an attempt to decrease ACL injury rates.[18-30] These studies employed what is commonly described in the literature as ‘preventative neuromuscular training’, which included one or more elements of: movement competency training; strength training; plyometrics; stretching; balance and/or proprioceptive training.[31,32] Some studies employed a stand-alone intervention, such as Soderman et al[28] in which intervention athletes used balance boards for 10-15 minutes at each training session.[19,20,24,26-28] Other studies employed what this review will refer to as a ‘neuromuscular warm-up’ (NM warm-up). In these studies the traditional sport warm-up before training sessions and games was replaced by a 15 to 25 minute session that included a combination of cardiovascular exercise, strength training, balance, and plyometric components, with exercises progressed throughout the season.[18,21-23,29,30,33]

Figure 1 - Article search strategy



The objective of this research was to perform a systematic critical review of prospective controlled trials that have investigated the effect of neuromuscular training interventions on the number of ACL injuries sustained by female athletes. The primary purpose was to evaluate the quality of the evidence and then to draw conclusions, based on the strength of the evidence, as to the effectiveness of such programmes. A secondary purpose was to evaluate the evidence for the efficacy of NM warm-up interventions as compared to other types of interventions.

METHODS

Literature Search

This review was conducted following the PRISMA Statement guidelines.[34] A literature search was conducted in December 2014. Databases searched included PubMED, CINAHL, EBSCO health databases, and MEDLINE. Dates searched were from 1995 to 1 December 2014. Search terms included “anterior cruciate ligament”, ACL, female, woman, women, train*, neuromuscular, intervention, program*, prospective, RCT, and “control* trial*”. See Table 1 for literature search strings. The language was limited to English. Studies were identified by one researcher (OS). The following inclusion criteria were applied: (1) participants were female athletes only, or if participants included both females and males, the data for females was analysed separately, (2) prospective controlled trial study design was employed, (3) a neuromuscular training intervention with the aim of preventing ACL injuries was undertaken, and (4) number of ACL injuries as confirmed by magnetic resonance imaging (MRI) or visualisation during surgery was reported. Abstracts and unpublished data were excluded. No authors were contacted for additional information. See Figure 1 for search strategy.

Table 1 - Literature search strings

#1:“anterior cruciate ligament” OR ACL
#2: female* OR woman OR women
#3: neuromuscular OR train* OR intervention OR program*
#4: prospective OR RCT OR “control* trial*”
#5: (combines #1 AND #2 AND #3 AND #4)

Data Collection Process

The following data were extracted independently by two reviewers (OS, DR): 1) study design; 2) participant sport and competition level; 3) participant age; 4) profession of person(s) who implemented the intervention; 5) nature of intervention; 6) timing of intervention; 7) intervention frequency; 8) duration of intervention sessions; 9) intervention compliance; 10) dropout rates; 11) number of ACL injuries incurred; 12) ACL injury mechanism (contact or non-contact); 13) incidence of ACL injury per 100 sporting hours.

Different studies reported the incidence of ACL injuries against athletic exposure (i.e. each game or training session) or against specific sporting hours. For those studies that expressed incidence against athletic exposure, we followed the protocols used in previous research to convert these estimates to align with sporting hours.[32,31] To standardise units, each athletic exposure (practice or game) was estimated as 2 hours then converted to sporting hours.[32,31] Incidence of ACL injury was then expressed per 1000 sporting hours. To add depth to the analysis, the number of overall knee injuries and knee injury exposure data was also extracted if reported.

Evaluation of Methodological Quality

The methodological quality of the included articles was analysed using a modified Downs and Black checklist.[35] The Downs and Black checklist has been shown to have good validity and both test-retest and inter-rater reliability for rating the methodological quality of both RCT and non-RCTs.[35,36] The first four items of the original Downs and Black tool relate to: reporting, external validity, internal validity – bias, internal validity – confounding.[35] The last item in the tool considers the power of the study. As has been previously reported[37] this item was modified from a score out of five to a score out of one to ensure consistent scoring across studies, with zero points awarded if no power calculation was attempted, and one point awarded if a power calculation was described. The total possible score for the modified Downs and Black checklist is 28. Two authors (OS, DR) reviewed the included studies independently and were blinded to each other's scoring. With eventual comparison of scoring, any scores that differed were discussed at the conclusion of the review process. If no consensus could be reached, the other authors (RE, SW) reviewed the papers and a final designation of the score agreed by consensus.

After each study was critiqued using a Quality Index which was derived to categorise methodological quality. The Quality Index enables studies to be categorised as being of poor, limited, moderate, or strong quality (Table 2). This measure has been used by several systematic reviews which have rated methodology using the modified Downs and Black checklist.[37,39] Meta-analysis was not undertaken due to the large variability in types of study, interventions and participant and also due to the inclusion of non-randomised trials. Sub-group analysis occurred after data was extracted.

Evidence Synthesis

Levels of evidence were derived from the criteria as outlined by Van Tulder et al.[40] See Table 3 for definitions used in making an overall statement as to the level of evidence.

RESULTS

Selection of Studies

The literature search identified 821 potentially eligible studies. Thirteen studies[18-30] were identified by author OS that met the inclusion criteria and exclusion criteria (Figure 1). The prospective crossover study of Myklebust et al. was included although it lacked a concurrent control group, because the results of the first sporting season became the controls for the following two sporting season.

Study Characteristics

Key characteristics of each study are summarised in Table 4 (see end of article).

Participants

There were a total of 23,314 female athletes in the included studies, with 10,979 in intervention groups and 12,335 in control groups. One study compared the effect of the intervention on both female and male controls,[20] while all other studies had female participants only. The participants ages ranged from age 12 to 24, although two studies did not report participant ages.[24,26] Ten of 13 studies included soccer players.[18-23, 27-30] Other sports represented were basketball,[20,22,27] volleyball,[20,22,27] handball[24,26] and floorball.[25] Sport level ranged from social leagues[21,25,26,29,30] to United States National Collegiate Athletic Association Division I soccer players[18] and Norwegian Division I handball players.[24]

Interventions

The types of intervention employed with each study are summarised in Table 3. Seven of 13[18,21-23,29,30,33] studies employed a NM warm-up lasting 15 to 25 minutes and was performed two to three times per week. The NM warm-up sessions included varying combinations of running or dynamic drills, movement skills, plyometrics and proprioceptive drills, strengthening exercises and stretching.[18,21-23,29,30,33] The other studies employed a variety of stand-alone interventions. One study used jump-land and deceleration training,[27] two utilised balance board and jump-land training,[24,26] one employed a daily home balance board programme,[28] and two interventions were pre-season gym-based strength training, stretching and plyometrics.[19,20]

Table 2 - Categorisation of Quality Index Scores

Total Modified Downs and Black checklist Score (/28)	Percentage	Quality Index
21+	75% +	Strong
14-20	50-74%	Moderate
7-13	25-49%	Limited
<7	<25%	Poor

Adapted from Hartling et al., 2004; Hignett, 2003; and Hing et al., 2009

Table 3 - Levels of evidence.

Strong	Consistent findings among multiple high quality RCTs
Moderate	Consistent findings among multiple low quality RCTs and/or CCTs and/or one high quality RCT
Limited	One low quality RCT and/or CCT
Conflicting	Inconsistent findings among multiple trials (RCTs and/or CCTs)

From Van Tulder et al., 2003

Two studies delivered the intervention during the pre-season period[19,16] and six during the competitive season.[18,22,23,25,27,30] Five studies performed the intervention through both pre- and in-season, with a median of 7 months total intervention time for all five studies.[21,24,26,28,29] The interventions in 12 of 13 studies were supervised by a team coach, physiotherapist or athletic trainer, whom had been trained to deliver the programme. Participant drop-out rates, if reported, varied widely among studies. Compliance and adherence to the prescribed interventions were also reported in varying ways, with low compliance sometimes accounted for in the data analysis (see Table 5 at end of article). For example, Gilchrist et al.[18] excluded the results from eight of 34 intervention group teams (24%) who had not completed the NM warm-up 12 times or more. In studies that reported adherence, this ranged from less than 50%[24,29] to over 90%,[23] with most studies reporting 50% to 70% adherence to their intervention programmes.

Control Groups

One study was an RCT,[19] six studies were cluster RCTs,[18,25,22,28-30] five studies were non-randomised cluster controlled trials (CCTs)[20,21,23,26,27] and one study was a non-randomised cluster crossover trial in which the first year results acted as a control for subsequent years.[24] Twelve of 13 studies compared the intervention group to a concurrent control group. The exception was the prospective crossover study of Myklebust et al.[24] The control groups for all studies completed their 'usual' warm-up routine or sport training, the specifics of which were not described in any study. Consequently, it is unknown if control group athletes performed exercises similar to those included in the interventions. Injuries and athletic exposures were reported by the coach, physiotherapist, or athletic trainer.

Outcomes

The main outcome measures used in all studies was the number of ACL injuries over a specified exposure period. The definition of an ACL injury varied across studies, with eight of 13 studies including injuries to the ACL as confirmed by MRI or arthroscopy.[18,19,21-24,29,30] Four studies included only ACL ruptures as confirmed by MRI or arthroscopy.[20,25,26,28] Six studies reported the ACL injury mechanism, either contact or non-contact.[18,20,21,33,26,29] Pfieffer et al,[27] LaBella et al,[22] and Mandelbaum et al[23] solely reported non-contact ACL injuries. Soderman et al[28] also reported the effect of the intervention on postural sway and balance measures. Furthermore, ten of 13 studies reported the incidence of all lower limb and/or knee injuries.[18-22,26,28-30,33]

Efficacy of Interventions

In total, control group athletes sustained 170 ACL injuries, as compared to 83 ACL injuries sustained by intervention group athletes. For control group athletes, mean injury incidence was 0.15 (range 0.03 to 0.24) ACL injuries and 0.11 (range 0.03 to 0.23) non-contact ACL injuries per 1000 sporting hours. For intervention group athletes, mean injury incidence was 0.08 (range 0.00 to 0.19) ACL injuries and 0.04 (range 0.00 to 0.09) non-contact ACL injuries per 1000 sporting hours.

Overall Effect and Injury Incidence by Sport

In studies of soccer players exclusively, six of eight studies showed that intervention groups had fewer ACL injuries,[18-21] reaching statistical significance in two of eight studies.[23,30] In soccer studies which captured athletic exposure data, the mean ACL injury incidence for female control group players was 0.16 per 1000 soccer hours (range 0.08 to 0.24).[18,21,23,29,30] In comparison, the mean injury incidence for intervention group players was found to be 0.06 (range 0.0 to 0.13).[18,21,23,29,30]

In studies of mixed high school athletes (soccer, basketball and volleyball players[20,22,27] two of three studies reported non-contact ACL injury incidence and did not report overall ACL incidence.[22,27] Non-contact ACL injury incidence for female control group players was found to be 0.13 per 1000 hours athletic exposure (range 0.11 to 0.24), whereas the incidence for those in the intervention group was 0.08 (range 0.05 to 0.08).[20,22,27]

In studies of handball and floorball players the ACL injury incidence in control group players was found to be 0.13 per 1000 sporting hours (range 0.03 to 0.21), whereas the incidence for those in the intervention group was 0.11 (range 0.04 to 0.19).[24-26] The lower efficacy found for handball and floorball players could have been related to the poorer overall quality of the research and the type of interventions, which were predominantly using balance boards.[24-26]

Methodological Quality

The methodological quality of each paper is outlined in Table 5 and Table 6. Authors OS and DR independently reached the same score for each article. The mean modified Downs and Black score of all studies was 18.5/28 (range 13 to 26). The mean modified Downs and Black score for studies that employed a NM warm-up intervention was 21.4/28,[18,21-23,29,30,33] as compared to 15.0/28 for other types of interventions.[19,20,24,26-28] The majority of studies clearly described their objectives, outcomes, interventions and results, and used appropriate statistical tests. Seven of thirteen studies included information about participants' characteristics.[18,21,22,24,29,30,33] Six studies included sufficient descriptions of participants lost to follow-up.[21,33,26,28-30] Due to the nature of the intervention, no studies were able to blind participants, while six of 13[19, 22, 25, 27, 29, 30] studies attempted to blind those measuring the intervention.

Strength of the Evidence

Three of thirteen studies included power calculations and recruited enough participants to detect a 50% reduction in injuries between groups.[25,28,29] All other studies either did not include a power calculation[18-23,27] or failed to recruit enough participants to have meaningful power as projected by their power calculations.[24,26,30] Quality Index scores for each study are outlined in Table 5 and Table 6. Mean quality score percentage of the reviewed studies was 66% (range 46% to 93%). For studies utilising NM warm-up interventions the mean Quality Index score was 76.6%. For studies utilising other types of interventions the mean Quality Index score was 53.7%.

Evidence Synthesis

There were four studies of strong methodological quality, two of which showed statistically significantly fewer ($P < 0.05$) ACL injuries as compared to the control group,[22,30] whereas the other two studies found no significant effect.[29,25] Of the eight

Table 5 - Modified Downs and Black Score of methodological quality and Quality Index percentage.

	Gilchrist et al (2008)	Heidt et al (2000)	Hewett et al (1999)	Kiani et al (2010)	LaBella et al (2011)	Mandelbaum et al (2005)	Myklebust et al (2002)	Pasanen et al (2008)	Peterson et al (2005)	Pfeiffer et al (2006)	Soderman et al (2000)	Steffen et al (2008)	Walden et al (2012)
Reporting													
1. Is the hypothesis/aim/objectives of the study clearly described (yes = 1, no = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? (yes = 1, no =0)	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Are the characteristics of the patients included in the study clearly described? (yes =1, no = 0)	1	0	0	1	1	0	1	1	0	0	0	1	1
4. Are the interventions of interest clearly described? (yes =1, no = 0)	1	0	1	1	1	1	1	1	1	0	1	1	1
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? (yes =2, partially = 1, no = 0)	2	0	0	2	1	0	0	2	0	0	1	2	2
6. Are the main findings of the study clearly described? (yes =1, no = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
7. Does the study provide estimates of the random variability in the data for the main outcomes? (yes =1, no = 0)	0	0	0	1	1	1	1	1	1	1	1	1	1
8. Have all important adverse events that may be a consequence of the intervention been reported? (yes =1, no = 0)	0	0	0	0	0	0	0	0	0	0	0	1	1
9. Have the characteristics of patients lost to follow-up been described? (yes =1, no = 0)	0	0	0	1	0	0	0	1	1	0	1	1	1
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001? (yes =1, no = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
REPORTING SCORE x/11	**8**	**4**	**5**	**10**	**8**	**6**	**7**	**10**	**7**	**5**	**8**	**9**	**11**
External Validity													
11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited? (yes =1, no = 0, unable to determine = 0)	1	1	0	1	1	1	1	0	0	0	0	1	1
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? (yes =1, no = 0, unable to determine = 0)	1	0	0	0	0	0	1	1	0	0	1	0	0
13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive? (yes =1, no = 0, unable to determine = 0)	1	0	1	1	1	1	1	1	1	1	1	1	1
EXTERNAL VALIDITY SCORE x/3	**3**	**1**	**1**	**2**	**2**	**2**	**3**	**2**	**1**	**1**	**2**	**3**	**2**
Internal Validity - Bias													
14. Was an attempt made to blind study subjects to the intervention they have received? (yes =1, no = 0, unable to determine = 0)	0	0	0	0	0	0	0	0	0	0	0	0	0
15. Was an attempt made to blind those measuring the main outcomes of the intervention? (yes =1, no = 0, unable to determine = 0)	0	1	0	0	1	0	0	1	0	1	0	1	1
16. If any of the results of the study were based on "data dredging", was this made clear? (yes =1, no = 0, unable to determine = 0)	0	1	1	1	1	1	0	1	1	1	0	1	1
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
18. Were the statistical tests used to assess the main outcomes appropriate? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
19. Was compliance with the intervention/s reliable? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	0	1	0	0	0	0	1
20. Were the main outcome measures used accurate (valid and reliable)? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
INTERNAL VALIDITY - BIAS SCORE x/7	**4**	**6**	**5**	**5**	**6**	**5**	**3**	**6**	**4**	**5**	**3**	**5**	**6**
Internal Validity – Confounding (Selection Bias)													
21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	1	1	1	1	1	1	1
22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? (yes =1, no = 0, unable to determine = 0)	1	1	1	1	1	1	0	1	1	1	1	1	1
23. Were study subjects randomised to intervention groups? (yes =1, no = 0, unable to determine = 0)	1	1	0	0	1	0	0	1	0	0	1	1	1
24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable? (yes =1, no = 0, unable to determine = 0)	1	0	0	0	1	0	0	1	0	0	0	1	1
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? (yes =1, no = 0, unable to determine = 0)	0	0	1	0	1	0	0	1	0	0	1	1	1
26. Were losses of patients to follow-up taken into account? (yes =1, no = 0, unable to determine = 0)	1	0	0	0	0	0	0	1	0	0	1	1	1
INTERNAL VALIDITY – CONFOUNDING (SELECTION BIAS) x/6	**5**	**3**	**3**	**2**	**5**	**2**	**1**	**6**	**2**	**2**	**5**	**6**	**6**
POWER x/1	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**
OVERALL SCORE x/28	**20**	**14**	**14**	**19**	**21**	**15**	**15**	**25**	**15**	**13**	**19**	**24**	**26**
QUALITY INDEX %	**71%**	**50%**	**50%**	**68%**	**75%**	**54%**	**54%**	**89%**	**54%**	**46%**	**68%**	**86%**	**93%**

studies with moderate methodological quality one showed statistically significant fewer (P = 0.05) ACL injuries in the intervention group,[41] six showed a trend toward a protective effect of the intervention which did not reach significance,[18-21,24,26] and one study which demonstrated a statistically significantly increase in incidence of ACL ruptures in the intervention group.[28] See Table 7 for the findings of individual studies by Quality Index level. Based on the criteria as defined by Van Tulder et al,[40] overall there is a moderate level of evidence that neuromuscular training decreases the number of ACL injuries in young female team-sport athletes.

Table 6 - Findings of studies by Quality Index

Study Design	Authors	Reporting (/11)	External Validity (/3)	Internal Validity – bias (/7)	Internal Validity – Confounding (/6)	Power Calculation (/1)	Total Quality Score (/28)	Percentage	Quality Index
RCT	Heidt et al. (2000)	4	1	6	3	0	14	50%	Moderate
RCT (cluster)	Gilchrist et al. (2008)	8	3	4	5	0	20	71%	Moderate
	LaBella et al. (2011)	8	2	6	5	0	21	75%	Strong
	Pasanen et al. (2009)	10	2	6	6	1	25	89%	Strong
	Soderman et al. (2000)	8	2	3	5	1	19	68%	Moderate
	Steffen et al. (2008)	9	3	5	6	1	24	86%	Strong
	Walden et al. (2012)	11	2	6	6	1	26	93%	Strong
Cohort study (prospective, non-randomised, cluster, with control group)	Hewett et al. (1999)	5	1	5	3	0	14	50%	Moderate
	Kiani et al. (2010)	10	2	5	2	0	19	68%	Moderate
	Mandelbaum et al. (2005)	6	2	5	2	0	15	54%	Moderate
	Peterson et al. (2005)	7	1	4	2	1	15	54%	Moderate
	Pfieffer et al. (2006)	5	1	5	2	0	13	46%	Limited
Cohort study (prospective, not randomised, 1st year acted as control group for subsequent years)	Myklebust et al. (2003)	7	3	3	1	1	15	54%	Moderate

DISCUSSION

The current review shows moderate evidence that neuromuscular training interventions result in fewer ACL injuries in female athletes. The reviewed studies were heterogeneous and thus there is value in discussing trends that emerged between studies and across all studies.

Effect of Low Power on Results

Ten of the thirteen reviewed studies[18-24,26,27,30] either did not include a power calculation, or failed to recruit enough participants to detect a 50% difference between groups. Although ACL injuries are devastating, they have a relatively low incidence, which this review found to be 0.15 per 1000 sporting hours. In order to have meaningful power to detect differences between groups, authors need to recruit and monitor thousands of participants and this can be logistically difficult. Therefore when assessing these studies, it is important to consider that a trend toward fewer ACL injuries may be indicative of a larger effect had enough participants been recruited.

Effect of Interventions on all Knee Injuries and/or Lower Limb Injuries

Although not the main purpose of this review, ten of 13 studies also captured incidence of overall lower limb and/or all knee injuries (see Table 7). Of these, four found statistically significantly fewer injuries,[20,21,28,30] three found a trend toward decreased overall injuries,[18,21,26] and three found no effect.[28-30] Lower limb sprains and strains have a much higher incidence that ACL injuries, and thus were represented in much higher numbers in the results. A large-scale, high quality cluster RCT conducted by Soligard et al[43] in Norwegian soccer players demonstrated that a comprehensive NM warm-up programme significantly reduced the risk of overall injuries, overuse injuries and severe injuries. In reality, the goal of implementing an injury prevention

Table 7 - Findings of studies by Quality Index

	Quality Index	Type of Study	Intervention Type	Number of ACL injuries in the intervention group as compared to control group (fewer/more/no difference)	Numbers of all knee injuries or lower limb injuries in the intervention group as compared to control group (fewer/more/ no difference/not reported)
LaBella et al. (2011)	Strong	RCT (cluster)	NM warm-up	**Fewer***	**Fewer***
Pasanen et al. (2009)	Strong	RCT (cluster)	NM warm-up	No difference	**Fewer***
Steffen et al. (2008)	Strong	RCT (cluster)	NM warm-up	No difference	No difference
Walden et al. (2012)	Strong	RCT (cluster)	NM warm-up	**Fewer***	No difference
Gilchrist et al. (2008)	Moderate	RCT (cluster)	NM warm-up	Fewer	Fewer
Kiani et al. (2010)	Moderate	Cohort (cluster)	NM warm-up	Fewer	Fewer
Mandelbaum et al. (2005)	Moderate	Cohort (cluster)	NM warm-up	**Fewer***	Not reported
Heidt et al. (2000)	Moderate	RCT	Cardiovascular/ plyometrics/strength training/stretching	Fewer	Fewer*
Soderman et al. (2000)	Moderate	RCT (cluster)	Balance board	**More***	No difference
Hewett et al. (1999)	Moderate	Cohort (cluster)	Plyometrics/strength training/stretching	Fewer	**Fewer***
Peterson et al. (2005)	Moderate	Cohort (cluster)	Balance board/ plyometrics	Fewer	Fewer
Myklebust et al. (2003)	Moderate	Cohort (clus-ter)+	Balance board	Fewer	Not reported
Pfieffer et al. (2006)	Limited	Cohort (cluster)	Plyometrics/ deceleration	No difference	Not reported

Note: *statistically significant (P = 0.05); RCT, randomised controlled trial; NM, neuromuscular; + 1st year acted as control group for subsequent years.

programme is not just to prevent ACL injuries but to prevent all injuries. This review shows there is also moderate evidence to support that neuromuscular training is effective in decreasing the number of all knee/lower limb injuries in female athletes.

Effect of the Intervention by Age

The reviewed studies included female athletes of varying ages and skill-levels. However, a direct comparison can be made between Mandelbaum et al[23] and Gilchrist et al[18] which both employed the Santa Monica Prevent Injury and Enhance Performance Program. There were 5703 participants in Mandelbaum et al,[23] aged 14 to 19 from a California youth soccer league. Gilchrist et al[18] studied 1435 university-aged players in NCAA Division I collegiate soccer teams. Mandelbaum et al[23] showed a statistically significant reduction in non-contact ACL injuries in athletes utilising a NM warm-up programme, with an 88% reduction in injury in year one and 74% in year two. There were 6-fold fewer non-contact ACL injuries for intervention participants. They found statistically significantly fewer non-contact ACL injuries, with an intervention group ACL injury incidence of 0.06 per 1000 soccer hours versus 0.11 for control group players. In comparison, Gilchrist et al[18] found 41% fewer non-contact ACL injuries in the intervention group and this result did not reach significance. Gilchrist et al[18] found an intervention group non-contact ACL injury incidence of 0.03 per 1000 soccer hours, versus 0.09 for control group players. The authors postulated that the 'PEP' programme had a greater effect with younger, less-skilled players as they were likely to initially have poorer strength and neuromuscular control as compared with top level university players.[18]

The training effect by age is supported by a meta-analysis by Myer, Sugimoto, Thomas & Hewett,[44] which analysed the influence of age on the effect of female ACL prevention neuromuscular interventions. They found that interventions had the greatest effect when performed by athletes aged 14 to 18, as compared to athletes aged 18 to 20, or over 20. They found a statistically greater knee injury risk reduction for athletes ≤ 18 years of age, as compared to those >18 year of age.[44] However, these and other authors have argued that the ideal time to commence neuromuscular training is before females begin puberty, before they commence their 'growth spurt' or period of peak height velocity.[44,45] Knee injury rates between males and females have been shown to be similar prior to puberty.[46,47] For both boys and girls, during puberty at the time of peak height velocity the tibia and femur grow rapidly, and there is an increase in height of their centre of mass.[48] There is also a corresponding increase in height and body mass increasing load on the joints.[48] This makes trunk and knee control more difficult during rapid movements.[49,50]

During adolescence boys demonstrate increased power, strength and coordination which matches their maturational phase, whereas girls show little change in these characteristics.[51,52,53] For example, boys vertical jump height increases, whereas girls do not have a corresponding increase.[52] Authors have demonstrated that in females the relative lack of hip abductor strength and trunk stability, during and immediately after this time of growth, leads to decreased knee control and increased knee valgus movement patterns.[49,50] These are the movement patterns that have been shown to put athletes at risk of ACL injury.[14,15] Indeed the peak rate of ACL injuries in females has been shown to be at age 16.[54] Thus, it could be concluded that neuromuscular training programmes would have a greater effect if they were first implemented before puberty at age 11 or 12, and continued throughout adolescence. Therefore when designing future studies, researchers may need to target interventions at the grassroots club level or middle school/early high school athletes. It would be helpful if future research into NM warm-up interventions were targeted for younger age groups, or results were stratified by age of athlete.

Effect by Intervention Adherence

A recent meta-analysis by Sugimoto et al,[42] which analysed the compliance data for six of the studies included in this review,[19-21,24,28,29] showed a clear inverse dose-response relationship between adherence to the neuromuscular intervention and incidence of ACL injury. Hagglund, Atroshi, Wagner and Walden[55] evaluated the adherence data from the Walden et al.[30] The authors stratified results in tertiles with participants who had low, moderate and high compliance to the intervention. They found that players in the high compliance tertile had 88% fewer ACL injuries as compared to controls, while those in the low compliance group had ACL injuries rates similar to that of the control group.[55]

When analysing compliance data, Soligard et al[57] found that players with high compliance to the FIFA 11+ neuromuscular warm-up programme had a 35% lower risk of all injuries as compared to those with moderate compliance. They found that the greatest factor associated with high compliance was a positive attitude of the coach towards the benefit of the programme for preventing injuries.[57] Similarly, Steffen et al[58] found over 80% adherence to the coach-led FIFA 11+ following education at a coaching workshop. These studies highlight that the key to adherence is 'buy-in' and consistent implementation by the coach.[22,30,56,57,58] Future research needs to be done around the best ways to educate coaches in the value of a NM warm-up programme, and how to best provide ongoing support that encourages coaches to continue to deliver the intervention. Now, with increasingly ubiquitous presence of communication technology, future research could be done into how best to use technology like smartphone apps, to help support coach-led initiatives.

Cost Effectiveness of an ACL Injury Prevention Intervention

Apart from the injury prevention benefits, there could be potentially large cost savings benefits to ACC by implementing NM ACL prevention warm-up programmes. LaBella et al[22] did a cost-to-benefit analysis of a coach-instructed NM ACL prevention warm-up intervention. They found that the cost of training a group of 20 coaches was the equivalent of $124 NZD per coach.[22] They calculated that 189 players would need to be exposed to the warm-up to prevent one ACL injury resulting in surgery, which equated to training 16 basketball coaches or 11 soccer coaches.[22] The cost of training 16 coaches was $1984, which is significantly less than the ACC reported surgical cost for one ACL reconstruction of $11,157 NZD.[4] Indeed, for the cost of one ACL reconstruction, 139 coaches could be trained which could have trickle-down effects to over 1500 athletes. Swart et al[59] performed a cost-effectiveness analysis of ACL prevention programmes for young athletes, which found universal neuromuscular training of all athletes was more cost-effective than screening all athletes and implementing interventions for high risk athletes. They determined that as compared to doing nothing and paying surgical costs for ACL reconstructions, universal neuromuscular training implemented with all young athletes would save the equivalent of $155 NZD per player per season.[59]

NM Warm-up Interventions in Relation to Jump-Land Sports

NM warm-up interventions target the strength deficiencies, lack of neuromuscular control and poor movement patterns that have been identified in young female athletes.[49,50] This review shows that this multi-modal approach with coach, physiotherapist or trainer, feedback is effective. However, the majority of NM warm-up programmes have been designed for soccer players, and this review finds they were more effective with soccer players as compared to other types of sports. Although the underpinnings of all team sports are similar, the movement patterns of soccer are very different to those of jump-land sports of basketball and netball. It is recommended that future research investigate if a NM warm-up intervention that specifically targeted the movement patterns of a jump-land sport would increase the preventative effectiveness for athletes in these sports. This would be particularly appropriate in a New Zealand context, given the high numbers of participation in netball by young females and the currently high ACL incidence rate.

Limitations

The authors acknowledge the following limitations of this systematic review. A meta-analysis was not performed due to the inclusion of non-randomised trials. Unpublished studies and PhD thesis were not included. Only studies in English were included.

CONCLUSION

ACL injuries have a relatively low incidence rate but a high financial cost and personal cost to athletes. A review of the literature found 13 prospective studies which employed a neuromuscular training intervention to prevent ACL injuries in female athletes. Four studies were of strong methodological quality, eight were of moderate quality and one was of limited quality. Studies varied substantially in all aspects of study design, types of interventions, outcome measures and populations studied. Due to lack of heterogeneity of studies, more research is required to come to strong conclusions. Overall, there is moderate level of evidence for the efficacy of neuromuscular interventions in preventing ACL injuries in female athletes. All female team sport athletes should participate in a supervised 15 to 25 minute NM warm-up before all training sessions and games.

AUTHOR AFFILIATIONS

Olivia E J Simpson BA BHSc PGDipHSc (Musculo Physio)

Kowhai Physiotherapy and Hand Therapy Clinic. Warkworth, New Zealand

Duncan A Reid DHSc

Health and Rehabilitation Research Institute, School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand

Richard F Ellis PhD

Health and Rehabilitation Research Institute, School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand

Steve G White MHSc (Hons) Dip Public Health Dip Manip Therapy

Health and Rehabilitation Research Institute, School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand

Table 4: Characteristics of Individual Studies

Author	Study Design	Sport/ Level	Group Size (number of participants)	Ages of Participants in Years	Intervention implementer	Intervention Type	When Implemented	Intervention Frequency and Duration	Comments on Compliance, Adherence and Drop-out Data
Gilchrist et al (2008)	Prospective randomized cluster controlled	Soccer/ US NCAA Division 1 Collegiate	C= 35 teams (852) I = 26 teams (583)	mean age = 19.88	NCAA team athletic trainers	'PEP' programme: - education - NM warm-up - strengthening - plyometrics	In-season	20min/session, all trainings throughout 1 season	Mean 25.8 sessions completed (range 12-37) Skilled observers noted mean of 70% of intervention warm-up being used by intervention teams in observed warm-ups. 24% of intervention teams that started the study (8/34) excluded from data analysis as had not completed warm-up 12 times or more.
Heidt et al (2000)	Prospective RCT	Soccer/ US high school league	C= (258) I = (42)	14-18	Sports training facility coaches /athletic trainers	-cardiovascular - plyometrics - strengthening - stretching	Pre-season	Time per session not specified, 3 d/wk for 7 weeks	Not specified
Hewett et al (1999)	Prospective non-randomized cluster cohort	Soccer, volleyball, basketball/ US high school league	C females= 15 teams (463) C males = 13 teams (434) I = 15 teams (366) female	14-18	Certified athletic trainers	- jump training, - strength - stretching	Pre-season	60-90min/ session, 3 d/wk for 6 weeks	Intervention teams required to complete 4 weeks of sessions to be included in the study 70% completed entire intervention 6% dropout
Kiani et al (2010)	Prospective non-randomised cluster cohort	Soccer/ Swedish leagues of various levels	C = 49 teams (729) I = 48 teams (777)	13- 19	Coach, physio	'HarmoKnee' programme: - education - NM warm-up - strength - plyometrics	Pre-season and in-season	25 min/session, 2 d/wk for 2 month pre-season, then 1 d/wk for rest of season 9 months total	45/48 teams had compliance of > 75%
LaBella et al (2011)	Prospective cluster RCT	Soccer, basketball, volleyball/ Low decile Chicago public high schools	C = 53 teams (755) I = 53 teams (737)	13-18	Coach	'KIPP' programme: - NM warm-up - strength - plyometrics	In-season	20 min/session for each training or game Mean sessions were 3.3 d/wk for 13.0 weeks	94.7 % of coaches completed the intervention Mean of 80.40% of full NM warm-up implemented at each training
Mandelbaum et al (2005)	Prospective non-randomized cluster cohort	Soccer/ US youth soccer league	Year 1 C = 95 teams (1905) I = 52 teams (1041) Year 2 C = 112 teams (1913) I = 45 teams (844)	14-18	Coach	'PEP' programme: - education - NM warm-up - strength - plyometrics	In-season	20min/session, all trainings throughout 1 season	Adherence to complete warm-up program for all sessions: Year 1 96.15% Year 2 100%
Pasanen et al (2009)	Prospective cluster RCT	Floorball/ Finnish leagues	C= 14 teams (201) I = 14 teams (256)	Mean age = 24	Coach & athlete instructors	- NM warm-up - running - balance - plyometrics - strength	In-season	20-30min/ session, initially 2 d/week, then 1 d/wk 6 months total	Mean of 74% of intervention session completed 5% dropout rate

Note: ACL, anterior cruciate ligament; AE, athletic exposures; C, control group; d/wk, day per week; h, hours; I, intervention group; NCAA, National Collegiate Athletic Association; NM, neuromuscular; physio, physiotherapist; min, minutes; RR, risk ratio; RCT, randomised controlled trial; SD, standard deviation; US, United States

Author	Total ACL Injuries (non contact ACL injuries) Total (noncontact) ACL Incidence per 1000 h of Athletic Exposure	All Other Knee Injuries and Incidence per 1000 h of Athletic Exposure	Study Results	Total Modified Downs and Black Checklist Score (/28)	Quality Index %
Gilchrist et al (2008)	Control Group ACL injuries = 18 (10) 1000h AE = 0.17 (0.09) Intervention Group ACL injuries = 7 (2) 1000h AE = 0.10 (0.03)	Knee injury as defined as injury requiring medical care by athletic therapist or physician, and caused one or more day of missed training/game. Control Group Knee injuries = 58 1000h AE = 0.55 Intervention Group Knee injuries = 40 1000h AE = 0.57	ACL Injury Differences in ACL injury rates between groups did not reach significance. However, overall ACL injury rate was 1.7 times less and noncontact ACL injury rate was 3.3 times less in intervention group, indicating a 41% decreased injury risk. **As compared with control group, in the intervention group ACL injuries were significantly lower during practice ($p = 0.014$) and in athletes with of previous ACL injury history ($p = 0.046$).** Overall knee/lower limb injury Positive trend towards fewer overall knee injuries, but did not reach significance.	20/28	71%
Heidt et al (2000)	Control Group ACL injuries = 8 (not reported) 1000h AE = not reported (not reported) Intervention Group ACL injuries = 1 (not reported) 1000h AE = not reported (not reported)	Knee injury as defined by injury that cause one or more day of missed training/game. Control Group Knee injuries = 29 1000h AE = not reported Intervention Group Knee injuries = 3 1000h AE = not reported	ACL Injury Trend toward fewer ACL injures, but did not reach significance. Overall Knee/Lower Limb Injury **Overall injury rates were significantly lower in intervention group vs control group ($p = 0.0085$).**	14/28	50%
Hewett et al (1999)	ACL rupture as confirmed by arthroscopy Control Group Females ACL injuries = 5 (5) 1000h AE = 0.11 (0.11) Control Group Males ACL injuries = 1 (1) 1000h AE = 0.02 (0.02) Intervention Group (all Female) ACL injuries = 2 (0) 1000h AE = 0.06 (0.00)	Serious knee injury was defined as a knee ligament injury that caused the player to seek care by an athletic trainer and that led to at least 5 days off training/games. Control Group Females Knee injuries = 10 1000h AE = 0.22 Control Group Males Knee injuries = 2 1000h AE = 0.05 Intervention Group Knee injuries = 2 1000h AE = 0.06	ACL Injury Trend toward fewer ACL injures, but did not reach significance Overall Knee/Lower Limb Injury **Overall injury rates were significantly lower in intervention group versus the female, but not male, control groups.** Untrained females had injury rate 3.6 times higher than trained females and 4.8 higher than untrained males	14/28	50%
Kiani et al (2010)	Control Group ACL injuries = 5 (5) 1000h AE = 0.08 (0.08) Intervention Group ACL injuries = 0 (0) 1000h AE = 0.00 (0.00)	Knee injury was defined as an injury that made player seek medical care. Control Group Knee injuries = 13 1000h AE = 0.20 Intervention Group Knee injuries = 3 1000h AE = 0.04	ACL Injuries Trend toward fewer ACL injures, but did not reach significance Overall Knee/Lower Limb Injury Trend toward fewer knee injuries, but did not reach significance. However, intervention group had 77% lower incidence of knee injury and 90% lower incidence of non-contact knee injury.	19/28	68%
LaBella et al (2011)	Control Group ACL injuries = not reported (6) 1000h AE = not reported (0.23) Intervention Group ACL injuries = not reported (2) 1000h AE = not reported (0.05)	Knee injury as defined by injury that cause one or more day of missed training/game. Control Group Knee injuries = 11 1000h AE = 0.24 Intervention Group Knee injuries = 6 1000h AE = 0.11	ACL Injuries **Statistically significant fewer ACL injuries in intervention as compared to control group (RR = 0.20, $p = 0.04$).** Overall Knee/Lower Limb Injury **Statistically significant lower amount of all knee injuries ($p = 0.03$) and all acute lower limb injuries ($p = 0.001$).** Intervention athletes had 65% less gradual onset injuries and 56% acute non-contact injuries.	21/28	75%
Mandelbaum et al (2005)	Combined years: Control Group ACL injuries = not reported (67) 1000h AE = not reported (0.24) Intervention Group ACL injuries = not reported (6) 1000h AE = not reported (0.04)	Not reported	ACL Injuries **Statistically significantly fewer non-contact ACL injuries in intervention as compared to control group (year 1 $p = 0.0001$; year 2 $p = 0.005$).** Results indicate, as compared with controls, intervention group had 88% reduction in non-contact ACL injuries in year 1 (relative risk 0.11), and 74% reduction in injuries year 2 (relative risk 0.26).	15/28	54%
Pasanen et al (2009)	Control Group ACL injuries = 4 (3) 1000h AE = 0.16 (0.12) Intervention Group ACL injuries =6 (3) 1000h AE = 0.19 (0.09)	Knee ligament injuries that caused one or more day of non-participation. Control Group Knee ligament injuries = 11 1000h AE = 0.44 Intervention Group Knee ligament injuries = 7 1000h AE = 0.65	ACL Injuries No significant difference between groups Overall Knee/Lower Limb Injury Significantly fewer non-contact leg injuries occurred in intervention as compared to control group ($p = 0.001$), which equated to a 66% reduced risk of injury in intervention group.	25/28	89%

Table 4: Characteristics of Individual Studies *(Continued)*

Author	Study Design	Sport/ Level	Group Size (number of participants)	Ages of Participants in Years	Intervention implementer	Intervention Type	When Implemented	Intervention Frequency and Duration	Comments on Compliance, Adherence and Drop-out Data
Myklebust et al (2003)	3 year prospective crossover study with 1st year acting as control group	Handball/ Norwegian Division I-III teams	Year 1 C = 60 (942) Year 2 I = 58 teams (855) Year 3 I = 52 teams (850)	Mean age = 21.5	Coach in year 1 Physio in year 2	-education -balance mats -balance board -floor exercises	Pre-season + in-season	15min/session, 3 d/wk for 5-7 weeks preseason, then 1 d/wk through season 5 months total	To fulfil compliance criteria, team completed a minimum of 15 intervention sessions with >75% player participation Year 1 26% fulfilled compliance criteria Year 2 29% fulfilled compliance criteria Data for 'compliers' and 'non-compliers' analysed together and then separately
Peterson et al (2005)	Prospective cluster non-randomized case-controlled	Handball/ German leagues of various levels	C = 10 teams (142) I = 10 teams (134)	Adult females	Coach, trainer or physio	- education - balance board - jump/land	Pre-season + in-season	10min/session, 3 d/wk for 8 weeks (pre-season), then 1 d/wk through season	2/12 teams (17%) dropped out of intervention group and 31 players (13 intervention group, 18 control group) dropped out of handball.
Pfeiffer et al (2006)	2 year prospective cluster cohort trial	Soccer, basketball, volleyball/ US high school league	C = 43 teams (577) I = 69 teams (862)	14-18	Certified athletic trainers	'KLIP' program: - deceleration - plyometrics	In-season	20min/session, 2d/week	Mean number of interventions from 18-23 for the different sports.
Soderman et al. (2000)	Prospective randomized cluster controlled trial	Soccer/ Swedish 2nd and 3rd leagues	C = 6 teams (78) I = 7 teams (62)	Mean age = 20.4±5.4	Home programme	Balance board	Pre-season & In-season	15min/session, initially every day for 30 days, then 3 d/wk for rest of season 7 months total Mean sessions completed 65±19	Teams having completed minimum of 35 intervention sessions were included in data analysis 37% participant dropout Did not track adherence to prescribed programme
Steffen et al (2008)	Prospective cluster RCT	Soccer/ Norwegian soccer leagues of various levels	C = 54 teams (1001) I = 59 teams (1091)	Mean age = 15.4±0.8	Coach, physical therapist	The FIFA '11': - NM warm-up - core strength - leg strength - plyometrics	Pre-season & In-season	15min/ session for 15 consecutive sessions then 1 d/wk for rest of season 7.5 months total	Mean sessions per season = 23 ±9 (SD) Used at 52% of trainings Mean player training attendance = 67±10% (SD)
Walden et al (2012)	Prospective cluster RCT	Soccer/ Swedish soccer leagues of various levels	C= 109 (2085) I = 121 (2479)	12 – 17	Coach, physio	- NM warm-up - strength - balance - plyometrics	In-season	15min/session, used as warm-up for each practice and game in-season 7 months total	Mean sessions per season = 28.8 ± 13.1 (SD) Mean session per week =1.3 ± 0.5 (SD) Mean player session attendance = 69 ± 21.7% (SD)

Note: ACL, anterior cruciate ligament; AE, athletic exposures; C, control group; d/wk, day per week; h, hours; I, intervention group; NCAA, National Collegiate Athletic Association; NM, neuromuscular; physio, physiotherapist; min, minutes; RR, risk ratio; RCT, randomised controlled trial; SD, standard deviation; US, United States

review

Author	Total ACL Injuries (non contact ACL injuries) Total (noncontact) ACL Incidence per 1000 h of Athletic Exposure	All Other Knee Injuries and Incidence per 1000 h of Athletic Exposure	Study Results	Total Modified Downs and Black Checklist Score (/28)	Quality Index %
Myklebust et al (2003)	Control Group (Year 1) ACL injuries = 29 (not reported) 1000h AE = 0.03 (not reported) Intervention Group (Year 2) ACL injuries =23 (not reported) 1000h AE = 0.13 (not reported) Intervention Group (Year 3) ACL injuries =17 (not reported) 1000h AE = 0.09 (not reported)	Not reported	ACL Injuries Trend toward fewer ACL injures, but did not reach significance. **Significant difference in the incidence of ACL injury in the elite division teams between intervention and control groups (p = 0.01)**	15/28	54%
Peterson et al (2005)	Control Group ACL injuries = 5 (5) 1000h AE = 0.21 (0.21) Intervention Group ACL injuries =1 (0) 1000h AE = 0.04 (0.00)	Knee injury as defined by injury that cause one or more day of missed training/game. Control Group Knee injuries = 9 1000h AE = 0.56 Intervention Group Knee injuries = 5 1000h AE = 0.18	ACL Injuries Trend toward fewer ACL injuries, but did not reach significance. However, all non-contact ACL ruptures (5) occurred in control group. Overall Knee/Lower Limb Injury Trend toward lower injury rates, but did not reach significance	15/28	54%
Pfeiffer et al (2006)	Control Group ACL injuries = not reported (3) 1000h AE = not reported (0.04) Intervention Group ACL injuries = not reported (3) 1000h AE = not reported (0.08)	Not reported	ACL Injuries No significant difference between intervention and control groups for ACL injury.	13/28	46%
Soderman et al. (2000)	Control Group ACL injuries = 1 (not reported) 1000h AE = not reported (not reported) Intervention Group ACL injuries = 4 (not reported) 1000h AE = not reported (not reported)	Knee injury as defined as traumatic injury that lead to non-participation in following game/training session. Control Group Knee injuries = 31 1000h AE = not reported Intervention Group Knee injuries = 28 1000h AE = not reported	ACL Injuries **Statistically significantly higher number of ACL ruptures in the intervention group as compared with control group (p = 0.02).** Overall Knee/Lower Limb Injuries No difference between groups	19/28	68%
Steffen et al (2008)	Control Group ACL injuries = 5 (2) 1000h AE = 0.08 (0.03) Intervention Group ACL injuries = 4 (3) 1000h AE = 0.06 (0.05)	Knee injury as defined as jury that lead to non-participation in following game/training session. Control Group Knee injuries = 30 1000h AE = 0.5 Intervention Group Knee injuries = 37 1000h AE = 0.6	ACL Injuries No difference between groups Overall Knee/Lower Limb Injuries No difference between group for knee injuries or overall lower extremity injuries.	24/28	86%
Walden et al (2012)	Control Group ACL injuries = 14 (not reported) 1000h AE = 0.23 (not reported) Intervention Group ACL injuries = 7 (not reported) 1000h AE = 0.12 (not reported)	Severe knee injury caused absence of 4 weeks or more. Control Group Severe knee injuries = 31 1000h AE = 0.24 Intervention Group Severe knee injuries = 26 1000h AE = 0.17	ACL Injuries **Statistically significant lower amount of ACL injuries in intervention as compared to control group (RR = 0.36, p =0.02).** Risk of ACL injury in intervention group was 64% less than control group. Overall Knee/Lower Limb Injuries Not significant difference in acute or severe knee injuries between groups.	26/28	93%

REFERENCES

1 Lohmander L, Östenberg A, Englund M, Roos H. High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthr Rheum* 2004; **50**(10):3145-52.

2 Myklebust G, Holm I, Mæhlum S, Engebretsen L, Bahr R. Clinical, functional, and radiologic outcome in team handball players 6 to 11 years after anterior cruciate ligament injury: A follow-up study. *Am J Sports Med* 2003; **31**(6):981-9.

3 Øiestad B E, Engebretsen L, Storheim K, Risberg M A. Knee osteoarthritis after anterior cruciate ligament injury a systematic review. *Am J Sports Med* 2009; **37**(7):1434-43.

4 Gianotti S M, Marshall S W, Hume P A, Bunt L. Incidence of anterior cruciate ligament injury and other knee ligament injuries: a national population-based study. *J Sci Med Sport* 2009; **12**(6):622-7

5 Agel J, Arendt E A, Bershadsky B. Anterior cruciate ligament injury in National Collegiate Athletic Association basketball and soccer a 13-year review. *Am J Sports Med* 2005; **33**(4):524-31.

6 Hootman J M, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train* 2007; **42**(2):311-9.

7 Prodromos C C, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury–reduction regimen. *Arthroscopy: J Arthrosc Rel Surg* 2007; **23**(12):1320-5.

8 Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W et al. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. *Br J Sports Med* 2008; **42**(6):394-412

9 Berns G S, Hull M, Patterson H A. Strain in the anteromedial bundle of the anterior cruciate ligament under combination loading. *J Orthop Res* 1992; **10**(2):167-76.

10 Krosshaug T, Slauterbeck J R, Engebretsen L, Bahr R. Biomechanical analysis of anterior cruciate ligament injury mechanisms: Three-dimensional motion reconstruction from video sequences. *Scand J Med Science Sports* 2007; **17**(5):508-19.

11 Beutler A I, De la Motte S J, Marshall S W, Padua D A, Boden B P. Muscle strength and qualitative jump-landing differences in male and female military cadets: the Jump-ACL study. *J Sports Sci Med* 2009; **8**(4):663-71.

12 Malinzak R A, Colby S M, Kirkendall D T, Yu B, Garrett W E. A comparison of knee joint motion patterns between men and women in selected athletic tasks. *Clin Biomech* 2001; **16**(5):438-45.

13 Padua D, Marshall S, Beutler A, Garrett W, editors. Prospective cohort study of biomechanical risk factors of ACL injury: The JUMP-ACL Study. *Am Orthop Soc Sports Med Annu Meet* 2009: 393-5.

14 Padua D A, Marshall S W, Boling M C, Thigpen C A, Garrett W E, Beutler A I. The Landing Error Scoring System (LESS) Is a Valid and Reliable Clinical Assessment Tool of Jump-Landing Biomechanics The JUMP-ACL Study. *Am J Sports Med* 2009; **37**(10):1996-2002.

15 Myer G D, Ford K R, McLean S G, Hewett T E. The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics. *J Strength Cond Res* 2006; **34**(3):445-455.

16 Padua D A, DiStefano L J, Marshall S W, Beutler A I, DiStefano M J. Retention of movement pattern changes after a lower extremity injury prevention program is affected by program duration. *Am J Sports Med* 2012; **40**(2):300-6.

17 Herrington L. The effects of 4 weeks of jump training on knee valgus and crossover hop performance in female basketball players. *J Strength Cond Res* 2010; **24**(12):3427-3432.

18 Gilchrist J, Mandelbaum B R, Melancon H, Ryan G W, Silvers H J, Griffin LY et al. A randomized controlled trial to prevent non contact anterior cruciate ligament injury in female collegiate soccer players. *Am J Sports Med* 2008; **36**(8):1476-83.

19 Heidt R S, Sweeterman L M, Carlonas R L, Traub J A, Tekulve F X. Avoidance of soccer injuries with preseason conditioning. *Am J Sports Med* 2000; **28**(5):659-62.

20 Hewett T E, Lindenfeld T N, Riccobene J V, Noyes F R. The effect of neuromuscular training on the of knee injury in female athletes: A prospective study. *Am J Sports Med* 1999; **27**(6):699-706.

21 Kiani A, Hellquist E, Ahlqvist K, Gedeborg R, Michaëlsson K, Byberg L. Prevention of soccer-related knee injuries in teenaged girls. *Arch Intern Med* 2010; **170**(1):43-9.

22 LaBella C R, Huxford M R, Grissom J, Kim K-Y, Peng J, Christoffel K K. Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools: cluster randomized controlled trial. *Archives Pediatr Adolesc Med* 2011; **165**(11):1033-40.

23 Mandelbaum B R, Silvers H J, Watanabe D S, Knarr J F, Thomas S D, Griffin L Y et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 2005; **33**(7):1003-10.

24 Myklebust G, Engebretsen L, Brækken I H, Skjølberg A, Olsen O E, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sports Med* 2003; **13**(2):71-8.

25 Pasanen K, Parkkari J, Pasanen M, Hiilloskorpi H, Makinen T, Jarvinen M et al. Effect of a neuromuscular warm-up programme on muscle power, balance, speed and agility: a randomised controlled study. *Br J Sports Med* 2009; **43**(13):1073-8.

26 Petersen W, Braun C, Bock W, Schmidt K, Weimann A, Drescher W et al. A controlled prospective case control study of a prevention training program in female team handball players: the German experience. *Arch Orthop Traum Surg* 2005; **125**(9):614-21.

27 Pfeiffer R P, Shea K G, Roberts D, Grandstrand S, Bond L. Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *J Bone Joint Surg* 2006; **88**(8):1769-74.

28 Söderman K, Werner S, Pietilä T, Engström B, Alfredson H. Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? *Knee Surg Sports Traumatol Arthrosc* 2000; **8**(6):356-63.

29 Steffen K, Myklebust G, Olsen OE, Holme I, Bahr R. Preventing injuries in female youth football–a cluster randomized controlled trial. *Scand J Med Sci Sports* 2008; **18**(5):605-14.

30 Waldén M, Atroshi I, Magnusson H, Wagner P, Hägglund M. Prevention of acute knee injuries in adolescent female football players: Cluster randomised controlled trial. *Br Med J* 2012; 344:e3042.

31 Sugimoto D, Myer G D, McKeon J M, Hewett T E. Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a critical review of relative risk reduction and numbers-needed-to-treat analyses. *Br J Sports Med* 2012; **46**(14):979-88.

32 Grindstaff T L, Hammill R R, Tuzson A E, Hertel J. Neuromuscular control training programs and noncontact anterior cruciate ligament injury rates in female athletes: a numbers-needed-to-treat analysis. *J Athl Train* 2006; **41**(4):450-6.

33 Pasanen K, Parkkari J, Kannus P, Rossi L, Palvanen M, Natri A et al. Injury risk in female floorball: a prospective one-season follow-up. *Scand J Med Sci Sports* 2008; **18**(1):49-54.

34 Liberatti A, Altman D, Tezlaff J, Mulrow C, Gotzsche P C, et al. The PRISMA Statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and Evaluation. *Ann Intern Med* 2009; **151**(4):W65-W94.

35 Downs S H, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998; **52**(6):377-84.

36 Saunders L D, Soomro G M, Buckingham J, Jamtvedt G, Raina P. Assessing the methodological quality of non-randomized intervention studies. *West J Nurs Res* 2003; **25**(2):223-37.

37 Hartling L, Brison R J, Crumley E T, Klassen T P, Pickett W. A systematic review of interventions to prevent childhood farm injuries. *Pediatr* 2004; **114**(4):e483-e96.

38 Hignett S. Systematic review of patient handling activities starting in lying, sitting and standing positions. *J Adv Nurs* 2003; **41**(6):545-52.

39 Hing W, Bigelow R, Bremner T. Mulligan's mobilization with movement: A systematic review. *J Man Manip Ther* 2009; **17**(2):39E-66E.

40 Van Tulder M, Furlan A, Bombardier C, Bouter L, et al. Updated method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group. *Spine* 2003; **28**(12):1290-9.

41 Mandelbaum B R, Silvers H J, Watanabe D S, Knarr J F, Thomas S D, Griffin L Y et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 2005; **33**(7):1003-10.

42 Sugimoto D, Myer G D, Bush H M, Klugman M F, McKeon J M , Hewett T E. Compliance with neuromuscular training and anterior cruciate ligament injury risk reduction in female athletes: A meta-analysis. *J Athl Train* 2012; **47**(6):714-23.

43 Soligard R, Myklebust G, Steffen K, Holme I, Silver H, Bizzini M, Junge A, Dvorak J, Bahr R, Andersen TE. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *Br Med J* 2008; 337:a2469.

44 Myer G D, Sugimoto D, Thomas S, Hewett T E. The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: A meta-analysis. *Am J Sports Med* 2013; **41**(1):203-215.

45 Myer G D, Chu D A, Brent J L, Hewett T E. Trunk and hip control neuromuscular training for the prevention of knee joint injury. *Clin Sports Med* 2008; **27**:425-448.

46 Andrish J T. Anterior cruciate ligament injuries in the skeletally immature patient. *Am J Orthop*. 2001; **30**:103-10.

47 Clanton T O, DeLee J C, Sanders B, Neidre A. Knee ligament injuries in children. *J Bone Joint Surg* 1979; **61**:1196-201.

48 Tanner J M, Davies P S. Clinical longitudinal standards for height and height velocity for North American children. *J Pediatr* 1985; **107**(3):317-29.

49 Hewett T E, Myer G D, Ford K R. Decrease in neuromuscular control about the knee with maturation in female athletes. *J Bone Joint Surg* 2004; **86**-A(8):1601-1608.

50 Ford K R, Myer G D, Hewett T E. Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc* 2003; **35**:1745-50.

51 Phillippaerts R M, Vaeyens R, Janssens M, Van Renterghem B, Matthys D, et al. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci* 2006; **24**(3):221-230.

52 Kellis S E, Tsitskaris G K, Nikopoulou M D, Mousikou K C. The evaluation of jumping ability of male and female basketball players according to their chronological age and major leagues. *J Strength Cond Res* 1999; **13**:40-6.

53 Beunan G, Malina R M. Growth and physical performance relative to the timing of the adolescent growth spurt. *Exerc Sport Sci Rev* 1988; **16**:503-40.

54 Shea K G, Pfeiffer R, Wang J H, Curtin M, Apel P J. Anterior cruciate ligament injury in pediatric and adolescent soccer players: an analysis of insurance data. *J Pediatr Orthop* 2004; **24**(6):623-628.

55 Hagglund M, Atroshi I, Wagner P, Walden M. Superior compliance with a neuromuscular training programme is associated with fewer ACL injuries and fewer acute knee injuries in female adolescent football players: secondary analysis of an RCT. *Br J Sports Med*. 2013; **47**:974-979.

56 Bizzini M, Junge A, Dvorak J. Implementation of the FIFA 11+ football warm up program: How to approach and convince the Football associations to invest in prevention. *Br J Sports Med* 2013; **47**:803-806.

57 Soligard T, Nilstad A, Steffen K, Myklebust G, Holme I, Dvorak J, Bahr R, Andersen TE. Compliance with a comprehensive programme to prevent injuries in youth football. *Br J Sports Med* **44**:787-793.

58 Steffen et al. Evaluation of how different implementation strategies of an injury prevention programme (FIFA 11+) impact team adherence and injury risk in Canadian female youth football players: a cluster-randomised trial. *Br J Sports Med* 2013; bjsports-2012-091887.

59 Swart E, Redler L, Fabricant P, Mandelbaum B, Ahmed C, Wang Y C. Prevention and screening programmes for anterior cruciate ligament injuries in young athletes: A cost-effectiveness analysis. *J Bone Joint Surg AM* 2014; **96**:705-11.

The effect of running demands and impacts on post-tournament markers of inflammation and haemolysis in women's rugby sevens

ANTHEA C CLARKE, JUDITH M ANSON, DAVID B PYNE

ABSTRACT

Aim
Rugby sevens is a physically demanding sport often leaving players fatigued and sore. This study aimed to quantify the short-term changes in biochemical and haematological variables of inflammation and haemolysis induced by a two-day women's rugby sevens tournament in State and National representative players, and explore the relationship between on-field movement patterns and select biomarkers.

Study Design
Cross-sectional study.

Setting
Australian Women's Rugby Sevens National Championships.

Participants
State (n = 10, 24.4 ± 4.3 y, 1.67 ± 0.03 m, 66.1 ± 7.9 kg) and National (n = 12, age 22.3 ± 2.5 y, height 1.67 ± 0.04 m, mass 65.8 ± 4.6 kg) female rugby sevens players.

Outcome Measures
Running movement patterns and impacts were recorded using 15 Hz GPS units over a two-day tournament. Biochemical and haematological variables were measured before and after the tournament.

Results
While National players completed greater on-field movements (effect size (ES) = 0.55–0.97), post-tournament leukocyte count increased similarly (30-50%) in both State (ES = 1.95) and National players (ES = 1.52). Neutrophil count positively correlated (r = 0.57–0.89) with all on-field movements for both groups. Haptoglobin concentration were 94% higher at baseline in National players (ES = 1.33), but declined ~20-40% in both groups. Creatine kinase increased 4-fold in State players, and 2.5-fold in National players (ES = 2.86–4.10), while creatinine increased moderately (10-14%) in both groups.

Conclusion
Greater haemolysis and muscle damage in State level players might be a consequence of lower strength and fitness, and being less accustomed to the contact demands of competition. Effective preparation and careful post-tournament management of players should promote improved game performance and enhanced recovery.

Keywords: football, female, leucocytosis, muscle damage, creatinine

See end of article for author affiliations.

Correspondence
Anthea C Clarke
Department of Physiology, Australian Institute of Sport
1 Leverrier Crescent
Bruce, ACT, 2617
Anthea.Clarke@ausport.gov.au

INTRODUCTION

Rugby sevens is a unique sport compared to other football codes. While rugby sevens games are shorter in duration (14-20 min) compared with rugby union (80 min), they are played in a tournament format, with up to three games played per day, over two to three consecutive days. The short duration of rugby sevens games, combined with the relatively greater amount of space available per player (seven on-field players compared to 15 within the same sized playing-field) yields a higher work-to-rest ratio.[1,8,24] Rugby sevens tournaments might therefore elicit greater inflammation, haemolysis and muscle damage in players compared to other football codes, based on the high-speed running demands on players. As both men's and women's rugby sevens will be making their Olympic debut in 2016, understanding the biochemical and haematological changes that occur over a typical two-day rugby sevens tournament could be important in the preparation for and recovery from tournaments.

To date, only one study has quantified the degree of inflammation after consecutive rugby sevens match play, with a cumulative inflammatory response occurring from one game to the next.[25] However, a single game of men's rugby union produces a greater inflammatory response than two games of rugby sevens, and post-game neutrophil counts correlated to the number of contacts and tackles players experience.[4] Given that rugby sevens tournaments include up to six games over two days, it is likely that a cumulative inflammatory response arises from the combination of the physical intensity of match play, total playing duration, and high work to rest ratios (both within- and between-games). However, the extent of inflammation following a rugby sevens tournament, and how that might influence recovery and subsequent match preparation is currently unknown.

In addition to inflammation, haemolysis and muscle damage also occur following competitive team sports. While muscle damage is greater in individuals of a lower training status,[28] haemolysis can be independent of athlete status, competition level,[23] VO_2 max or marathon finish time.[6] Haemolysis, indirectly measured by a decline in serum haptoglobin concentration, is increased in response to exercise.[16] Research on haptoglobin has mainly been in male athletes and few studies have investigated haemolysis in female team-sport athletes. While a competitive game of women's soccer elicited no substantial change in haptoglobin concentration,[9] a single field-based training session yielded a ~13% decrease.[26] Interestingly, goalkeepers, who ran 40% less distance and completed very few or no efforts at high-speed had similar results. Other activities, such as jumping, diving and tackling may have contributed to the haemolysis observed in goalkeepers, in contrast to the higher running load of field players. This assertion is of particular interest to women's rugby sevens where players spend a substantial portion of a match in high physical impact situations (tackling, wrestling). However, the presence of haemolysis and the contribution of running and physical impacts have yet to be addressed in women's rugby sevens.

Understanding the short term changes in creatinine concentration following rugby sevens tournaments is also important for the practitioner. Serum creatinine concentration correlates with individuals' muscle mass[2,9] but can also be influenced by creatine supplementation and intense exercise.[9,20] Given that creatinine is commonly measured to assess renal health, understanding the acute changes induced by a two-day rugby sevens tournament is important to be able to differentiate a clinical health issue with a normal acute response to demanding physical activity. Knowledge on the extent of inflammation and haemolysis from a rugby sevens tournament can help inform the clinical management of players presenting with substantial post-tournament fatigue or soreness by providing adequate recovery interventions and appropriate prescription of training following competition.

In progressing athletes to an elite level of competition, understanding how the physical demands differ between elite and sub-elite players is important to ensure the correct management and development of players. The aims of this study were to quantify the short-term changes in biochemical and haematological variables of inflammation and haemolysis induced by a two-day women's rugby sevens tournament in State and National representative players, and explore the relationship between on-field movement patterns and select biomarkers.

METHODS

Experimental Approach to the Problem

This study was a cross-sectional study comparing haematological and biochemical changes in State and National level Women's Rugby Sevens players. This study was completed over a single two-day tournament where National level players competed in their respective State teams, while State players were all part of the same team. Changes in haematological and biochemical measures were analysed over the two-day tournament to determine relationships with on-field performance measures and athlete playing level.

Subjects

National (n = 12, age 22.3 ± 2.5 y, height 1.67 ± 0.04 m, mass 65.8 ± 4.6 kg; mean ± SD) and State (n = 10, 24.4 ± 4.3 y, 1.67 ± 0.03 m, 66.1 ± 7.9 kg) representative Women's Rugby Sevens players participated in this study. Players were made aware of the purpose, methodology, benefits and risks of this study prior to obtaining their written informed consent, and were free to withdraw at any time without penalty. This study was approved by the Australian Institute of Sport Ethics Committee and the University of Canberra Human Research Ethics Committee.

Procedures

Players presented themselves to the Australian Institute of Sport physiology laboratory on the afternoon prior to, and the evening following the two-day women's rugby sevens National Championships (outdoor ambient temperature 22-26°C). Post-tournament blood samples were collected within three hours of the completion of players' final game of the tournament. Nine National players also returned one week after for a follow-up blood sample. Players were rested in a supine position for several min prior to blood collection. Venous blood draws were obtained by a trained phlebotomist. A total of 4 mL of blood (one x 2 mL serum separator tube, one x 2 mL EDTA tube) was taken from a forearm vein. Haematological parameters (leukocytes, erythrocytes (RBC), haemoglobin (Hb), haematocrit (Hct), platelet count, and mean cell volume (MCV) were analysed using a Sysmex XT-2000i (Roche Diagnostics, Australia). Biochemistry analysis was performed on a Cobas Integra 400 plus (Roche Diagnostics, Australia) and serum samples analysed for iron, transferrin (Tfr), ferritin (Fer), transferrin saturation (%TfrSat), creatine kinase (CK), haptoglobin, and creatinine. All analytes underwent internal and external quality control checks prior to analysis.

On-field game movement data was collected throughout the tournament using 15 Hz GPS units (SPI HPU, GPSports Systems, Canberra, Australia), which are considered valid and reliable for use in team-sports.[3,11] These units also contain a 16 G accelerometer capable of measuring the impact forces on players. Each unit was positioned within a specialised harness worn underneath the playing jersey. For analysis, the half time interval was excluded so that only on-field playing time was included. Due to injury, coach selection and finals progression, players competed in 3-6 games over the two-days, resulting in 64 game files for National players and 51 game files for State players. Two National players who did not play on the second day due to injury were not included in post-tournament data analysis. GPS variables reported include total playing time, total distance, distance covered at high-speed (>5 m·s^{-1}), total number of impacts and impacts >10 g.

The use of recovery modalities and non-steroidal anti-inflammatory drugs (NSAIDs) were not controlled within this study. All players had access to cold water immersion but it was up to their team management as to the frequency of use. As a minimum, players used cold water immersion following games on the first day of the tournament, but some players also reported using them between

Table 1 - Biochemical and haematological response in State and National level female rugby sevens players following a two day tournament.

	State				National			
	Pre (n=10)	Post (n=8)	ES, ±90% CL	Qualitative Outcome	Pre (n=12)	Post (n=10)	ES, ±90% CL	Qualitative Outcome
Leukocyte Count (109L-1)	7.24 ± 1.26	10.56 ± 2.75	1.95, ±0.62	Large +	8.25 ± 1.85	11.78 ± 2.30	1.52, ±0.29	Large +
Neutrophil Count (109L-1)	4.45 ± 1.05	7.72 ± 2.38	2.04, ±0.46	V Large +	5.14 ± 1.72	9.05 ± 2.21	1.67, ±0.29	Large +
Lymphocyte Count (109L-1)	2.14 ± 0.45	1.90 ± 0.57	-0.61, ±0.66	Moderate -	2.33 ± 0.26	1.83 ± 0.43	-2.32, ±1.24	V Large -
Monocyte Count (109L-1)	0.51 ± 0.10	0.87 ± 0.36	2.03, ±0.80	V Large +	0.62 ± 0.21	0.88 ± 0.26	1.03, ±0.43	Moderate +
Red Blood Cells (1012L-1)	4.44 ± 0.26	4.27 ± 0.25	-0.85, ±0.38	Moderate -	4.32 ± 0.25	4.26 ± 0.23	-0.24, ±0.36	Small -
Haematocrit (ratio)	38.2 ± 2.1	36.6 ± 1.8	-0.99, ±0.42	Moderate -	36.93 ±1.86	36.3 ± 1.9	-0.47, ±0.42	Small -
Haemoglobin (g·dL-1)	13.2 ± 0.7	12.8 ± 0.5	-0.87, ±0.38	Moderate -	12.73 ± 0.67	12.6 ± 0.7	-0.32, ±0.38	Small -
Iron (μmol·L-1)	20.3 ± 7.5	14.8 ± 4.5	-0.78, ±0.47	Moderate -	16.1 ± 3.5	19.2 ± 4.2	0.90, ±0.35	Moderate +
Ferritin (μg·L-1)	62.1 ± 37.0	85.0 ± 45.7	0.56, ±0.34	Small +	43.2 ± 16	61.2 ± 20.0	0.66, ±0.20	Moderate +
Transferrin (g·L-1)	2.60 ± 0.25	2.49 ± 0.26	-0.27, ±0.21	Small -	3.28 ± 0.61	3.33 ± 0.65	0.07, ±0.13	Trivial
Venous CK (mmol·L-1)	177 ± 71	1119 ± 959	4.10, ±1.07	V Large +	243 ± 155	1031 ± 570	2.86, ±0.34	V Large +
Creatinine (μmol·L-1)	76.6 ± 11.0	84.4 ± 9.7	0.64, ±0.34	Moderate +	80.5 ± 9.2	92.3 ± 16.4	1.05, ±0.45	Moderate +
Haptoglobin (mg·dL-1)	49.2 ± 19.6	33.5 ± 19.2	-1.93, ±1.93	Large -	85.6 ± 28.1	58.3 ± 37.1	-1.64, ±1.26	Large –

CK – creatine kinase, CL – confidence limits, Conc – concentration, ES – Cohen's effect size, Hb – haemoglobin. + indicates an increase in analyte concentration after the tournament, whereas – indicates a decrease.

games. Up to 90% of players also reported using compression garments for a minimum of 2 hrs on the evening between game days. Given the potential influence of recovery modalities and NSAIDs on the inflammatory response this is a confounding variable in this study. However, given the common use of NSAIDs and recovery techniques within the athletic population, the results of this study are still applicable.

Statistical Analyses

Descriptive data are presented as mean and standard deviation (SD). Raw data was log-transformed prior to analysis using inferential statistics. Data were analysed for playing-level and time. Standardised mean change or difference (Cohen' effect size, ES) were used to characterise the magnitude of effects against the following criteria: ES <0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large, and >2.0 very large.[10] Precision of estimation was indicated with 90% confidence limits (CL). When the CL crossed the threshold of ±0.2 the change (or difference) was deemed unclear. The Pearson's Product-Moment correlation was used to assess relationships between game movement patterns and blood markers. Correlations (r-values) were interpreted against the following criteria: r<0.1 trivial; 0.1-0.3 small; 0.3-0.5 moderate; 0.5-0.7 large; 0.7-0.9 very large; and >0.9 almost certain.[10] Confidence intervals (CI) were set with 90% precision of estimation and when they spanned the threshold of ±0.1 the association was deemed unclear.

RESULTS

Table 1 shows the haematological and biochemical changes across the two-day tournament. One State player presented with pre and post ferritin values greater than two SD above the mean (pre, 162 $\mu g \cdot L^{-1}$; post, 189 $\mu g \cdot L^{-1}$) and was removed from mean group analysis. National players had substantially lower Hb (-4%, ES = -0.66, ±0.68, mean, ±90% CL), Hct (-3%, -0.57, ±0.66), iron (-16%, -0.45, ±0.58) and %TfrSat (-35%, -0.99, ±0.58) at baseline, while Tfr was higher (28%, 2.26, ±1.02). No clinical or practically important changes in MCV, platelet count, basophils or eosinophils were apparent.

No substantial difference between groups was observed for CK or creatinine concentration at any time point, however levels of CK increased almost 4-fold in State players and ~2.5 fold for National players over the tournament. At baseline, haptoglobin was 94% greater in National compared to State players (ES = 1.33, ±0.58), however, levels fell 20-40% over the tournament in both groups, with no significant difference between the two groups post-tournament.

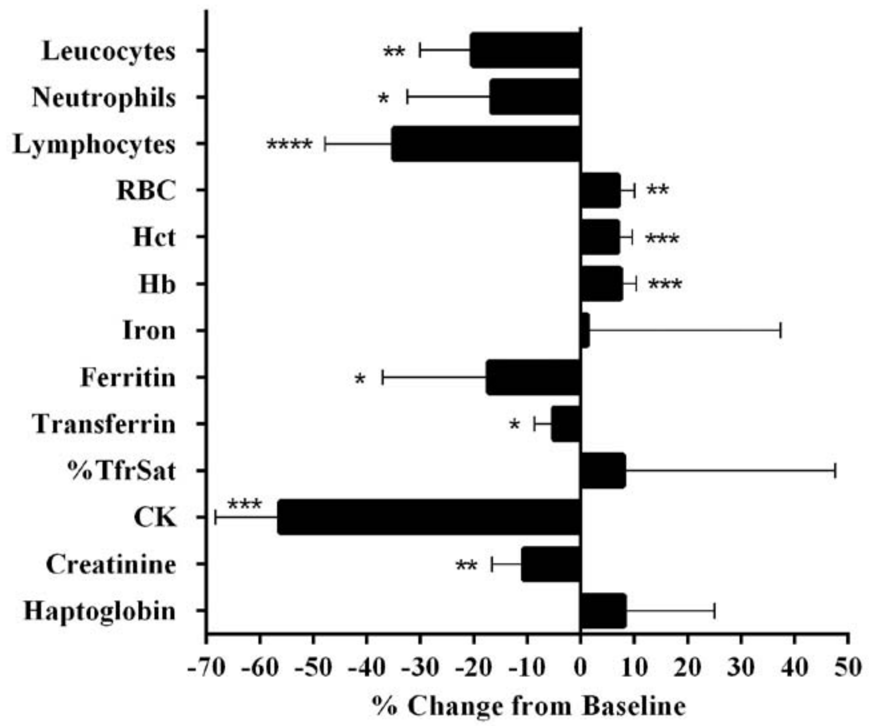


Figure 1 - Percent change in haematological and biochemical values from baseline to 1 week post a two-day women's rugby sevens tournament in National representative players. Data are presented as mean ± SD. Magnitude of change is represented as small (*), moderate (**), large (***), or very large (****).

One week post, National players had moderate to large increases in RBC, Hb and Hct (~7.2% ± 2.9%; mean ± SD) compared to baseline, while substantial decreases occurred for ferritin, creatinine, CK, leukocyte, neutrophil and lymphocyte counts (Figure 1).

The game movement patterns of State and National players are presented in Table 2. Neutrophil counts following the two-day tournament were large to very largely correlated with all on-field measures for State and National players (r = 0.57-0.89, ±~0.30; range, ±90% CL, Figure 2). In National players, total playing time, playing distance, and total number of impacts showed large correlations (r = 0.51-0.57, ±~0.38) with post-tournament creatinine, however, no clear correlations were observed for State players. Despite substantial uncertainty, post-tournament haptoglobin concentration had a large negative correlation with the number of impacts >10g in State players (r = -0.56, -0.88 to 0.10; mean, 90% CI), but was unclear in National players (r = -0.08, -0.55 to 0.44). Haptoglobin was not correlated with any other on-field measure for State or National players. Interestingly, for State players large to very large positive correlations were evident between CK and high-speed running (r = 0.60, -0.05 – 0.89) and impacts >10g (r = 0.87, 0.53 – 0.97) only, whereas National players had positive correlations between CK and all on-field measures (r = 0.50 – 0.77, ~±0.30).

Table 2 - Total game movement patterns in State and National players over a two-day women's rugby sevens tournament.

	State Players	National Players	Effect Size, ±90% CI	Qualitative Outcome
Game time (min)	50 ± 20	74 ± 22	0.97, ±0.69	Moderate
Distance (m)	4800 ± 2200	7100 ± 2100	0.85, ±0.66	Moderate
High-speed running (m)	584 ± 324	881 ± 410	0.57, ±0.72	Small
Total impacts (n)	5200 ± 2400	7300 ±2200	0.75, ±0.64	Moderate
Impacts >10g (n)	22 ± 11	29 ±11	0.55, ±0.60	Small

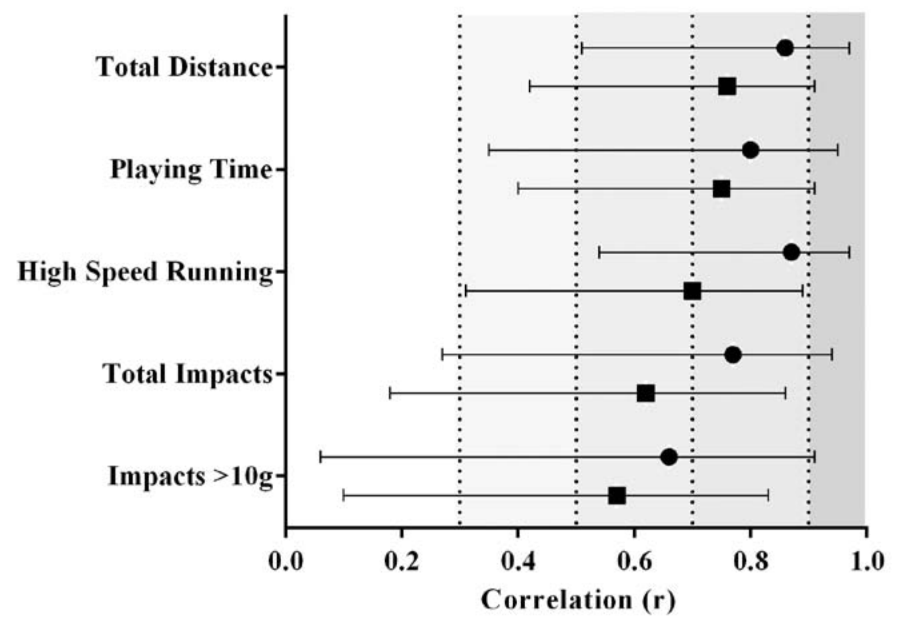


Figure 2 - Correlation between neutrophil count post a two-day women's rugby sevens tournament with on-field game performance metrics in State (●, n = 10) and National (●, n = 12) players. Dotted lines represent the threshold between moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9) and almost certain (>0.9)

DISCUSSION

A two-day women's rugby sevens tournament resulted in substantial inflammation and haemolysis in both State and National players. Leucocytosis occurred following the tournament and correlated largely with all on-field running measures. National players appear to be more accustomed to the intensity of exercise performed due to less muscle damage (CK) despite the greater on-field movements. While baseline haptoglobin was ~90% higher in National players, both groups experience similar acute changes following the tournament. Some players, dependant on playing-level, are likely to present with elevated levels of inflammation and haemolysis. Players need to prepare adequately for the physical and contact demands of rugby sevens tournaments, and coaches and trainers need to be alert to the need for targeted post-tournament recovery and management of players.

The large increase in leukocyte and neutrophil count immediately post-tournament is consistent with other rugby literature and correlated with the on-field movements of players. Neutrophil count in this study increased ~60-80% following a two-day rugby sevens tournament (4-6 games). Following two games of men's rugby sevens neutrophil counts increased by ~60%,[25] while an international rugby union match produced an increased neutrophil count of ~250%.[4] A number of factors, including gender,[27] total running/physical collision load, as well as the timing of testing[14,18] may contribute to the small differences between this women's rugby sevens tournament and the two games of men's rugby sevens. Over a rugby sevens tournament it is likely there is an initial influx of neutrophils influenced by playing duration and game intensity, but post-tournament values may be trending towards baseline. While physical contacts (r = 0.82) and tackles (r = 0.64) have been correlated with neutrophil count,[4] our study also showed large correlations with total playing time, distance, high-speed running and number of impacts. Inflammation brought on by a rugby sevens tournament is likely influenced by both mechanical and metabolic stressors.[19]

Despite larger correlations in State players, leukocyte and neutrophil counts were not substantially different between groups over the tournament, consistent with previous literature showing that chronic exercise training does not influence the acute exercise response of leukocytes.[15] One week post-tournament, having completed a comparatively light training week (three field sessions and two gym sessions), National players leukocyte counts were below baseline. While this may suggest an adaptive response to competition, a more reasonable explanation may be that these players entered the tournament with some degree of residual inflammation (given both WBC count and CK were higher in National than State players at baseline). These outcomes are important findings for specialists working in rugby sevens and show that, despite an athletes' competition level or fitness, a substantial amount of exercise-induced inflammation can occur following a rugby sevens tournament, and that one week of a reduced training load is sufficient for adequate recovery. Further research is needed to document the typical time-course for recovery following rugby sevens tournaments in both men and women. Attention should also be given to the potential positive effects of recovery modalities such as cold water immersion and compression garments to promote recovery after physically demanding tournaments.

Although the inflammatory response was similar between playing-levels, the degree of muscle damage and haemolysis were markedly higher for State players. Despite National players performing greater on-field movements over the two days, CK concentration increased 4-fold in State players and only ~2.5-fold in National players. However, when expressed per minute of play State players received a slightly greater number of total impacts (104 impacts.min^{-1} compared to 99 impacts.min^{-1} for National players) and a similar number of impacts >10g (State 0.44 impacts.min^{-1}, National 0.39 impacts.min^{-1}). Potentially, the rate at which impacts are received may also have an effect on muscle damage, along with the absolute number sustained. Similarly, while all on-field metrics correlated with post-tournament CK concentration in National players, only high-speed running and impacts >10g correlated (highly) with State players. This outcome provides evidence that running and impacts are major contributors to muscle damage in State players, whereas a more even distribution of game movements may contribute to the muscle damage in National players. Given the combined effects of both training adaptation and exercise familiarity, this result highlights the importance of adequate and appropriate training to prepare athletes for competition.

The initial haptoglobin levels in National players were ~90% higher than for State players, and are similar to those of elite female soccer players[9] and male endurance runners.[15] The greater baseline haptoglobin concentration in National players is possibly a long-term adaptive response to training, although this has not previously been demonstrated.[17] Potentially, the greater haptoglobin concentration in National players may also be contributed to the greater lean muscle mass in these players, although not directly measured. The increased availability of haptoglobin allows a greater portion of free Hb to be recycled during haemolysis and can reduce the loss of iron from the body.[13] While previous research shows little difference between haptoglobin levels and training status,[23] this data was pooled from endurance, power and mixed-discipline athletes at various points within their respective competitive season. Runners, however, had lower haptoglobin concentrations compared to cyclists, who were similar to the untrained controls.[23] While this result indicates a short-term haemolytic response in runners, two days of relative rest preceded blood collection and so determination of whether this outcome is a short-term response to exercise or a long-term adaption in runners is unclear.

While State players haptoglobin concentration was ~50% lower than National players following the completion of the tournament, the magnitude of haemolysis for both groups is similar to that following two consecutive heavy running sessions[16] and greater than a single women's soccer game,[9] suggesting a cumulative effect of competition on haemolysis. The finding that soccer goalkeepers have a similar haemolytic response to training,[26] despite running less, is important in relation to rugby sevens players, where a large portion of their game is spent tackling and wrestling other players for ball possession, activities not directly quantified in common monitoring tools such as GPS. The large correlation between haptoglobin levels and impacts >10g in State players implicates heavy-impact activities in haemolysis for female rugby sevens players. While a similar response was not seen in National players, it may be that their greater training adaptations and familiarity with the demands of rugby sevens competition reduces the haemolytic effects of heavy physical collisions. However, further research is required to confirm this potential adaptive response.

Despite the observed haemolysis and muscle damage resulting from rugby sevens match play, the ~7% reductions in RBC, Hb and Hct following the tournament are more likely due to plasma volume (PV) shifts than RBC turnover.[21] Using the method described by Dill and Costill,[5] State players had an estimated PV expansion of ~9% and National players ~3%. Increases in PV following exercise are influenced by exercise intensity, with greater intensity resulting in a larger shift.[7] For this reason, athletes with greater physical fitness require higher training loads to exhibit a similar PV shift.[22] The differences between State and National players are likely related to differences in physical fitness, although this was not measured. Given the large 50-400% increases in cell and analyte concentrations after tournament play, the small PV changes account for very little of the inflammatory and haemolytic responses. Similarly, correction for PV change following the tournament had no effect on the reduction in haptoglobin concentration (data not shown).

Despite moderate increases in creatinine following the two-day tournament, all values were within a healthy, normal range[12] and, in National players, had returned to below baseline levels one week post. A game of women's soccer resulted in a transient increase in creatinine by ~30%,[9] compared to an increase of 10-15% in this study. It is thought that exercise-induced increases in serum creatinine can recover quickly following the cessation of exercise,[20] explaining the modest changes in this study. National players tended to have higher creatinine levels both pre- and post-tournament, likely due to differences in the muscle mass[2,9] of National and State players, although body composition was not directly quantified in this study. Understanding that the high physical demand of rugby sevens does not place any excess stress or demand on the renal system than observed in a normal, healthy population is advantageous information for the clinician. Blood tests conducted for health reasons can exclude the possibility of clinically high creatinine levels being related to rugby sevens game play, however, modest elevations can be expected, particularly in athletes with larger muscle mass.

In conclusion, both State and National level players exhibit a similar change in haematological markers of inflammation following a two-day women's rugby sevens tournament. Despite differences in on-field play, markers of haemolysis and muscle damage increased more in State players, possibly due to poorer physical strength and fitness and being less accustomed to the physical demands of rugby sevens. This information may be useful for the physical development of players for optimal performance, clinical management of players, and prescription of training following a tournament. Future research with increased participant numbers and careful selection of anthropometric, physical and physiological measures is needed to confirm the outcomes of this study. Understanding the influence of NSAIDs and recovery modalities such as cold water immersion and compression garments will also be beneficial for coaches and support staff to promote recovery of their players post-tournament.

PRACTICAL APPLICATIONS

Given that post tournament markers of inflammation correlated with the total on-field movements of players, irrespective of playing level, recovery time following tournaments should be tailored to individuals based on their own playing duration and intensity. Physical fitness and a greater familiarity with the high running and impact demands of rugby sevens reduces the changes in markers of muscle damage and haemolysis resulting from a tournament. As such, strength and conditioning staff should focus on improving the physical fitness of players as well as getting them accustomed to the high physical contact load in order to reduce physiological disturbance and subsequent recovery time required post tournaments.

ACKNOWLEDGEMENTS

We thank the players and coaches involved in this study. We also thank the staff and students at the Australian Institute of Sport for assistance with data collection and the use of laboratory facilities. No external funding was provided for this study.

AUTHOR AFFILIATIONS

Anthea C Clarke

Department of Physiology, Australian Institute of Sport, Canberra Australia

Research Institute for Sport and Exercise, University of Canberra, Canberra, Australia

Judith M Anson PhD

Research Institute for Sport and Exercise, University of Canberra, Canberra, Australia

David B Pyne PhD FACSM

Department of Physiology, Australian Institute of Sport, Canberra Australia

REFERENCES

1 Austin D, Gabbett T, and Jenkins D. The physical demands of Super 14 rugby union. *J Sci Med Sport* 2011; **14**:259-263

2 Banfi G, Del Fabbro M, and Lippi G. Creatinine values during a competitive season in elite athletes involved in different sport disciplines. *J Sports Med Phys Fitness* 2008; **48**:479-482

3 Cummins C, Orr R, O'Connor H, and West C. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Med* 2013; **43**:1025-1042

4 Cunniffe B, Hore AJ, Whitcombe DM, Jones KP, Baker JS, and Davies B. Time course of changes in immuneoendocrine markers following an international rugby game. *Eur J Appl Physiol* 2010; **108**:113-122, 2010.

5 Dill D and Costill DL. Calculation of percentage changes in volumes of blood, plasma, and red cells in dehydration. *J Appl Physiol* 1974; **37**:247-248

6 Egan LM, Watts PB, and Silta BC. Changes in serum haptoglobin as an acute response to a marathon road race. *J Sports Sci* 1987; **5**:55-60

7 Fellmann N, Ritz P, Ribeyre J, Beaufrère B, Delaître M, and Coudert J. Intracellular hyperhydration induced by a 7-day endurance race. *Eur J Appl Physiol Occup Physiol* 1999; **80**:353-359

8 Granatelli G, Gabbett TJ, Briotti G, Padulo J, Buglione A, D'Ottavio S, and Ruscello B. Match Analysis and Temporal Patterns of Fatigue in Rugby Sevens. *J Strength Cond Res* 2014; **28**:728-734

9 Gravina L, Ruiz F, Lekue JA, Irazusta J, and Gil SM. Metabolic impact of a soccer match on female players. *J Sports Sci* 2011; **29**:1345-1352

10 Hopkins W, Marshall S, Batterham A, and Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 2009; **41**:3

11 Johnston RJ, Watsford ML, Kelly SJ, Pine MJ, and Spurrs RW. Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. *J Strength Cond Res* 2014; **28**:1649-1655

12 Jones CA, McQuillan GM, Kusek JW, Eberhardt MS, Herman WH, Coresh J, Salive M, Jones CP, and Agodoa LY. Serum creatinine levels in the US population: third National Health and Nutrition Examination Survey. *Am J Kidney Dis* 1998; **32**:992-999

13 Lim S-K, Ferraro B, Moore K, and Halliwell B. Role of haptoglobin in free hemoglobin metabolism. *Redox Rep* 2001; **6**:219-227

14 Lucas SJ, Anglem N, Roberts WS, Anson JG, Palmer CD, Walker RJ, Cook CJ, and Cotter JD. Intensity and physiological strain of competitive ultra-endurance exercise in humans. *J Sports Sci* 2008; **26**:477-489

15 Ndon J, Snyder A, Foster C, and Wehrenberg W. Effects of chronic intense exercise training on the leukocyte response to acute exercise. *Int J Sports Med* 1992; **13**:176-182

16 Peeling P, Dawson B, Goodman C, Landers G, Wiegerinck ET, Swinkels DW, and Trinder D. Cumulative effects of consecutive running sessions on hemolysis, inflammation and hepcidin activity. *Eur J Appl Physiol* 2009; **106**:51-59

17 Petibois C, Carzorla G, and Deleris G. The biological and metabolic adaptations to 12 months training in elite rowers. *Int J Sports Med* 2003; **24**:36-42

18 Priest J, Oei T, and Moorehead W. Exercise-induced changes in common laboratory tests. *Am J Clin Path* 1982; **77**:285-289

19 Pyne D. Exercise-induced muscle damage and inflammation: a review. *Aust J Sci Med Sport* 1994; **26**:49-58

20 Refsum H and Strömme S. Urea and creatinine production and excretion in urine during and after prolonged heavy exercise. *Scand J Clin Lab Inv* 1974; **33**:247-254

21 Robach P, Boisson RC, Vincent L, Lundby C, Moutereau S, Gergelé L, Michel N, Duthil E, Féasson L, and Millet G. Hemolysis induced by an extreme mountain ultra-marathon is not associated with a decrease in total red blood cell volume. *Scand J Med Sci Sports* 2014; **24**: 18-27

22 Sawka MN, Convertino VA, Eichner ER, Schnieder SM, and Young AJ. Blood volume: importance and adaptations to exercise training, environmental stresses, and trauma/sickness. *Med Sci Sports Exerc* 2000; **32**:332-348

23 Schumacher YO, Schmid A, Grathwohl D, Bultermann D, and Berg A. Hematological indices and iron status in athletes of various sports and performances. *Med Sci Sports Exerc* 2002; **34**:869-875

24 Suarez-Arrones L, Arenas C, López G, Requena B, Terrill O, and Mendez-Villanueva A. Positional Differences in Match Running Performance and Physical Collisions in Men Rugby Sevens. *Int J Sports Physiol Perform* 2014; **9**:316-323

25 Takahashi I, Umeda T, Mashiko T, Chinda D, Oyama T, Sugawara K, and Nakaji S. Effects of rugby sevens matches on human neutrophil-related non-specific immunity. *Brit J Sports Med* 2007; **41**:13-18

26 Tan D, Dawson B, and Peeling P. Hemolytic Effects of a Football-specific Training Session in Elite Female Players. *Int J Sports Physiol Perform* 2012; **7**: 271-276

27 Tiidus PM. Estrogen and gender effects on muscle damage, inflammation, and oxidative stress. *Can J Applied Physiol* 2000; **25**:274-287

28 Vincent H and Vincent K. The effect of training status on the serum creatine kinase response, soreness and muscle function following resistance exercise. *Int J Sports Med* 1997; **28**:431-437

COMMENTARY

James McGarvey

This study takes a solid if simple design and applies it capably. However the sample size is very small (22 athletes over a single event) and this means all correlations derived from this study are questionable.

If the results are taken at face value the next issue faced by clinicians reading the paper is how this changes clinical practice. The lack of change of creatinine related to a sevens tournament could be useful knowledge. The changes seen in other blood parameters however do not really allow any more accurate prescription of recovery, training load or game play. Activity causes inflammation and haemolysis, we know this, and the individual variation in blood parameter responses means that in my opinion blood testing does not add to simple clinical assessment of where an athlete is at physically. Possibly creating a 'biological passport' type system where each individual's blood response was monitored over multiple exercise events could be more useful. This would then give individual baseline data, which might be accurate enough to more readily interpret subsequent results. However this would be laborious, invasive and have no guarantees.

In general I think it is counterproductive to add any fuel to the obsession of some athletes and management members with blood tests as a gold standard measure for a healthy athletes condition.

I think a combination of GPS and clinical assessment will continue to have more accuracy for measuring and monitoring physical load.

AUTHORS' RESPONSE

Although the sample size of this study was modest the substantial effects of elevations in haemolysis and muscle damage are noteworthy in exploring the demands of women's rugby sevens. The observed correlations can be interpreted in light of the confidence limits which indicate the likely (true) range of the mean effect in the population. Clearly routine testing of blood parameters only yields limited results, and more importantly the outcomes here are for the benefit of clinicians, strength and conditioning specialists, and recovery staff, who work directly with players during and after football games and tournaments.

Beware the "Benign" Bump

THOMAS MARKS

INTRODUCTION

Pseudoaneurysm of the superficial temporal artery is an unusual but not uncommon sequelae of blunt trauma to the forehead. It can be iatrogenic but is more commonly encountered during contact or collision sports. This case report details the diagnosis in a young soccer player, its investigation and management.

CASE REPORT

A 21 year old soccer player presented with a small (~1cm) lump on the left side of his forehead. He had been elbowed in the forehead whilst playing soccer 6 or 7 days prior to presentation. On the evening of the impact, he noticed a small firm swelling in the area. The lump had persisted, was mildly sore and was causing cosmetic inconvenience. The player suffered no other sequelae of the head injury. He was otherwise fit and well with no regular medications, allergies or significant medical history.

Figure 1 – pulsatile swelling associated with the superficial temporal artery

Examination revealed a well-circumscribed lump approximately 1 cm in diameter, located in the left anterior temporal area (figure 1). It was firm to touch, mobile under the skin and minimally tender. No pulsation was noted, and there was no discolouration. Differential diagnoses at this point included simple cyst, a sebaceous cyst or fat necrosis .

Clinician and patient agreed to manage the lump expectantly and if it had not resolved in one month to have a further review. At this initial consult it was felt that if it had not resolved, aspiration and the injection of a small amount of steroid may be an appropriate treatment option.

One month later the athlete returned without a significant change in appearance. The lump had not been painful but continued to be unsightly. As a management plan had previously been discussed with the patient, some local anaesthetic was drawn up ready to be injected prior to aspiration of the contents of the lump. However, further examination of the lump prior to infiltration revealed a pulsation in the lump.

The intended aspiration was aborted, and the diagnosis of a traumatic false or pseudoaneurysm was made. The diagnosis was confirmed on ultrasound (figure 2).

The patient was duly referred to vascular outpatients where under local anaesthetic he underwent an uneventful ligation and excision of the offending pseudoaneurysm. He returned to sport shortly after, without concern.

DISCUSSION

False aneurysm of the superficial temporal artery is well described in the literature. Whilst it is usually acquired from trauma, it can also be iatrogenic.[2,3] A similar case in the literature involving soccer reported the swelling appearing two weeks after a blunt trauma during a match.[6] This is in contrast to this case where the swelling was noticed fairly instantaneously.

The diagnosis can be confirmed by ultrasonography and the treatment is surgical, involving proximal and distal ligation and resection.[1] Endovascular treatment might be an option in a small group of patients.[5] Kim et al[4] recently developed a treatment protocol for the treatment of these injuries depending on their time since appearance, with treatment options including surgical resection, thrombin injection and radiological intervention. However, small numbers involved allow limited definitive conclusions to be drawn.

This case highlights the importance of careful examination and review of any traumatic swelling.

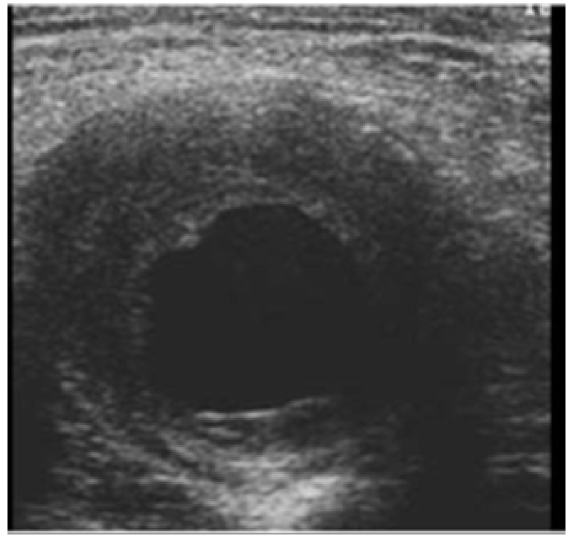


Figure 2 – ultrasonagraphic evidence of pseudoaneurysm

AUTHOR AFFILIATION

Thomas Marks BM, BSc(Hons) PGDipSportMed

General Practitioner/Sports Doctor

Auckland

REFERENCES

1 Chatelain B1, Meyer C, Vitte F, Ricbourg B. False aneurysm of the superficial temporal artery: report of two cases. Rev Stomatol Chir Maxillofac. 2009 Nov;110(5):299-302.

2 Dinner MI, Hartwell SW Jr, Magid AJ. Iatrogenic false aneurysm of the superficial temporal artery. Case report. Plast Reconstr Surg. 1977 Sep;60(3):457-60.

3 Giele H, Robbins P, Smith C. False aneurysm of the superficial temporal artery: a surgical complication. Ann Plast Surg. 1996 Feb;36(2):219-20.

4 Kim SW, Jong Kim E, Sung KY, Kim JT, Kim YH. Treatment protocol of traumatic pseudoaneurysm of the superficial temporal artery. J Craniofac Surg. 2013 Jan;24(1):295-8.

5 van Uden DJ1, Truijers M, Schipper EE, Zeebregts CJ, Reijnen MM. Superficial temporal artery aneurysm: Diagnosis and treatment options. Head Neck. 2013 Apr;35(4):608-14.

6 Wiendels DR1, Poelhekke LM. A man with a pulsatile temporal swelling. Ned Tijdschr Geneeskd. 2006 Sep 23;150(38):2085.

Take care of the steroid flare

BRUCE HAMILTON, MEGAN MUNRO, JAKE PEARSON, JORDAN SALESA, LOUISE JOHNSON, DANIEL EXETER, CHRIS MILNE

INTRODUCTION

For over 50 years, corticosteroid injections have been utilised in sports medicine to reduce inflammation in joints, bursae and around tendons.[1] Some authors have proposed that they are also beneficial in managing acute soft tissue injuries such as muscle strains, although this remains controversial.[2,3] While their efficacy in reducing inflammation is well recognised, corticosteroid injections are not without potential adverse-effects. Adverse effects may be defined as "an adverse event for which the causal relation between the intervention and the event is at least a reasonable possibility".[4] However, as a result of the heterogeneity of research into adverse outcomes, a recent systematic review of the adverse-effects of extra-articular corticosteroid injections was unable to establish the incidence of adverse outcomes, but did highlight a wide range of possible adverse outcomes. (Table 1). In addition to these relatively minor and frequent outcomes, severe allergic reactions, tendon rupture,[5] hyperglycaemia in diabetics and infections have been reported reported.[4,6,7]

Table 1: Minor adverse effects of corticosteroid injections (modified from[4,6])

Description	Frequency (%)
Post injection pain	3.4-81
Numbness in hand post CTS Injection	5%
Skin Discolouration	3-11%
Menstrual Disturbance	50%
Flushes	3-28%
Transient sympathetic reaction	2%
Bruising	1%
Skin Depigmentation	1-4%
Subcutaneous Atrophy	1.5 – 40%
Steroid Flare	30%
Cellulitis	4%

A delayed increase in pain following both intra and extra-articular corticosteroid injections, known as a steroid or cortisone flare, may occur in up to 30% of patients, but paradoxically is only rarely reported in the literature.[4,6] The following case highlights features of the post-injection steroid flare.

CASE REPORT

PC is an elite Paralympic swimmer who sustained an acute injury to her left shoulder while tumble turning, approximately 8 weeks prior to a major competition. Clinically, symptoms and signs were suggestive, but not conclusive for a gleno-humeral intra-articular aetiology. Relative rest, physiotherapy and non-steroidal anti-inflammatories (NSAIDs) had little initial impact. Imaging, including and MR Arthrogram of her shoulder was inconclusive, and therefore based on a clinical impression of an internal impingement and in an effort to advance her training status, a radiologically guided gleno-humeral injection of triamcinolone acetonide (40mg) was performed. The injection also included a "very small" amount of omnipaque 300 (to confirm the location) and ropivacaine 0.75% (2mls). Immediately post injection, her pain score moved marginally from 5/10 to 4/10. PC was fully informed of the goals, risks and benefits of the procedure and the infiltration and immediate post injection period was unremarkable. The Athlete was advised to have 4-5 days off swimming, and to have a clinical review prior to returning to training. As a result of this training down time, PC returned to her home town (at a distance from the treating practitioners) immediately post injection.

The day following the injection procedure, PC awoke feeling unwell, with "flu-like" symptoms, was nauseas and had a headache. She felt hot and had a bright red flush over her face, neck, left shoulder and chest. Her shoulder was extremely painful both at rest and with any movement. On contacting her treating Physician, she was immediately referred into her local General Practitioner for a clinical review. PC was afebrile, and was haemodynamically stable. She was diagnosed with a "post-steroid flare" and was prescribed an NSAID and paracetamol for the pain. PC spent a day in bed, with her "flu-like" symptoms, flushing and headache gradually resolving over 24 hours. Her flare of shoulder pain lasted for approximately 10 days.

Ultimately, the corticosteroid injection had little impact on her shoulder symptoms, and she continued to be treated with oral anti-inflammatories and physiotherapy, with symptoms and signs slowly but steadily improving enabling a graduated return to full training.

DISCUSSION

This case highlights an adverse effect of an intra-articular corticosteroid injection in an elite Paralympic swimmer. The delayed onset of increasing shoulder pain experienced in this case was typical of a "steroid flare", although the general malaise, and widespread skin flushing are rarely described in the literature in direct relation to a steroid flare.[4,6,7] While the adverse impact was ultimately of short duration, the outcome of the procedure may have been substantially different, had injection been performed in an immediate pre-competition period. A 2002 clinical guide, highlighted that corticosteroid injections should not be used without a clear diagnosis, and that physicians should resist the use of cortisone injections to expedite a return to play.[7] As this case illustrates, without a clear diagnosis, injected corticosteroids may be of little benefit, and that even with the best of intentions, adverse outcomes will occur.

A steroid flare typically begins 2-3 hours after an injection and is self-limiting, resolving after about 24 hours. It is thought to result from a crystal induced synovitis, caused by preservatives in the injectate. While there appears little clinical evidence, it is believed that the type and volume of corticosteroid injected may relate to the risk of a flare reaction, with short acting glucocorticoids and larger injectate volumes having greater risk (Table Three).[4] While not based on any available empirical evidence, reduction in the rate of flare reactions may be achieved by utilising a slow rate of injection, the

application of ice post injection, and the prophylactic prescription of non-steroidal anti-inflammatories.[4] A recent trial showed no benefit from utilising a buffer in the injectate in reducing the incidence of post injection flare.[4]

The possibility of post injection sepsis, or a reaction to another of the injection components, should always be considered. After excluding other potential causes of the symptoms, the treatment of the steroid flare is expectant, managing the synovitis with non-steroidal anti-inflammatories (oral prednisone is a consideration in severe cases), and simple analgesia for additional pain. Relative rest, intermittent ice to the affected area will assist in pain management.

PC continues to have shoulder pain related to swimming, which is being actively managed with Physiotherapy, strengthening, posture and stroke correction. While the injection appeared to have little immediate benefit and indeed appeared to delay the planned training progression, it is possible that the depot injection of corticosteroid (unrelated to the intra-articular location it was deposited) has had a sustained clinical benefit. The dramatic nature of this steroid flare raises concerns regarding any future use of corticosteroid injections in this athlete. Repeat corticosteroid injections in the future do not appear to be contra-indicated, but at the very least, repeat administration of the offending corticosteroid should be avoided.

Table 2: Duration of action and potency of commonly utilised corticosteroid injections

Corticosteroid	Duration of Action	Potency
Hydrocortisone	Short Acting	Low
Methylprednisolone	Intermediate	Intermediate
Dexamethasone	Long	High
Betamethasone	Long	High

REFERENCES

1 Bass A L, Rehabilitation After Soft Tissue Injury. *British Journal of Sports Medicine*, 1966: p. 162-172.

2 Levine W N, et al, Intramuscular Corticosteroid Injection for Hamstring Injuries: A 13-Year Experience in the National Football League. *American Journal of Sports Medicine*, 2000. **28**(3): p. 297-300.

3 Stevens K, et al, Imaging and Ultrasound-Guided Steriod Injection of Internal Oblique Muscle Strains in Baseball Pitchers. *American Journal of Sports Medicine*, 2010. **38**(3): p. 581-585.

4 Goldfarb C A, et al, Extra-Articular Steroid Injection: Early Patient Response adn the Incidence of Flare Reaction. *Journal of Hand Surgery*, 2007. **32A**: p. 1513-1520.

5 Hamilton B, et al, Achilles tendon rupture in an elite athlete following multiple injection therapies. *J Sci Med Sport*, 2007.

6 Brinks A, et al, Adverse effects of extra-articular corticosteroid injections: a systematic review. *BMC Musculoskelet Disorders*, 2010. **11**(206).

7 Cardone D A and A F Tallia, Joint and Soft Tissue Injection. *American Family Physician*. **66**(2): p. 283-288.

PATIENT INFORMATION SHEET - POST INJECTION STEROID FLARE

Background

Cortisone injections are frequently used in the management of musculoskeletal problems, as a means of reducing inflammation and pain. In the majority of cases, the injection is uncomplicated, but in some individuals, there may be unwanted side-effects. A transient increase in pain after a cortisone injection, known as a "steroid flare" may occur in up to 30% of patients.

When does it come on?

Pain may begin to increase after any local anaesthetic utilised has worn off, usually 1-4 hours after the injection.

What may happen?

There may be severe pain at the site of the injection. It may be worse than the pain arising from the condition being treated.

How long will it last?

The pain of a "steroid flare" will usually subside over 24 hours, but may on occasion last up to one week.

What causes it?

It is not entirely clear what causes this in some individuals, but it is thought to be due to elements in the cortisone "crystallising" in the tissue.

How is it treated?

The recommended treatment includes:

- Review with your Medical Practitioner to ensure there is no other consideration.
- Regular application of ice (15-20 minutes, every 1-2 hours) to the affected area. This is best performed with an ice pack, with a towel to protect the skin from ice burns.
- Anti-inflammatory medication (eg. Nurofen, Voltaren)
- These should be taken regularly until the pain subsides.
- SImple pain killers such as panadol may be used in addition to anti-inflammatory medication.
- Further medication may be recommended by your Medical Practitioner in severe situations.

Can it be Prevented in the Future?

Yes. If in the future you require a corticosteroid injection, you may be treated with a different form of corticosteroid, treated in advance with medication to reduce your chances of having a problem, and using ice in the immediate post injection period. You should ensure your Medical Practitioner is aware of your previous responses to corticosteroids.

What if the pain doesn't settle?

See your Medical Practitioner if your pain is progressing or not settling after 24 hours post injection.

Healthy Living

NAT ANGLEM

Scenario

- 44 year old overweight male (or female) presents to your clinic wanting "to get fit".
- Has had a poor lipid profile from his GP during a routine visit(but no other investigations), and was told he could get good advice here.
- Played rugby at school, but hasn't done any formal exercise since he was 25. Occasionally plays a game of social football. History of "grumbly knees" and occasional low back pain.
- No other known medical history.
- Family History of parents with IHD in fifties.
- Married with 2 kids aged 10 and 8.
- Works as a professional in a sedentary job.

In this example, we have a patient who has a desire to change the direction of his well-being. He has gone so far as to make and attend an appointment with someone who is outside his primary healthcare team. This is a positive indication of his level of motivation to address his issues.

Before assessing the patient in any way, there is some basic information that needs to be collected in the waiting room. This includes collecting the patient's ethnicity (this then needs to be confirmed with the patient during the consultation), and getting an agreement to share information with his GP.

Ethnicity data is important in all medical environments because of ethnic health discrepancies which can only be successfully addressed when the ethnicity is correctly recorded. Maori patients in particular suffer poor health outcomes in New Zealand and it is important that we as medical practitioners assess how we can be a part of the solution rather than part of the problem. According to my understanding of New Zealand literature poor outcomes include both injury and cardiovascular statistics, so this is doubly relevant in this example.

A starting point for this sort of consultation might be to understand the motivation. The patient presents wanting to get 'fit'. In his opinion, what is "fit", or "fit for what?" Remembering that fitness is discipline specific, and you get fitter at what you do, and not at what you don't do. Sometimes "fit" is a euphemism for wanting to lose weight. It might also be a euphemism for not dying from cardiovascular disease in the next decade. Irrespective of what the motivation is, it is a good marker of the belief system of the patient and can be explored quite extensively to understand how the patient could enhance their life experience. Understanding the motivations, and why the patient is presenting now, is a key part of the first consultation. Having identified the patient's objective, and ideally the motivation, fears and beliefs behind that motivation, I would tend to look at what currently exists in the patient's world. I use the following headings to understand the context for the patient and their presentation: Exercise, Work, Financial pressures, Family, Relationships, Injury/Medical needs. These first six relate to elements that require energy and attention. However, the following elements may loosely be described as what nourishes the patient: sleep, rest, nutrition, psychology/thoughts, spirituality. Going through these categories individually with the patient identifies what is normal for the patient, and what the current situation is. The patient will quickly see how inter-related they are; for example injury or knee pain may reduce the exercise capacity, reduction in exercise means for some people the loss of an effective stress management (psychology) pathway, which subsequently results in an increase in a perception of stress which may come from home or work life. Not finding relief of stress can affect sleep, which leads to tiredness and malaise, "comfort eating" or "boredom" which can result in weight gain. Weight gain in the context of injury will further reduce fitness and will often appear like a Catch-22. Advice to exercise to lose weight in this context would be counter-productive unless it addresses the specific context. Hence, any solution must interrupt the above negative cycle for the body to 'heal' or find 'health'.

Once the practitioner has an understanding of how things inter-relate for the individual, it will be easier to create a plan that addresses the patient's reality. In my view it is also critical to understand when in the patients life did major life changes occur. Most major health changes are tied into significant life events. For example, people's weight changes when they get bullied, get depressed, lose loved ones, get stressed and overworked. Heart attacks occur when there are earthquakes, family upsets, career changes. Drawing a time line for this patient might help with the understanding of what changed for him from the ages of 25 to 44 years, and what some of the factors are that have affected his well-being over that time.

With this sort of approach, it is possible to target the two or three areas that need the most attention for now. For the above patient, it might be finding a way to combine regular and appropriate exercise with time spent with his two children. He might identify the stressful thoughts which are affecting his sleep and make a plan to address those issues. He might identify gaps in his nutrition knowledge or he might identify risky times when despite good understanding he makes a choice to eat food with little nourishment.

There is some further information which is needed in this case and it includes some of the specific medical tests which would be accepted as normal in this presentation. Such things as heart rate and rhythm, blood pressure, blood glucose level, renal function tests in addition to the cholesterol levels already taken can be used to stratify cardiovascular risk in someone undertaking exercise. The "knowyournumbers.co.nz" website can be a useful tool for the patient to understand some of these risks.

Having now identified the patients objective and motivation, the reasons behind that objective and the context for the difficulties, and having formulated a clear plan that identifies what steps might be taken, a plan for monitoring is needed. Medically, that monitoring is very important, but it is important that the monitoring relates to the objectives that have been set, not just measuring what we can measure. If the objective is to spend time with the kids in a sporting and active environment, to relieve stress, get fitter with regard to playing touch rugby next season, and setting a good example of healthy living to members of the family, then using body weight as a marker of progress is not necessarily helpful.

Ultimately it must be the patient who decides what their intervention needs to be to fit their needs, but only after they have a clear understanding of what stands between them and well-being.

AUTHOR AFFILIATION

Nat Anglem

Sports Physician, Christchurch

MATT WOOD, NIGEL HARRIS

That the patient has presented to the clinic / facility / professional and requested at least a start on personalised advice for an ongoing plan is fundamental to a potential positive outcome. That is, the general practitioner (GP) or sports doctor/physician has identified a number of lifestyle considerations and cardiovascular risk factors and, we assume, referred to or at least recommended the patient seeks ongoing advice. It represents an ideal scenario for a multidisciplinary approach whereby the medical practitioner and physiotherapist liaise with the clinical exercise physiologist and registered exercise professional for an orchestrated sequential plan. The following treatment is based on the clinical exercise physiologist's and registered exercise professional's approach.

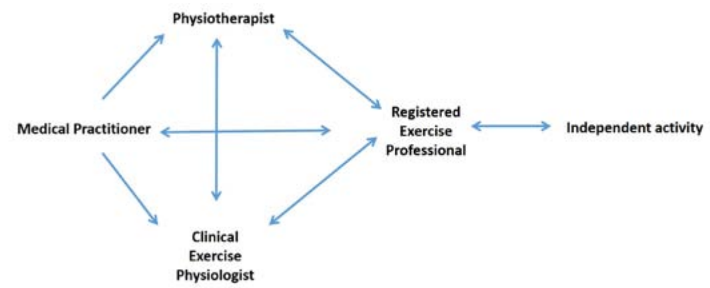
As a first step, we would conduct a pre-screen interview. The pre-screen would take the form of the NZ Registered Exercise Professional (NZ REPs) Pre-Exercise Screen,[1] which has a risk stratification component based on accepted international models such as of the American College of Sports Medicine. The screening would identify a risk stratification of at least four factors (overweight, sedentary, lipids and family history ischaemic heart disease) hence we would request clearance from the medical practitioner and further evaluation prior to ensuing prescription beyond low intensity activity. We would also refer to a physiotherapist for diagnosis, indications and contraindications regarding the previously identified knee and back issues. It would be expected that some ongoing treatment from the physiotherapist would be integral to the initial stages of any plan so the structured exercise would be in context to physiotherapy treatment and recommendations.

Having liaised with the medical practitioner and physiotherapist, we would then discuss in detail with the patient their goals (and attempt as part of that process to unravel motivating factors), history of activity and any structured exercise, and situation with regards to willingness and ability to access ongoing support. That is, having presented to us after a prompt, are they wanting and expecting ongoing advice and more detailed personalised prescription, or a general plan to then conduct independently? We agree completely with Dr Anglem's approach regarding the importance of identifying and addressing behavioural beliefs including any history of issues that interfere with behavioural change and perceived barriers. We would include as part of that a discussion on the importance of cardiovascular fitness above a focus on weight loss and as the single greatest modifiable risk factor for CVD related and all-cause mortality,[2] and the importance of lean muscle mass and associated strength levels in order to attenuate otherwise inevitable sarcopenic dynapenia (ie. age related muscle and strength loss).[3] Assuming the patient is willing and able to engage our services, we would then embark on a sequential plan outlined below.

Baseline measurements (dependent on situation and resources):

Blood pressure, height, weight, waist circumference (waist and waist-to-height ratio), joint ROM. Individualised cardiopulmonary exercise assessment using respiratory gas-exchange equipment to measure O_2 consumption and CO_2 production for accurate measurement of, and tracking change in cardiorespiratory fitness, monitoring physiological and psychological responses to exercise, and prescription of appropriate exercise intensities. Alternatively, a sub-maximal indirect assessment using heart rate and exertion responses if resources are limited.

Exercise options:



First, increased general physical activity options and awareness of decreasing sedentary activity. Perhaps a standing desk at work, walks with family and/or pets, activity breaks at work, awareness of screen time. Encourage anything that increases general activity levels as part of daily life, particularly where an identified level of engagement of enjoyment is identified. Football would be encouraged subject to the knee condition.

Structured exercise via a progressive individualised exercise programme. Ideally in a small group setting initially, then with supervision tapering as exercise independence increases. Monitored exercise in a controlled environment allows us to address any physical or psychological concerns, provide education and practice self-monitoring before transition of exercise behaviour to a less-supervised environment.

Programme structure:

Thirty minute combined progressive interval training/resistance programme 3 x week for 10-12 weeks, then 2 x week thereafter. Advantages of this type of programme include time efficiency, conserving the knee, and adherence. Ongoing re-assessment of general strength levels and aerobic capacity would be implicit with the programming.

After a more detailed programming and monitoring period subject to progress, we would then liaise with a NZ registered exercise professional towards ongoing semi-structured exercise programming and monitoring. Specific indications and contraindications would be directly communicated.

In summary, we see the general flow for this as per the schematic below, centred on the patient / client / person. The patient may not have access to a clinical exercise physiologist in which case the process would be ostensibly the same but the referral network would occur directly between the medical practitioner, physiotherapist and registered exercise professional. Nevertheless, it is preferable to engage a clinical exercise physiologist, particularly for moderate to high-risk individuals looking to engage in exercise above moderate intensity and/or those requiring more elaborate monitoring, education, behavioural and psychosocial support.

AUTHOR AFFILIATIONS

Matt Wood

Lecturer, School of Sport and Recreation

Manager Human Potential Centre

AUT University

Nigel Harris PhD

Senior Lecturer in Exercise Science

AUT University

REFERENCES

1. A link to the guide may be found at **www.reps.org.nz/prescreenguide**
2. Blair S N, Physical inactivity: the biggest public health problem of the 21st century. *British Journal of Sports Medicine* 2009; **43**(1):1-2.
3. Mitchell W K, Atherton P J, Williams J, Larvin M, Lund J N, Narici M. Sarcopenia, dynapenia and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. *Frontiers in Physiology* 2012; **3**(260): 1-18 .

Athletes with a spinal cord injury: Musculoskeletal issues and remedies

MEGAN MUNRO, JUSTIN RALPH, JAKE PEARSON

True / False:

1. Spinal Cord Injury (SCI) wheelchair using athletes report higher rates of shoulder pain than non-athlete wheelchair users.
2. Para-cycling athletes with a SCI are more likely to sustain upper limb injuries than non-athletes who use wheelchairs.
3. The musculoskeletal assessment of an athlete with a spinal cord injury is different to that of an able-bodied athlete.

The previous article in this series covered the key medical issues for athletes with a SCI. This article will discuss some of the musculoskeletal issues that need to be considered in an athlete with a SCI, with a particular emphasis on swimming and cycling athletes.

The shoulder tends to function as a weight bearing joint for wheelchair propulsion and transferring - a role for which it is not anatomically designed. As a result, the shoulder is the most commonly injured body part in the overall wheelchair SCI population with a reported incidence of 30 to 73%,[3,7] and athletes are no exception to this. For example, a study of female wheelchair basketball players found that shoulder and upper extremity pain was reported by over 90% of the subjects interviewed.[4] Interestingly however, some studies have reported that non-athlete wheelchair users may actually be at a higher risk of shoulder pain, due to lower levels of physical conditioning.[5] Constant use of the shoulder for propulsion and transferring results in exposure to both higher intra-articular pressures and the abnormal distribution of forces across the subacromial space.[6]

The prevalence of shoulder pain in able-bodied swimmers is well documented in the literature and reported to be as high as 91%.[8] Coupling continuous manual wheelchair propulsion with the demands that swimming places on the shoulders, results in an increased risk of rotator cuff pathology, impingement, and stress across the AC joint and distal clavicle. Even if an athlete has an incomplete SCI and does have some kicking ability in the water, the arms remain the dominant propulsive force.

As a result, SCI athletes who swim tend to have excessively dominant shoulder abductors and relatively weak external rotators. Scapulothoracic stabilisers may be weak due to the sitting and propelling posture in the wheelchair (as well as potential neurological compromise depending on the level of spinal cord lesion). Complete rest of the shoulders is not really an option for this athletic population, but physiotherapy can minimise muscle imbalance issues of the glenohumeral joint and improve both scapulothoracic stabilisers and thoracic mobility. Care must be taken when an athlete transfers on and off a plinth as depending on the level of lesion the athlete will have reduced sitting balance and core muscle activation. With a lesion of T6 and below, the therapist should expect some compromise of trunk stability. SCI athletes should have a well-considered strength and conditioning dry land programme, and complete specific movement preparation and mobility exercises to perform prior to warming up in the pool. Examples of these are active seated thoracic rotation stretches, thoracic extension stretches over a foam roller, active shoulder range of movement stretches, theraband resisted exercises for the rotator cuff, latissimus dorsi, serratus anterior and rhomboids and prone holds and side plank holds for abdominal activation. The main aim of the dry land program is to minimise the injury risk to the shoulders. In swimming, training loads in the pool and the gym need to be closely monitored by coaching and support staff, and altered when needed. If a particular stroke such as freestyle is aggravating the shoulders back stoke may be pain free due to the differences in the mechanical forces produced on the shoulders (freestyle pull-through phase requires the scapula to be protracted while the humerus is adducted, extended and internally rotated whereas back stoke pull-through phase requires scapular retraction, with humeral horizontal abduction and external rotation at hand entry) and may be a good alternative to still allow the athlete to train If training in the pool is compromised, avoiding heavy resistance or explosive work in the gym may also be necessary.

Swimmers with a SCI are eligible to swim all four strokes – freestyle, back stroke, breast stroke and butterfly. They are assessed on their muscle power on dry land and their functional ability in the pool. If they have full power in their arms and trunk, they will have a higher classification status. Swimmers with a complete SCI are unlikely to swim breast stroke due to the legs being the main propelling force in this stroke. Swimmers with an incomplete SCI lesion should be able to get some propulsive force from the legs. Starts, turns and finishes can all be altered depending on an athlete's functional ability and is assessed and recorded as part of their classification status. An example of this would be using the assistance of a support staff member whilst on the diving blocks for balance or only having to 'show intent' to touch the wall with two hands on a breast stroke finish.

Para-cycling is a sport in which athletes with a SCI compete on a recumbent handcycle using their upper limbs to power the bike and, depending on the SCI level, their trunk to help them stabilise. Unfortunately, studies reporting the incidence of injuries specifically in handcycling athletes are currently non-existent. However, studies have suggested that shoulder joint forces generated during handcycling are less than in hand-rim propelled wheelchairs.[1,2] Hence, from a rehabilitation perspective handcycling has been recommended as a good alternative to handrim propelled wheelchairs. However, since elite handcyclists produce a significantly higher amount of power at significantly higher cadences (up to 125 revolutions per minute) for sustained periods of time, they would seem at risk for overuse injuries of the upper limb and shoulder joint in particular. Shoulder load is also affected unilaterally in those handcyclists who have a scoliosis related to altered trunk muscle function depending on their level of injury. The handcyclist's posture can therefore mean that one shoulder is further from the pedal than the other, increasing the strain on that side.

Photo credit; Katrina Robinson Photography

To help minimise these injuries, athletes are set up on their handcycle in such a way that both full elbow extension and flexion are avoided, thereby helping maintain a stable position of the shoulder. Handcycles are complex, and seat position, crank length and crank width can all be modified to help attain an optimal position on the handcycle.

In the musculoskeletal assessment of a SCI athlete a significant emphasis must be placed on the subjective assessment, gaining an understanding of the athlete's functional capacity associated with the level of their SCI. The level of spinal cord injury will determine which muscles are expected to function and therefore where the assessment should be focused. It is important to determine a testing position, most commonly in supine or seated. Athletes are likely to compensate with certain movements and special care should be taken to place them in the correct position to isolate the desired muscles or movements. Following specific musculoskeletal assessment a functional component is carried out (this is also the way athletes are classified for competition). For example, an athlete with a lower thoracic SCI will retain some dynamic trunk stability, reducing the risk of shoulder injury, whereas an athlete with a higher level spinal cord injury will be more at risk due to loss of trunk stability.

Following a musculoskeletal assessment an appropriate exercise programme will likely include components of rotator cuff, scapulothoracic and trunk stability exercises, depending on the level of SCI and what specific issues the assessment has highlighted. The primary aim of this intervention is to prevent overuse injuries in the upper limb. Working closely with SCI athletes allows the identification of their functional ability and capacity, and helps guide specific training volumes and intensity, and any rehabilitation required, to minimise the risk of injury in this group of athletes who challenge their bodies on a daily basis.

AUTHOR AFFILIATIONS

Megan Munro

Lead Physiotherapist Paralympics NZ Swimming and Shooting, Tauranga

Justin Ralph

Lead Physiotherapist Paralympics NZ Bike, Hamilton

Jake Pearson

Paralympics NZ Medical Director, Sports Physician, Wellington

REFERENCES

1 Arnet U, van Drongelen S, van der Woude, L H, Veeger D H. Shoulder load during handcycling at different incline and speed conditions. *Clinical Biomech (Bristol, Avon)* 2012 Jan; **27**(1):1-6. doi: 10.1016/j.clinbiomech.2011.07.002.

2 Arnet U, van Drongelen S, Scheel-Sailer A, van der Woude L H, Veeger D H. Shoulder load during synchronous handcycling and handrim wheelchair propulsion in persons with paraplegia. *J Rehabil Med* 2012 Mar; **44**(3):222-8. doi: 10.2340/16501977-0929.

3 Ballinger D A, Rintala D H, and Hart K A. The relation of shoulder pain and range-of-motion problems to functional limitations, disability, and perceived health of men with spinal cord injury: a multifaceted longitudinal study. *Arch Phys Med Rehabil* 2000; **81**:1575–1581

4 Curtis K A & Black K, Shoulder pain in female wheelchair basketball players. *J Orthop Sports Phys Ther* 1999; **29**(4):225-31.

5 Fullerton H D, Borckardt J J, Alfano A P, Shoulder Pain: a comparison of wheelchair athletes and nonathletic wheelchair users. *Med Sci Sports Exerc* 2003; **35**(12):1958-1961

6 Klenck C and Gebke K, Common Problems in Disabled Athletes. *Clin J Sport Med Volume*, 2007; **17**(1):55-60.

7 Pentland W E and Twomey L T, The weight-bearing upper extremity in women with long term paraplegia. *Paraplegia* 1991; **29**: 521–530

8 Sein M L, Walton J, Linklater J, Appleyard R. Kirkbride B. Kuah D. Murrell G. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sports Med* 2010; **44**:105–113.

Freeski and snowboard: Park and pipe injury rates, patterns and prevention
A New Zealand/USA perspective

GINNY RUTLEDGE

As part of a Prime Ministers Scholarship, I recently attended both the ACSM in San Diego and visited the USSA Centre of Excellence (COE) training centre in Utah. The USSA COE is the equivalent of the HPSNZ national training centre for USA Winter Sports. This was an opportunity to explore and compare injury rates, patterns and prevention strategies across the NZ and US park and pipe programmes, and this report captures that comparison.

Background to Park and Pipe: The Evolution of an Olympic Sport

While snowboard halfpipe was first seen in the Nagano Olympic Games in 1998, it was not until 2011 that freeski (FS) halfpipe as well as freeski and snowboard (SB) slopestyle was added to the Olympic programme. Sochi 2014 was the showcase for these sports on the Olympic stage.

As a result of this being a new Olympic sport, in 2011 there was notable variation in strength and conditioning backgrounds of many of the athletes competing in these events, with a number having only a limited training period prior to inclusion into the NZ team.

For example, in 2012 USSA compared the relative strength of this new group of limited training age athletes against mogul skiers who have similar sport demands. The strength ratios of the free ski women (2.18 x Kg/BW) were found to be well below that of the mogul skiers (2.7 x kg/BW) (Figure 1).

Prior to 2014, both the USA and NZ were faced with the challenge of developing strength and neuromuscular control, as well as safe landing patterns, teaching training, recovery and competition strategies in a relatively short timeframe leading into the Olympic competition.

Injuries in Freeski and Snowboard

Injury data capturing information collected around the time of injury may help direct staff toward the greatest area of modifiable risk. This data includes weather and snow conditions, injury mechanisms, physical conditioning, fatigue and other factors. Both NZ and USA have aligned this with International Federation of Ski who have an existing injury surveillance system that cover world cup events.

In the 2014 New Zealand park and pipe programme, 13 funded athletes suffered a total of 25 injuries that required time off snow. Our total time loss to injury for the year was a staggering 680 days with the average days lost being 27.2 days per athlete. Fifty per cent of all reported injuries occurred in general training, with 25 % occurring in competition training or during competition.

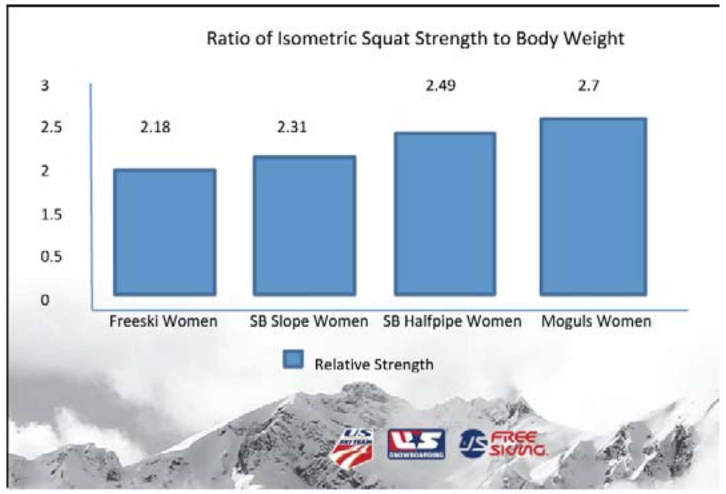


Figure 1: USSA data on Isometric Squat and Body weight. Reproduced with permission of USSA Ski and Snowboard Association

USA, with a larger group of (freeski) athletes (27) reported 3800 days' time loss to injury from September 2013 to April 2015. This equates to a staggering 10 years of injury time loss over a two year period.

As NZ has only a small pool of carded athletes (13) our current data can be used as a snapshot only with two major injuries; one season ending and one career ending significantly influencing our data.

Thirty-six per cent of injuries to the NZ team in 2014 were knee injuries, however the percentage of total lost days attributed to knees was 57%. The average days off snow for a knee injury being 43 days.

If we compare this to FIS (International Federation de Ski) ski and snowboard athletes competing in world cup,[2] 44 % of injuries occurred to the knee. This is lower than is reported in alpine whereby at world cup level 68% of all injuries are reported as knee injuries.[2]

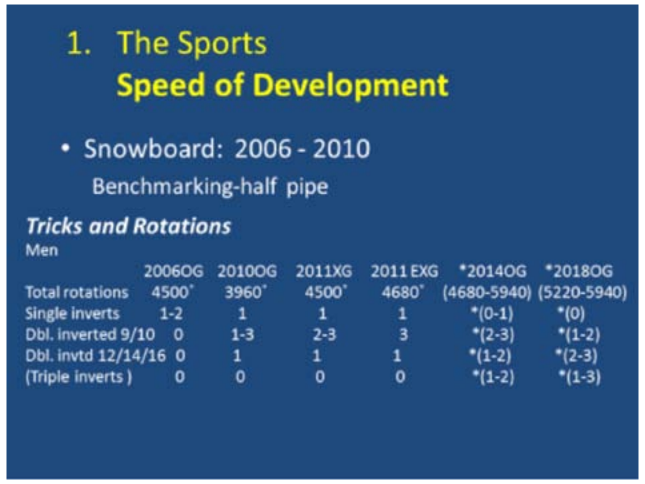
Prior to the 2014 winter Olympics, 3 out of 13 New Zealand team freeski and snowboard athletes had suffered an anterior cruciate ligament (ACL) injury with one athlete having also sustained a recurrent ACL injury. Subsequent to Sochi another of this same group ruptured an ACL making a total of 5/13 ACLRs in this small group. USA report similar eye-opening statistics.

With the 2011 decision to include freeski into the Olympics in 2014, there was a jump in the total number of ACL injuries in the 2012 season. In USA, 9 out of 20 freeski athletes (45%) experienced season ending injuries with the majority of these being ACL injuries.

Where do freeski park and pipe ACL accidents occur?

Currently, there is limited research into mechanisms of park and pipe freeski and snowboard ACL injury. However USA surveyed athletes post ACL injury and reported that the majority of accidents unsurprisingly occurred during landing from an aerial trick. The three most common landing positions that resulted in (ACL) knee injuries include landing in the back seat (or on the tails of the skis), coming up short on landings (thereby landing on a flat surface) and finally overshooting a jump and landing beyond the "sweet spot". Less common was landing on the deck of the half pipe or landing flat in the half pipe.

By comparison with freeski, alpine ski racing has recently been intensively studied, with three distinct ACL injury mechanisms being described by Bere et al.[2] 20 cases of ACL injury reported through the International Ski Federation Injury Surveillance System for 3 consecutive world cup seasons (2006-2009) were obtained on video. Video footage was then reviewed in an effort to more clearly understand the loading mechanisms that may cause injury.



	2006OG	2010OG	2011XG	2011 EXG	*2014OG	*2018OG
Total rotations	4500˚	3960˚	4500˚	4680˚	(4680-5940)	(5220-5940)
Single inverts	1-2	1	1	1	*(0-1)	*(0)
Dbl. inverted 9/10	0	1-3	2-3	3	*(2-3)	*(1-2)
Dbl. invtd 12/14/16	0	1	1	1	*(1-2)	*(2-3)
(Triple inverts)	0	0	0	0	*(1-2)	*(1-3)

Figure 2: Benchmarking tricks and rotations: 2006 to 2010 in Men's Snowboard half Pipe with predictions leading up to 2018. (Reproduced

In alpine skiing, 50 per cent of ACL injuries occurred via a mechanism referred to as the "slip catch", described as occurring during a turn before or without falling. The racer loses the pressure on the outside ski and while extending the knee to regain grip the inside edge of the downhill ski catches abruptly forcing the knee into internal rotation and valgus causing injury.

A second mechanism described is referred to as "back weighted" which can be explained by a skier landing on the tails of the ski with near straight or extended knees. This may occur if a skier is out of balance backwards over a jump. While still unclear, the loading mechanism may be a boot induced anterior draw or a quadriceps anterior draw as part of a recovery mechanism as the skier attempts to recover from the back seat position. The third mechanism described is the 'dynamic snowplough'. The skier is out of balance backward and inwards and at the time of injury the skier is in a deep dynamic snowplough. The injuring knee rolls from the outside to the inside edge catching in the snow thereby forcing the knee into internal rotation and valgus. This is similar to that described in the slip/catch mechanism.[2]

Confounding Variables in Skiing Injuries

Confounding variables which may play a part in injury causation in free skiing injuries, include course conditions, visibility and weather. It is important that we keep a good database around these factors, but it may not play as important a part as we think. Specifically, it may be that athletes modify their tricks to adjust to the conditions; this was the case in difficult slow and wet course conditions in Olympic halfpipe final where amplitude could not be gained. Athletes were not able to show their winning runs and trick level was modified potentially mitigating potential injury.

Judging

An important factor relating to injury prevention may lie in the breakdown of points. When more points are awarded for the highest degree of trick difficulty with less focus on style, it fosters a term called "spin to win". Style in this context would include trick mastery with focus on control in the air and with safe and controlled landings. The focus may need to be on this rather than the difficulty of tricks encouraging athletes to progress within their skill capability.

Development of Snowboard and Freeski

The rate of progression of tricks within the sport is extraordinary. In snowboarding in 2010 double corks-1080s (combination of flips and spins equalling three rotations) were the highest tricks achieved. If we move to 2015, triples, 1620s are being performed with a phenomenal 4.5 rotations. In 2015 a Great Britain slopestyle snowboard athlete has completed the first quad cork (four aerial rotations) setting the benchmark higher again (Figure 2).

Freeski has had a similarly fast progression progressing to triples with complicated spin direction and changes in axis as well as technical grabs.

Increasing amplitude (vertical height measured from the lip of the pipe) is required

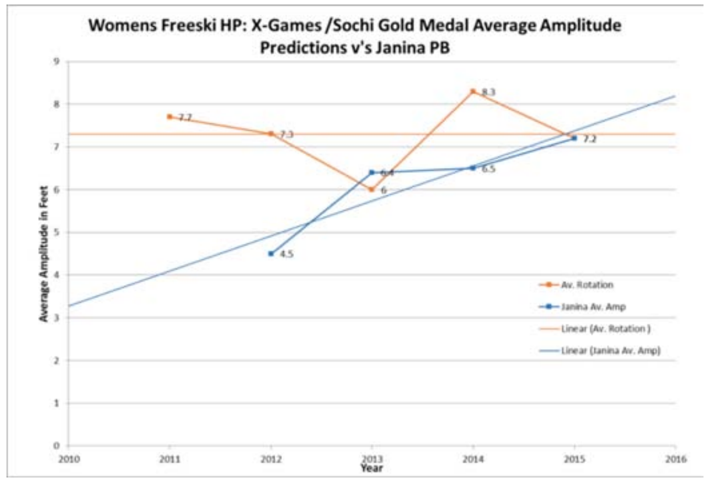


Figure 3: Progression of Amplitude in Half pipe freeskiing: Olympics and NZ Athlete example. Reproduced with permission of Snow Sports New Zealand.

to deliver increasingly more challenging number of rotations or inverts. Figure 3 illustrates the gradual increase in amplitude demonstrated by a NZ free ski half pipe athlete as compared to the Sochi gold medallist between 2012 and 2015. The NZ athlete demonstrates an increase in amplitude of 4.5 feet to 7.2 feet during that period.

Baseline Testing and Return to Snow following ACL Injury

The current SSNZ return to snow criteria following an ACL injury, includes successful completion of the lower limb range of motion (ROM), thigh girth, strength measures (isometric mid-thigh pull and handheld dynamometry), balance testing (Y Balance test), International Knee Documentation

Committee (IKDC) subjective knee assessment score/ psychological readiness (0-100), hop for distance and single leg hops.

Importance is placed on quality of movement, landing patterns and neuromuscular control. To date NZ has assessed neuromuscular control using box drop vertical jump (BDVJ) test. However a current goal is to introduce a more demanding, and therefore sensitive and/or predictive tool, such as a box drop vertical jump with a lateral component. Tim Hewitt's research team (Cincinnati ACL research group) is currently validating this assessment tool and USSA have introduced it into both their preseason baseline and return to snow testing. There is a need for a more challenging assessment tool like this since the quality of the landing pattern is of critical importance.

Following injury, our goal is to return athletes to the snow 10% stronger and more powerful utilising the injury as a window of opportunity to correct symmetry and enhance neuromuscular control. We acknowledge that no-one is clear what factors will directly affect ACL injury reduction on the snow for freeski. However, we anticipate that strength, power and symmetry are likely to help.

Given that most of our knee injuries are ACL ruptures (with or without chondral, meniscal and MCL injuries) in young athletes who continue to compete, we are conservative with our return to snow. This is return to snow plan with a 6 week lead in to competition – we would like to allow an even longer time frame as this would be even more appropriate, however, there is the normal pressures of obligations and external modifying factors (money, key selection and pinnacle events etc) We are mindful of Tim Hewitt's presentation at the recent ACSM conference highlighting the high re-injury rate seen in younger athletes participating in jumping and change of direction sports with the re-rupture rate highest in the first two years post ACL reconstruction. Highlighting this, the USA ski team report that 45% of the athletes who had an ACL reconstruction in 2011 have since re-ruptured.

Hewitt and colleagues would like to see a minimum of one year and preferably two years to return to the snow (especially in female athletes) following ACL reconstruction.

While prevention applies to everyone, our attention is focused on modifiable risk factors – particularly in the female free ski group as they continue to be the group with the highest injury rate. Prevention involves working with coaches and athletes regarding the risks involved in progressing athletes who are weak and with poor control. Ensuring there is a compulsory periodised window of gym time prior to and post both the domestic and northern hemisphere seasons. Having coaches lead ACL focused warm up programmes is a new and key strategy for 2015.

Where to from here?

We are aware that unlike many mainstream sports, halfpipe and slopestyle do not have current methods of objectively monitoring on snow training. There is a need to identify and analyse key performance indicators such as the number and nature of landing impacts, time on snow, trick identification and difficulty index, calculating session load or intensity, and tracking progression against set goals and performances. SSNZ is currently in partnership with HPSNZ and Otago University to develop these measures to improve our knowledge and to test our assumptions.

AUTHOR AFFILIATION

Ginny Rutledge

Snow Sports NZ Physiotherapy Lead

HIgh Performance Sport New Zealand

REFERENCES

1. Bower G. Head Team Physical Therapist USSA. Centre of Excellence Park City USA (personnel communications) 2015.
2. Bere T, Florenes T,Krosshaug T, Mechanisms of Anterior Cruciate Ligament Injury in World Cup Alpine Skiing. A systematic video Analysis of 20 cases. *AJSM* 2011; **39**(7):1421-1428
3. Florenes T, Nordsletten L, & Bahr R, Injures among World Cup Ski and snowboard athletes. *Scandinavian Journal of medicine and Science in Sports* 2012; **22**(1). 58-66.
4. Florenes T, Nordsletten L, & Bahr R, Recording injuries among World Cup Skiers and snowboarders a methodological study. *Scand J Med Sci* 2009; doi: 10.1111/j.1600-0838.2009.01048.x
5. Hewitt, T. Assessing Risk in Return to Sport Following ACLR in the Adolescents Athlete. ACSM, San Diego, Clinical presentation, 2015

Bike Fit Myths

Reflections from the 2015 Medicine of Cycling Conference

MARK HARRIS

Alongside the increased popularity of cycling there has been a surge in the services offered to cyclists including custom bike fit. For anybody who has worked with cyclists or athletes that use cycling as a training modality you will know how important bike fit is for reducing injury risk and for comfort of the rider. There is however a lack of consensus in all aspects of bike fit and many myths that still pervade the bike fit world. Compounding this is a lack of up to date good quality research to inform current practice. These are some of the reasons that the Medicine of Cycling (MOC) group was formed and a subgroup tasked with looking at improving the standards and delivery of bike fit. MOC has now published a Bike Fit Consensus Statement (Medicine of Cycling, 2013) as a starting point to help address some of these issues. MOC runs an annual conference and in 2015 had a Bike Fit stream alongside the main conference. This was designed as another forum to build consensus, understanding and present literature related to Bike Fit. The following is a summary of some of the highlights from this section of the conference.

Steve Carre, Master Specialised Bike Fitter, presented on the area of 'Saddle Fit and Selection'. The key messages to take away from this session were to consider other aspects of the bike, body, and clothing that can contribute to comfort on the saddle. Identify anatomical and individual needs of the cyclist; for example, the difference between male and female athletes. Realise that the time trial position is very different to the normal road bike position and therefore requires different saddle considerations. Overall the key goal with saddle selection is to facilitate the pelvic bridge to allow pressure to be taken by the skeleton rather than the soft tissue.

John McDaniel's presentation on 'Myths and Science of Cycling' was arguably the best evidence informed presentation of the conference. He presented on four specific themes: pedalling rate, crank length, pedalling technique and non-round chain rings. For pedalling rate, the main messages were for non-elite cyclists pedalling rates around 70 revolutions per minute (RPM) is the most metabolically efficient. However higher pedalling rates appear to minimise recruitment of fast twitch fibres, reduce muscle fatigue and improve leg blood flow which is why they may be favoured by elite cyclists. It also appears that elite cyclists have trained the ability to pedal at higher RPMs leading to reduced neuromuscular fatigue. For crank length the key take home was that the body has a large capacity to adapt to change and altering crank length by quite large amounts has a very minimal impact on power output. Crank length can therefore be selected to optimise other areas such as aerodynamics and bike fit. Pedalling technique appeared to be very individual and many of the widely held beliefs that pulling up or aiming to pedal in circles did not improve power output. Pedalling is a basic leg flexion-extension action and likely hard wired at the spinal level, with large individual variation and no one technique fitting all. Self-selected pedalling technique is likely the most efficient. Non-elliptical chain rings do not appear to help or harm in terms of power output.

Overall the message for what we should be working on to improve performance is to maximise the power an athlete can produce via well designed training programs, good bike fit, good nutrition, optimal recovery, and minimise the power they must produce via reducing aerodynamic drag, reduced braking and well maintained equipment.

The third talk worth highlighting was by Chris Yu entitled 'Aerodynamics and Fitting - Is Lower Faster? And Other Lessons from the Wind Tunnel Aerodynamics Research & Development Engineer'. He highlighted that there are many widely held misconceptions about what is a faster position. Ultimately the fastest position will be very individual and is the balance between reducing drag and maximising power output. Finding this position needs to be done with systematic, well designed testing in the wind tunnel and in the field and general rules of thumb cannot be applied.

These were the highlights of the Bike Fit section of the conference however, there were many good presentations and informal discussions along with some excellent presentations in the MOC Conference. A general reflection from the conference was that there is a lack of well-designed up to date literature relevant to cycling. However, MOC is striving to improve this along with providing consistency of standards and terminology in relation to Bike Fit. Many myths and misconceptions still pervade the cycling world and those working directly with athletes need to engage with the research in an evidence informed practice model. There also needs to be better interdisciplinary practice in support of cycling athletes as illustrated in providing an optimal bike fit which should be a collaborative process. Finally every athlete is individual and highly adaptable and therefore every aspect from training to bike fit should be customised to the individual rather than relying on a one size fits all approach.

AUTHOR AFFILIATION

Mark Harris

Physiotherapist

High Performance Sport New Zealand

REFERENCE

Medicine of Cycling. Medicine of Cycling Task Force First Consensus Statement on Definitions and Key Concepts, 2013. Available at: http://www.medicineofcycling.com/guidelines/

Medicine on the Edge
High Altitude and Expedition Medicine Conference 2015

SANDRA WEBB

Why not combine a bit of CME with some fun and exercise? There are several organisations arranging these expeditions now, and as I read through the "Medicine On The Edge" (MOTE) website, the Peru conference caught my eye. I'd wanted to see Machu Picchu since I can remember: throw in some interesting topics and the chance to trek for 5 days at high altitude and after briefly considering that the chance of dying was slim, I booked the tickets.

The topics sounded intriguing: everything from high altitude syndromes and their treatment, to lightning strike, avalanche medicine, and why we live or die when things go wrong in the mountains. There was also the added bonus of the trekking and campsite sessions, with the opportunity to tramp to 5000 m and see how it felt. I'd never been higher than the South African rugby venues (Ellis park sits at 1810 and Bloemfontein at 1400 metres above sea level), so I had no idea how my particular physiology would cope with exercise and altitude.

I write this from the perspective of a humble kiwi tramper, so those of you who are serious mountaineers can stop reading now! The conference consisted of 3 days of lectures in Cusco, (3400 m) then trekking the Salcantay trail, before joining the Inca trail and finishing at Machu Picchu.

We met up in Cusco: a mix of 3 GP's, a colorectal surgeon, one physiotherapist, an emergency physician, a commercial photographer, and our leader who was also an emergency physician. The lectures in Cusco were planned so that we could acclimatise somewhat to the altitude, as all of us had flown in from sea level and would experience the effects of hypobaric hypoxia; but with plenty of time to explore the city.
It is an extraordinary feeling climbing a couple of sets of stairs and being as breathless as if you had run up twice as many. All participants experienced varying degrees of sleep problems, especially periodic breathing, and most of our small group had headaches - I have to admit I didn't get them, which probably means (if you believe the tight brain theory) that my brain is loose and beginning to atrophy .

Acetazolamide when used prophylactically is started at a dose of 125 mg twice daily (which is half a tablet in NZ) 24-48 hours before arriving at altitude. Potential side effects include allergy (especially in those who react to sulpha drugs), diuresis, (fairly universal, and not surprising as it is a diuretic, but can be a bit annoying) paraesthesiae in the extremities, (these seem to be intermittent and happen at random times) altered taste , decreased appetite, and nausea. The medication can be stopped after 2-3 days at peak altitude, though I chose to continue taking it until I left Cusco on my way home.

The conference was also planned to coincide with Inti Raymi (Festival of the Sun, where the locals celebrate the return of the Sun God at winter solstice) so we were treated to the city in all its finery, with many sections of the community represented in full local dress, dancing and parading through the streets.

Onwards and upwards ...

After a long drive passing through the Sacred Valley, and a couple of hours of tramping, the first nights camping was at 4000 m. We were just across the valley from the majestic Salcantay (Wild Mountain) and listened to the nearby avalanches which occurred at frequent intervals. During the night the full moon and the frost on the ground made the place look magical. The next day at the Salcantay pass (4950 m) a pulse oximeter was produced, and we were all treated to the sight of our oxygen saturations at levels which would normally be alarming.

From that point on, it was either steeply down or steeply up, or "Inca flat" (meaning not quite as steep and either down or up but never flat). The path is well defined, and for much of the way consisted of rocks which had been placed to form the path. On day 4 we joined the Inca Trail, where the rocks continued but with the additional fun of hundreds of stone steps. We now met up with a lot more groups and their porters, the latter usually racing past us with their seemingly impossible loads.

Although all our our group took prophylactic diamox, three of us did get symptoms of acute mountain sickness, probably because they stopped their diamox early. In each case, the symptoms resolved by recommencing the medication or in one case after arriving back at sea level at Lima on her way home The group had two cases of gastroenteritis, and one severe knee contusion after falling and landing directly on a patella on the rocky path. While two of our porters were also treated by the team, they did appear to be supermen - racing ahead of us carrying enormous loads at twice the speed we were progressing, setting up the camp, and producing amazing carbohydrate laden meals out of only what had been carried in. They do stop to rest, and we did note in several of them the signs of chronic oxygen deprivation-barrel chests and clubbed fingers. Only a few seemed to be chewing coca leaves; loud music seemed to be more of a motivator.

The top of the Salcantay Pass, stopping for chocolate and waiting for the rest of the group.

As we progressed there were more Inca ruins to see, lots of very photogenic sites, until finally after a day of seemingly endless descents and switchback paths, we reached the ultimate site of Macchu Picchu. There are no campsites in Macchu Picchu, so the accommodation is in the town of Aguas Calientes, in the valley below, where we had the first showers since we'd left Cusco and a celebratory Pisco Sour. Bliss! Much of Macchu Picchu has been restored to as close to its original state as possible, using original techniques and with stones found at the site.

Suggestions for the non-mountaineer if you are considering doing this:

1 Ideal training would be to carry 10 kg on your back for 7 hours a day, with an hour off for lunch, up and down uneven steps. Anything even close to this is better than nothing. I'm only partly kidding here.

2 There is no good coffee in Cusco. Get over it and drink coca tea - everyone else does.

3 Exploding cosmetics. Everything you packed has air pockets in it, which will expand at altitude. (Boyle's law in practice!) Thus things in enclosed tubes such as sunblock, cosmetics and even sealed packs of hand wipes tend to explode or leak on opening at their new altitude. Only toothpaste seems to be immune from this. Nobody warned me.

4 It is going to be colder up there than you think. The best sleeping bag you can afford is the right sleeping bag, and a good ground mat helps. Most of us shivered through the first couple of nights, even wearing several layers inside our bags.

5 The porters (amazing athletes though they are) have rules which state they are only permitted to carry a bag weighing 7 kg for each person, and this has to include your sleeping bag and mat. They stack these up into enormous bundles, and race off up the mountain ahead of everyone. Everything else you carry yourself and what goes in with you must come out with you - there are no rubbish bins en route. You could choose to carry everything yourself, but you are depriving a local person of a job, which he needs, and the number of porters per party is regulated by the local authorities.

6 The Inca Trail section has to be done as part of a guided group - there is no freedom walking any more and numbers are strictly regulated.

7 Take your own toilet paper and have some arrangement whereby you can get at it while squatting without losing your balance. Enough said.

The Inca trail is great, Macchu Picchu is as incredible as it sounds, but the Salcantay was more amazing for the views, and much less frequented. I'd definitely recommend doing it if you are even mildly interested. MOTE uses a really helpful travel agent, the hotels at the beginning and end were comfortable, and our guide Pepe was extremely knowledgeable about everything from the trail itself, the Inca ruins and the flora and fauna on the trail.

AUTHOR AFFILIATION
Sandra Webb

Sports Doctor/General Practitioner

Dunedin