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Email: admin@sportsmedicine.co.nz
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CONTRIBUTORS

Chris Milne

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

Jasper Wong

Jasper is a PhD candidate at the Auckland University of Technology and works within the Sports Performance Research Institute NZ at AUT. The current focus of his research is on running biomechanics and running injury prevention.

***Chris Whatman** is an Associate Professor, Sports Injury Prevention, at Auckland University of Technology and a member of SPRINZ. Chris originally qualified as a physiotherapist and worked in private practice and with various sports teams for over 10 years prior to becoming an academic. The focus of his research is prevention of sports injuries in youth with an interest in neuromuscular training, early specialisation, the adolescent growth spurt and knowledge/attitudes to injury.*

Kelly Sheerin

Kelly is a Senior Lecturer within the Department of Sport and Exercise Science, and a researcher within the Sports Performance Research Institute at AUT. Kelly is a registered Physiotherapist and sports scientist, and the President of the Auckland Branch of SMNZ. His research focus is on the impact of injury prevention strategies in a wide range of sports, and he operates on the interface of the sub-disciplines of injury monitoring, sports biomechanics, anthropometry and data science to bring high-level injury prevention support to athletes at a range or levels.

Robert Borotkanics

Robert Borotkanics is a biostatistician. He is currently Associate Editor at Australian Health Review, a former US National Institutes of Health Research Fellow and alumnus of Johns Hopkins

Denny Wells

Denny completed his PhD in Biomechanical modelling during sport at the University of Western Australia. Following the completion of his Doctorate in 2018, Denny moved across the ditch to undertake a 12-month position at Auckland University of Technology as part of the Sports Performance Research Institute (NZ), where he maintains a Research Associate role. In 2018 he moved to Queensland to join Logemas, bringing nearly 10 years experience in Sport and Life Science. Denny now works across Australia and New Zealand with Universities and high performance sporting institutions, advising on motion capture and Biomechanical measurement.

Brianna Larsen

Brianna is a Lecturer of Sport and Exercise at the University of Southern Queensland (Australia). Her research areas include thermoregulation and exercise performance, with an emerging track record in the field of female athlete health. Brianna has conducted a number of laboratory- and survey-based studies investigating hormonal contraceptive use in elite female athletes, and has ran educational workshops for several high-level sporting organisations on female athlete menstrual health (e.g., Swimming Australia, Queensland Academy of Sport).

Clare Minahan

Clare is an Associate Professor at Griffith University, Queensland Australia, and has led the Griffith Sports Science group since 2002. Clare's interests are in the advancement of human performance with a key focus on the determinants of performance in female athletes. She has documented unique responses to exercise in female athletes including locomotor movement patterns, muscle damage, thermoregulation, and immune function. In 2021, Clare was recognised by Exercise & Sports Science Australia as one of three Female Leaders in Exercise & Sports Science.

Rebecca McLay-Cooke

Rebecca is a Performance Nutritionist with High Performance Sport New Zealand based in Christchurch, New Zealand. She works with male and female athletes from a variety of sporting disciplines including endurance, power and team sports from development through to the elite level. Her previous research interests include prevalence of low energy availability in athletes, effects of the menstrual cycle on performance and substrate utilization, comparisons of conventional and alternative weight loss strategies and potential menstrual cycle specific nutrition strategies.

Kylie Cox

Kylie is a Physiotherapist with a post graduate qualification in Sports Medicine and a Master in Sport Science. Her special interest focusses on the female athlete, working clinically, in consultancy and as an educator, highlighting female athlete health related issues. Kylie is Director of The Healthy Athlete Project and has worked most recently on a female health education initiative for Netball New Zealand's NetballSmart programme. She also works in musculoskeletal private practice and with Basketball New Zealand's Female U17 National team as a Physiotherapist.

Stephen P. Bird

Stephen is Associate Head of School (Allied Health) and Associate Professor in Sport and Exercise Science at the University of Southern Queensland (Australia). His research activities centre on the application of sport science technology for health, wellness and athletic performance, including strength and conditioning methodology, nutritional supplementation, recovery enhancement and performance optimisation. Stephen currently serves as the Head of Athlete Performance and Wellbeing for Basketball New Zealand Senior National teams.

Post the glow of Birmingham gold, time to maximise the opportunity sport provides

CHRIS WHATMAN

Many congratulations to the New Zealand athletes and support staff who attended the recent Birmingham Commonwealth Games. By all accounts the Games were a huge success and obviously pleasing from a Kiwi perspective. The most gold medals ever (20) and the highest total medal tally (49) achieved by a New Zealand team at an overseas games, with medals won in a wide range of sports. A timely good news story in high performance sport which hasn't always been in the news for the right reasons of late.

Great to see this success in the high-performance space, but are we making the most of the positive impact sport could have for all New Zealanders? No better time to focus on the opportunity sport can provide to positively impact on the lives of all New Zealanders, especially our young people. I've recently had the opportunity to be involved in discussions with Sport NZ and several National Sports Organisations and it is clear there is still much concern around the drop off in sports participation during youth. Sport NZ data suggests youth sports participation peaks between the ages of 12 and 14 with a decline in participation between the ages of 15 and 17[1]. Encouragingly however, recent studies based on Sport NZ data showed a positive association between enhanced wellbeing and organised sport participation in young people, over and above participation in other forms of physical activity/recreation[2,3]. These studies suggest participants in organised sports have better wellbeing during adolescence than non-participants and this relationship is enhanced when participating in a variety of sports. Although not designed to establish causation, these findings support multiple previous studies linking positive experiences of sport to improved health and wellbeing in young people. Positive sporting experiences, especially with good coaches, may contribute to increased social connections and an improved sense of belonging, competence, and achievement – all factors that have been linked to enhanced wellbeing.

The question we now face is how we maximise the opportunity sport provides, and how we ensure more youth have a positive experience and stay in sport for longer. Our conversations with several sports over recent months would suggest there are several common opportunities at play. The need for appropriate support is a recurring theme with suggestions we need to better understand what support youth need from parents and coaches to ensure a positive sport experience for as many as possible. Additionally, it's acknowledged there is a lack of culturally distinctive opportunities, limiting the ability for some in our communities to thrive and remain in sport. There are also many barriers to participation for those with disabilities and the potential for significantly increased participation in this group. The integration of all athletes in the Birmingham Games appeared a huge success and highlights the need to improve access to our disabled community.

Delivery structures that promote early success rather than long term development and nurturing a lifelong love of sport in our young people are also commonly discussed areas that could be improved. Concerns are often expressed about youth sport selection processes kicking in too early with youth having to make premature decisions to focus on a particular sport. Studies have confirmed the 'late maturer', often physically disadvantaged during adolescence, will likely become a casualty of a selection bias that favours early maturers[4]. In some sports the delivery systems are also thought to be fragmented with less-than-ideal cooperation between school and club sport to the detriment of participants. While many sports have signed up to the Sport NZ "Balance is Better" initiative, there is still work to be done on how this is implemented in specific sports. Similarly sport clearly has many benefits, but challenges remain in relation to minimising the risk of injury and their associated costs. Much evidence is available to support injury prevention initiatives such as neuromuscular training/warm-up, however dissemination and implementation in real world community sport settings remains a challenge.

Sport NZ and all sports are aware of these challenges and opportunities and are working hard to enhance the youth sporting experience and increase participation rates and retention. There is a clear focus on the well being of young people with many great initiatives underway including comprehensive injury prevention programmes, youth advisory groups, alternative delivery structures to better suit the age and stage of participants, more inclusive opportunities, coach developer programmes and growing organisational cultural competency. There is a significant body of research that provides understanding of what makes an enriching sporting experience for young people. The challenge is to translate this knowledge into real world on-the-ground practice and maximise the opportunity sport provides.

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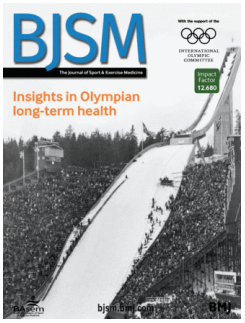
From the British Journal of Sports Medicine 2021

CHRIS MILNE



2021 marked the beginning of a new era in the editorship of BJSM. Jonathan Drezner took over the reins from Karim Khan and paid due respect to Karim's time in the editor's chair for the previous 12 years.[1] He undertook to continue publishing high-quality peer-reviewed articles and developing innovative ways to make key clinical information more accessible to the 25 BJSM clinical societies and the SEM community at large. The January issue published in association with the IOC contained a major study of the health of retired Olympians from 131 countries.[2] 3357 responded to an invitation to participate, and almost two-thirds of them reported at least one Olympic career significant injury. The knee, lumbar spine and shoulder were the most commonly injured anatomical locations. One-third of the sample attributed current pain, and functional limitations to an injury sustained during their Olympic careers.

Sports medicine education continues to develop. In the second issue, there was a report on a Delphi developed syllabus for the speciality co-authored by David Humphries, Past President of ACSEP and senior colleagues from over a dozen countries.[3] They proposed a core syllabus with additional input from national medical organisations to refine and adapt the syllabus to their needs and consider evolving knowledge. Patient voices are important and Mary Johnson relates her story of battling chronic pain and learning self-advocacy whilst dealing with a complex injury with an unhealed sacral stress reaction.[4] She saw several clinicians with varying degrees of empathy, and her takeaway message from the 18 month odyssey was this: "listen, educate and uphold authority without being an arsehole". She concludes even your most difficult patients (I was certainly one of them) will thank you for it. A compelling article.

The pandemic has forced us to use tele-health over the last couple of years. A Brazilian group led by Jane Dias reported on the effect of exercises by tele-rehabilitation.[5] They conducted a systematic review of randomised controlled trials, and 48 were included in the quantitative analysis. The conclusion was that whilst exercise by tele-rehabilitation may be an alternative to treat pain, physical function and quality of life compared with other interventions, the evidence is of relatively low quality.

In the fourth issue, Keith Stokes and colleagues studied the effect of reducing the height of the tackle through law change in elite men's rugby union.[6] They found that the rule change meant that tacklers made contact with the ball carrier's head and neck 30% less often, but this did not influence concussion incidence rates. Tacklers in the lower tackle height setting suffered more concussions than did tacklers in the standard tackle height setting. This is what one would expect from first principles.

Issue five was the Sports and Exercise Physiotherapy New Zealand edition and was published during the honeymoon period of dealing with the Coronavirus before it became established in our community. In this issue, Robert De Vos and colleague wrote an article with the intriguing title "Diagnosing Achilles tendinopathy is like delicious spaghetti carbonara: it is all about key ingredients, but not all chefs use the same recipe".[7] If the clinical case is less than straightforward, i.e. where the tendon is painful but there is no thickening, it is a challenge to define the point at which tendinopathy is deemed to be present. The continuum model of pathology proposed by Cook and Purdam describes a potential sequence of changes. There is varying expert opinion regarding the role of imaging at different stages of the condition. In essence, this is part of the art of being a good clinician. It means taking evidence from the literature and applying that knowledge with due consideration of the patient's life circumstances. There was a useful infographic comparing foot orthosis and hip exercises and their effect on the outcome of patellofemoral pain.[8] This was a combined Australian and Danish study co-authored by Mark Mathews and colleagues. They found no difference between either intervention. My practice is to start with posterior gluteus medius exercises and consider orthotics at an early stage if the patient has pes planus.

The sixth issue included an article entitled "The Relationships between Rugby Union and Health and Wellbeing": a scoping review.[9] Compiled by editors mainly from the UK, the response from a New Zealand perspective would be, " I would not think you would need to ask". This is because rugby is embedded in the New Zealand psyche. Nevertheless, this article touches on the effects on health plus it considers the downside of injury, particularly concussion and the potential long-term sequelae of multiple concussions. This is an evolving area of research. Later in the same issue was an article with the provocative title "You are the best liar in the world": a grounded theory study of rowing athlete's experience of low back pain.[10] Co-authored by Fiona Wilson, a senior Irish physiotherapist and colleagues from Canada and Australia, it provides a searing analysis of how athletes will try to hide an injury so as not to jeopardise their seat in the boat. It is essential reading for anybody dealing with high-level athletes, as the concealment of injury is a relatively widespread phenomenon, and we clinicians need to be open and supportive of our athletes.

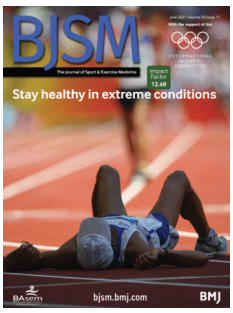
In the seventh issue, there was a detailed review on the comparative effectiveness of treatments for patellofemoral

pain.[11] Marinus Winters and colleagues from Denmark, UK, Australia, Qatar and the Netherlands collaborated and evaluated 22 trials. They concluded that education and combined with a physical treatment, including exercise, orthoses or patella taping, was most likely to be effective at three months. All treatments were superior to wait and see, and they recommended avoiding that approach. Most New Zealand clinicians would adopt the active approach these authors advocate.

The eighth issue included a detail consensus statement on nutrition in elite football.[12] Co-authored by many leading experts, including Ron Maughan, who will be well known to New Zealanders, this UEFA expert group have provided a state of the art review. They recommend a "food first" philosophy and believe that supplements have been overrated. There is a useful infograph summarising their findings later in the same issue.

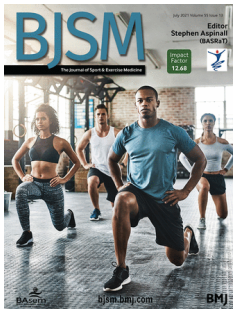
Issue nine included a useful article on exercise interventions in lateral elbow tendinopathy, i.e. tennis elbow.[13] Karanasios and colleagues analysed thirty randomised control trials with 2123 participants. They found that exercise was more effective than passive interventions, but the effect was small. Their research confirmed other expert reviews showing that exercise performs better than corticosteroid injections, and these have generally fallen from favour in recent years. In my experience, if there is a partial tear in the common extensor tendon, then a platelet-rich plasma injection has a definite role in treatment.

In issue ten, network meta-analysis is a clever and popular statistical method for comparing numerous treatments for a condition.[14] It allows for two treatments to be compared statistically even if they have not been compared directly in any previous randomised control trial via a common comparator. Doosti-Irani and colleagues provide a two page primer with some tips for clinicians who read these studies and those who would perform them.



Issue eleven contained a vital article entitled "Be Aware: New Rules for Corticosteroids", written by Lars Engebretsen.[15] This drew on recent research from Rosa Ventura and colleagues analysing the effect of glucocorticosteroids in great detail. Following publication of their research, the World Anti-Doping Agency announced all injectable routes of administration of glucocorticoids will be prohibited in sport from 1 January 2022. The authors present new washout periods to enable clinicians to use glucocorticoids safely and avoid the risk of athletes testing positive in a doping test. Triamcinolone, the most commonly used glucocorticoid, has the longest washout period, and the authors state this to be ten days, with other glucocorticoids having a shorter washout period of three days. I believe it is wise to include a generous margin for error, and if your patient needs an intra-articular or peritendon glucocorticoid injection less than two weeks prior to competition, then you should apply for a therapeutic use exemption for that athlete to avoid potential later issues.

Issue 12 had an important article entitled "Clinicians Use Courses and Conversations to Change Practice, not general articles: is it time for journals to peer review courses to stay relevant?".[16] Co-author Rod Whiteley and colleagues make the point that frontline clinicians mostly do not have time to read many of the journal articles to guide their practice. They argue that suppliers, i.e. those who do clinical research have a responsibility to translate the research to clinical practice. This column I have put together over the last decade or more has consistently aimed to do that and save you the hassle of wading through numerous articles of little clinical relevance. Later in the same issue there was an article by Stephen West and colleague noting trends in match injury risk in professional male rugby union.[17] The authors reviewed 10851 match injuries over sixteen seasons in the English premiership. The most common injury site was the face, with the knee being the location with the highest overall burden. Overall concussion incidence, severity and burden increased dramatically over the last decade of the study, and we need to be mindful of this as it impacts on our national game.



Issue 13 in July contained a useful editorial by Steve Aspinall entitled "Treating the patient in front of you and the power of language; integrating research into effective clinical practice".[18] This was a call to clinicians to be careful in the language they use and not make patients overly anxious by using words like "tissue damage" but instead reframing these as comments such as "normal for your age". Later in the same issue, there was a useful infographic entitled "When is abnormal normal?" reframing MRI abnormalities as a normal part of ageing.[19] Also in the same issue, Adam Culvenor mentioned the same thing in the context of MRI findings Approximately eight out of ten adults aged over 40 years have asymptomatic disc degeneration, whereas almost half of all adults aged over 40 years have chondral lesions in their knee but no pain. The prognosis of these asymptomatic findings is not well established.

Issue 14 included the useful article by William Johnson and colleagues regarding recommendations for determining the validity of consumer wearable and smartphone step count.[20] This was a consensus that was promulgated by the interlive consortium. They recommend that wearable and smartphone step count manufacturers seek to validate their devices using standardised and transparent methodologies and include tables detailing best practice validation protocol. This is relevant for those people who seek to get an accurate assessment of their habitual daily activity.

Issue 15, in collaboration with the IOC, contained an excellent summary of how to manage travel fatigue and jet lag in athletes.[21] The lead author was Dena Van Rensburg. The author has recommended maximising rest and sleep during a sleep window corresponding to nighttime at the place of departure, with individualised sedative use via a doctor's order. Once arriving at the destination, they recommend coinciding training sessions with light exposure and progressively increasing training intensity as tolerated.

Issue 16 contained a valuable consensus statement for preventing and managing low back pain in elite and sub-elite adult rowers.[22] The lead author was Fiona Wilson from Ireland, and our own Craig Newlands from the Rowing New Zealand programme contributed to the paper. They recommend prevention via education on risk factors, rowing mechanics and training load. If treatment is needed, they recommend early unloading from aggravating activities but effective pain control and exercise therapy. The role of surgery is unclear. In my 17 years of managing our elite rowers surgery was only required in less than half a dozen cases.

In issue 17 Jane Thornton and colleagues explore what we can take from elite sport to give back to wider public health.[23] A comment that sport for health is a continuum, not a category. The role of sport and physical activity on the immune system and thus on communicable disease is especially relevant now during the Covid-19 pandemic. The following issue had a useful infographic entitled "Benefits and harms of exercise therapy in people with multimorbidity, authored by Alessio Bricca and colleagues.[24] They reviewed 23 studies from 17 countries and found that exercise improved physical function and health-related quality of life. This in turn benefits physical and psychosocial health, and therefore should be recommended in clinical practice.

Plantar heel pain is a chronic tiresome condition, and management is often controversial. Dylan Morrissy and colleagues performed a systematic review of 51 eligible trials with nine RCTs suitable for determining proof of efficacy for ten interventions.[25] They recommend taping and plantar fascia stretching in the short term and shockwave therapy plus orthoses if things were not improving. In my practice, I still find a role for injections. If a partial tear is evident, then I would have a low threshold for recommending platelet-rich plasma injections. If there is significant hypervascular change, then a cortisone injection may have value, but it should be explained to the patient that good post-injection care is required, and there is still a risk of rupture of the plantar fascia.

Issue 20 included a major consensus statement by Robert DeVos and colleagues from the Netherlands on diagnosis and management of Achilles tendinopathy.[26] They split the condition into mid-section and insertional tendinopathy and explained that the criteria for determining the diagnosis are not sufficiently known. The role of imaging in Achilles tendinopathy is unclear. My personal view is that ultrasound can be a useful adjunct in management, particularly to look for new vessel formation and the presence or absence of an associated partial tear. These, in turn, have implications for patient management in, particularly the use of injections.

Issue 21 contained information on the ACSEP annual scientific conference, which was held virtually last year. There was a useful editorial by Hamish Osborne promulgating the truism "He Tangata" – it is the people in our lives that are important to us.[27] Later in the same issue was a report of a four year prospective study into the aetiology and incidence of sudden cardiac arrest and death in young competitive athletes in the USA.[28] The senior author was Jonathan Drezner, a known leader in the field. They have found that cardiomyopathy accounted for nearly half of the cases whilst coronary artery anomaly played a more important role than expected in middle school, i.e. intermediate school-aged athletes. Of the 331 confirmed cases, 173 resulted in sudden death so this is an important condition. To my knowledge this is the first major prospective study of its type.

Mental health issues have assumed increasing prominence in the past few years. In issue 22 Alan Currie and colleagues reported on the recently released IOC Mental Health in Elite Athletes tool kit and laid out future directions for optimising athlete mental health.[29] Later in the same issue was an article by Wil Greenberg and Jo Clubb entitled "Why Best Practice is not always best in Sport."[30] They point out that best practice guidelines are a useful start, but clinicians need to take into account the athlete's personal circumstances. This is particularly true for complicated problems such as relative energy deficiency in sport and concussion management.

Tokyo 2020 Olympic Games threw up environmental challenges and raised the issue of potential use of new cooling technology and associated ethical dilemmas. Co-authored by Borja Muniz-Pardos and colleagues it included recently developed wearable technology designed to cool an individual in a hot environment.[31] This includes neck coolers, wrist coolers, pocket air conditioning devices and cooling fabrics and patches. Widespread data from use of these devices has yet to be disseminated, but will be important information for athletes competing in hot environments in future. The Covid-19 pandemic created many challenges to ensure a safe environment for competitive sport. Fabio Pigozzi and colleagues outlined the process for protecting Olympic participants from Covid-19 infection.[32] The strategy put in place was highly successful and resulted in safe participation for the ten thousand or so athletes competing in Tokyo in 2021.

Community-based physical activity events are popular but potentially can result in life-threatening incidents. Most of these, approximately 80%, are cardiac-related. Charles Pedlar and colleagues reported on park run events over a six year period involving nearly 30 million participants.[33] Fortunately, only 84 serious life-threatening events took place, and of these, only 18 were fatal. Nevertheless, it behoves organisers of such events to have adequate medical backup. Combat sports have become increasingly popular, and Bruno Follmer and Paul Zehr argue that combat sports should be ground zero for research on concussion.[34] I agree. As they state, strikes directly to the head are intentional and critical to success in several combat sports. However, unlike other sports, fighting sports often do not obey the mandatory immediate removal of the player requirement when signs of concussion are observed. This, therefore, allows a brain-injured fighter to receive further head impact despite being concussed. This is definitely an area where the sports need to up their game if they are truly concerned about athlete welfare.

That's all for this instalment. A full year's journals reviewed in one article. No doubt I have missed some important ones, but this will give you a flavour of the range of topics covered by BJSM in recent times.

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The relationship between training and game workload and injury risk in elite male basketball

JASPER WONG, CHRIS WHATMAN, KELLY SHEERIN, ROBERT BOROTKANICS AND DENNY WELLS

See end of article for author affiliations.

Correspondence

Jasper Wong

jasper.wong@aut.ac.nz

ABSTRACT

This study aimed to investigate the relationship between workload and injury risk in professional men's basketball. Player workload (training and game) and injury data were collected from 16 elite basketball players belonging to a National Basketball League (NBL) team over one full competitive season. Trunk mounted tri-axial accelerometers were used to quantify player workload. Workload measures included cumulative loads (2-, 3-, and 4-weekly), acute workload (1 week workload), chronic load (4-week rolling average workload), absolute difference in acute workload, and acute:chronic workload ratio (ACWR) (acute workload divided by chronic workload). All workload measures were categorised as low, moderate, high, very high based on quartiles and modelled against injury data using a frailty model. Using low as the reference category a hazard ratio (HR) was calculated for each category to determine the relative risk of injury. There were no statistically significant differences in injury risk between high and low ACWR (HR = 1.98; p>0.05). Furthermore, no significant associations were detected between injury risk and different categories for 2 week accumulated workload (HR = 1.02 to 2.02; p>0.05), 3 week accumulated workload (HR = 0.22 to 1.21; p>0.05), 4 week accumulated workload (HR = 0.35 to 0.71; p>0.05) or absolute difference in acute workload (HR = 0.64 to 1.75; p>0.05). These findings do not support the use of any of the investigated workload measures to inform injury risk in a single men's professional basketball team. Further research, combining multiple squads to provide a larger sample, may provide a clearer picture.

INTRODUCTION

Basketball is an intermittent high intensity team sport requiring a combination of technical skill and physical athleticism, involving repeated accelerations, decelerations, changes of direction and jumping movements.[1] Within professional basketball, the frequency of competitive games is high. Teams in the Australia New Zealand National Basketball League (NBL) play between one to two games each week, in addition to regular training sessions, whereas teams in the American National Basketball Association (NBA) play up to four games each week. Consequently, players are exposed to high physical workloads over the course of a season, with short between-game recovery times. While it is accepted that a certain workload level is required to improve performance, coaches need to allow sufficient recovery to prevent overtraining, which could increase the risk of training related injury.[2] Data from the NBA indicates a high frequency of overuse and inflammatory conditions, which account for the greatest amount of time lost from games and trainings.[3,4] These injuries can have a negative effect on team success, and while there are many factors that contribute to injury risk, athlete workload is considered an important modifiable risk factor.[5] Therefore, appropriate workload monitoring strategies need to be implemented to allow for sufficient recovery, potentially reducing the risk of workload related injury.

Understanding the relationship between workload and injury risk may be beneficial for load prescription and management during the season. Currently, there is limited research investigating the workload-injury relationship in basketball.[6,7] Research from other team sports has found that both high and low weekly workloads (termed acute workload) are associated with a greater injury risk.[8-11] This has led to the suggestion that working within a certain workload range could minimize injury risk, while maximizing performance.[8,12] In contrast, higher average weekly workload over four weeks (termed chronic workload) has been associated with decreased injury risk compared to low chronic loads. This supports the idea that a certain level of physical stimulation is required to ensure athletes are physically prepared for competition.[9,13] Exposure to higher workloads is thought to improve an athlete's tolerance for higher workloads, as a result of multiple adaptations to the musculoskeletal and cardiovascular systems.[11] This is thought to

offer a protective effect against sudden increases in weekly workload, which have also been associated with increases in injury risk.[6,11] Therefore, consideration of proper training load periodisation is important to ensure athletes are physically prepared for changes in workload, especially following periods of inactivity such as breaks in the season or when returning from injury.

Recent research investigating the workload-injury relationship has focused on the use of the acute to chronic workload ratio (ACWR) as a metric to inform injury risk and aid workload prescription.[9,14] The ACWR assesses the acute workload relative to the average workload performed in the previous four weeks (chronic workload). The resulting workload index provides an indication of whether the athlete's weekly acute workload is greater than, equal to, or less than that which they had prepared for in the previous chronic period, and thus provides a measure of the magnitude of change in weekly workload.[15] Although this measure originated from a workload-performance perspective, studies in Australian football, soccer and rugby league have suggested that spikes in ACWR are associated with a greater injury risk.[10,14-17] There have also been reports of an ACWR sweet spot, where injury risk is lower compared to ACWRs above and below this range[14,15], although controversy exists as to the validity of the ACWR as a workload measure.[21,22] Only one study has investigated the relationship between workload and injury risk in basketball using the ACWR.[7] This study observed that an ACWR range of 1.0-1.49 was associated with the lowest injury risk compared to ACWR ranges above and below this threshold, however further statistical analysis did not reveal clear differences between injury risk for different ACWR categories. Further research is needed to determine whether the ACWR is useful as a load monitoring strategy in informing injury risk in professional basketball. This has the potential to reduce injury rates, minimise time loss from trainings and games, and maximise team performance. Therefore, the aim of this study was to investigate the relationship between different workload measures and injury risk in professional men's basketball.

METHODS

Participants

In-season data (excluding pre-season and post-season) were collected from male professional basketball players (n=16; 26.3 ±4.9 yrs) from a single NBL team over the 20 weeks of the 2017-2018 season (28 games and 41 training sessions). Four players were excluded from the final analysis due to being in the development squad and not participating in any games. A further three players were excluded as they were on temporary contracts and were not with the team for the entire season. Following exclusion there was a total of 597 individual player sessions available for analysis. Ethical approval was obtained from the university ethics committee, and all players provided written consent.

Quantifying Workload

Player workload data were collected for all team training sessions and matches using wearable sensors (ClearSky T6, Catapult Innovations, Australia) incorporating global positioning system (GPS) tracking, in addition to tri-axial accelerometer, gyroscope and magnetometer sensors. The sensors were placed between the scapulae, held in place using a tight fitting vest. Real-time tracking of GPS data were unavailable due to the indoor setting, therefore only accelerometer based data (sampled at 100 Hz) were used to quantify workload. External workload was quantified as an arbitrary player load (PL), calculated based on the formula:

$$\text{Load} = \sqrt{((Ac1n - Ac1n{-}1)^2 + (Ac2n - Ac2n{-}1)^2 + (Ac3n - Ac3n{-}1)^2)}$$

Ac1, Ac2 and Ac3 represent the instantaneous rate of change in acceleration in the three planes of body movement.[18] This metric has been shown to be a valid and reliable measure of workload in basketball compared to session rating of perceived exertion (sRPE).[18,19]

For match data that was incomplete or recorded incorrectly (n=65 of 252 player sessions; 26%), estimations were made based on matches with complete data recordings over four quarters of play. An average player load per minute was calculated according to individual game time and multiplied against playing time for matches with incomplete data in a manner similar to that reported previously.[16]

Injury Definition

Injury information, including location and diagnosis, were recorded by the team physiotherapist. An injury was defined as any physical complaint sustained during training or match-play that required assessment from the physiotherapist, regardless of any time lost from team activities.[20]

Data Analysis

Workload data were grouped into weekly blocks from Monday to Sunday. Acute workload was calculated as the absolute workload performed in one week, and chronic workload was calculated as the four-week rolling average of acute workload. The ACWR was calculated by dividing the acute workload by the chronic workload. Based on recently highlighted limitations of the ACWR and suggestions regarding alternative load measures in recent studies,[21,22] additional load measures included cumulative workload (2-4 weeks) and the absolute difference in workload from the previous week.[10,14,16] Each workload measure was split into four quartile categories (very low, low, moderate, high) which were used in the subsequent analysis. Overall injury incidence was calculated by dividing the total number of injuries by the total number of training and match hours. Injury incidence for individual workload categories were taken to be the number of injuries relative to the number of exposures in each category.

Statistical Analysis

The relative risk of injury in the subsequent week for each workload variable was estimated via a frailty model. The frailty model is an extension of the Cox proportional hazards model dealing with time to event analysis, and has been suggested as a more appropriate method of statistical analysis when dealing with sports injury recurrent events.[23] For each workload variable the frailty model calculated the hazard ratio (HR), with 95% confidence intervals, associated with each category of the workload variable. Separate univariate models were run for each workload variable, with the 'low' category used as the reference group, in order to gain a preliminary understanding of how workloads are associated with injury risk in basketball players.[11] The frailty model could not be run successfully with quartiles when ACWR was the independent variable due to a low number of cases. Therefore the ACWR was dichotomised using the median value to reduce the likelihood of excessive data cells with small counts in the model.[24] An additional frailty model was run where ACWR was categorized into three groups (<1.0, 1.0-1.5, >1.5), using an ACWR range of 1.0-1.5 as the reference group, as previous research has suggested that this is the ACWR 'sweet spot' in professional basketball.[7] Resulting HRs below 1.0 indicated a lower injury risk relative to the reference group, whereas a HR above 1.0 indicated a higher injury risk relative to the reference group, and a HR of 1.0 indicated no difference. All data was analysed using Stata v15 (StataCorp, Texas, USA) with statistical significance set at p<0.05 throughout.

RESULTS

A total of 27 injuries were recorded over the season, at an incidence rate of 0.81 injuries per 1,000 hours of training/matches. The majority of injuries occurred in the lower limb (ankle n=7, 26%; Achilles n=4, 15%; calf, n=2, 7%; hamstring, n=2, 7%).

The results of the frailty model for accumulated workload (2 to 4 weeks) and absolute difference in acute workload are presented in Table 1. There were no statistically significant differences between any of the four workload categories and injury risk in the subsequent week for either of these workload measures.

There were also no statistically significant differences in injury risk between different workload categories for acute workload, chronic workload or the ACWR (Table 2). However, visual inspection of descriptive statistics presented in Table 3 suggested that a higher proportion of injuries occurred in the very high ACWR category. It was also observed that a higher proportion of injuries occurred when the absolute difference in acute workload was high and very high. There were no such observable patterns for accumulated workload, chronic workload or acute workload.

Table 1: Injury risk in the subsequent week for accumulated workload (2-4 weeks) and absolute difference in acute workload

Model Variable	Hazard Ratio (95% CI)	p	Standard Error (SE)	z
Accumulated workload (2 weeks)				
Low (≤2332AU)	-	-	-	-
Mod (2333-2950AU)	1.02 (0.28-3.74)	0.98	0.68	0.02
High (2951-3419AU)	1.83 (0.43-6.90)	0.44	1.22	0.77
Very High (>3419AU)	2.02 (0.39-10.47)	0.40	1.70	0.84
Accumulated Workload (3 weeks)				
Low (≤3636AU)	-	-	-	-
Mod (3637-4350AU)	0.55 (0.12-2.50)	0.44	0.43	0.77
High (4351-5063AU)	1.21 (0.33-4.43)	0.78	0.80	0.28
Very High (>5063AU)	0.22 (0.03-1.67)	0.14	0.23	1.47
Accumulated Workload (4 weeks)				
Low (≤4777AU)	-	-	-	-
Mod (4778-5906AU)	0.56 (0.13-2.50)	0.45	0.43	0.76
High (5907-6805AU)	0.71 (0.19-2.66)	0.62	0.48	0.50
Very High (>6805AU)	0.35 (0.06-2.09)	0.25	0.32	1.15
Absolute difference in acute workload (±)				
Low (≤234AU)	-	-	-	-
Mod (235-480AU)	0.64 (0.11-3.62)	0.61	0.56	0.51
High (481-834AU)	1.75 (0.39-7.79)	0.46	1.33	0.73
Very High (>834AU)	0.78 (0.08-7.65)	0.83	0.91	0.21

Abbreviations: AU=Arbitrary units; Mod=moderate.

Table 2: Injury risk in the subsequent week for acute workload, chronic workload and ACWR.

Model Variable	Hazard Ratio (HR) (95%)	p	Standard Error (SE)	z
Acute workload				
Low (<1073AU)	-	-	-	-
Moderate (1073-1480AU)	1.20 (0.15-9.29)	0.86	1.25	0.17
High (1481-1807AU)	1.09 (0.11-10.74)	0.94	1.27	0.07
Very High (>1807AU)	0.92 (0.09-10.00)	0.95	1.12	-0.07
Chronic workload				
Low (<1194AU)	-	-	-	-
Moderate (1194-1475AU)	0.56 (0.13-2.50)	0.45	0.43	-0.76
High (1476-1701AU)	0.71 (0.19-2.66)	0.62	0.48	-0.50
Very High (>1701AU)	0.35 (0.06-2.09)	0.25	0.32	-1.15
ACWR				
Low (≤1.05)	-	-	-	-
High (>1.05)	1.98 (0.23-17.13)	0.54	2.18	0.62

Abbreviation: ACWR=acute chronic workload ratio.

Table 3: Count of players injured/uninjured in the subsequent week in each category for (A) Absolute difference in acute workload (±) and (B) ACWR.

(A) Absolute difference in acute workload (±)				
	Low	Moderate	High	Very High
No Injury	32	35	32	40
Injury	5	2	6	10
Total	37	37	38	50
Proportion injured	0.14	0.05	0.16	0.20

(B) ACWR category				
	Low	Moderate	High	Very High
No Injury	30	34	27	48
Injury	4	2	3	14
Total	34	36	30	62
Proportion Injured	0.12	0.06	0.10	0.23

Risk of Injury in a Proposed Sweet Spot

The results from the frailty model using an ACWR range of 1.0-1.5 as the reference group are presented in Table 4. There was no statistically significant increase in risk of injury for workload ratios above this reference category. A HR was unable to be calculated for the low group (<1) due to a small number of cases in this ACWR range.

Table 4: Injury risk in the subsequent week using ACWR 1.0-1.5 as the reference.

ACWR Category	Hazard Ratio (HR)	Confidence Intervals (95%) Lower	Upper	p	Standard Error (SE)	z
1-1.5	-	-	-	-	-	-
<1	NC	NC	NC	NC	NC	NC
>1.5	1.41	0.26	7.68	0.69	1.22	0.40

Abbreviation: NC=not calculable

DISCUSSION

The objective of this study was to explore the relationship between different workload measures and injury risk in men's professional basketball. The findings showed no statistically significant differences in injury risk between different workload categories for acute workload, chronic workload or the ACWR. Additionally, no significant associations were detected between injury risk in the subsequent week and accumulated workload or absolute difference in acute workload. This is one of the few studies to investigate the relationship between injury and workload in professional basketball, and the first study to analyse this relationship using a frailty model.

The main finding from the present study was that the ACWR was not informative of injury risk in a single men's professional basketball team. To date, only one other study has investigated the relationship between the ACWR and injury risk in basketball.[7] Based on measures of perceived exertion, this study reported a small-to-moderate reduction in the proportion of injured players at an ACWR between 1.0-1.49 compared to all other workload ratios outside of this range.[7] However, this was based on a very small sample of six athletes, and further statistical analysis using a form of binary logistic regression actually showed unclear differences in injury risk between different workload ratio ranges.[7] Based on these findings, the current study used the suggested 1.0-1.49 ACWR range as the reference category to further investigate the existence of the proposed sweet spot using a more robust method of statistical analysis. While our findings suggested there may have been a greater injury risk associated with an ACWR greater than 1.50 (HR=1.41), this association was not significant and therefore there was insufficient evidence to support the use of the proposed ACWR sweet spot in basketball. It should be noted that the current study used an external load variable, as opposed to the internal load variable used previously which likely reflected workload differently.[7]

Additionally, the injury definition used in the present study could have impacted on the scope of injuries observed, and thus the relationship between load and injury. It has been suggested that injury definition based on diagnosis by the team physiotherapist is less sensitive in detecting overuse injuries in professional basketball compared to injury classification based on a self-reported overuse injury symptom questionnaire.[25] Thus consideration needs to be given to the most appropriate injury definition for the context when investigating links between injury and workload. Given the small team size in basketball, players often continue to train or compete despite the presence of symptoms and this may not be diagnosed as an injury by medical staff if they are not aware of the issue or until the injury results in time loss.

The results from the present study also differ to previous findings regarding the relationship between workload and injury risk in team sports. It has generally been reported that an ACWR sweet spot exists, and working at an ACWR higher or lower than this range is associated with a higher injury risk.[9,10,14-17] Previous research has also reported that higher acute loads and accumulated loads were associated with an increased injury risk,[10,11,15] and that higher chronic loads were associated with a decreased injury risk.[9,11,13,14] It should be noted that while many studies have observed this positive link between workload and injury risk, the actual workload category values differ between studies, even when studies have been conducted in the same sport. For example, studies in Australian football have all reported different sweet spot values of 0.8-1.0,[26] 0.8-1.2[14] and 0.6-1.5.[17] This could have been due to differences in the number of players and seasons that data were collected from, which would have affected the spread of the data and subsequently the categorisation of workload. There were also differences in acute and chronic time periods used in the calculation of the ACWR. It is likely that previously reported findings are highly specific to the sample population used in different studies, and therefore generalisation of results should be made with caution.

The lack of any significant observations in the present study could also be due to the low number of injuries observed in the sample population, particularly given the injury incidence of 0.81 injuries/1000hr was much lower than that reported in previous studies.[14,17] However, this was similar to another study that used an injury definition based on diagnosis by the team physiotherapist (0.97 injuries/1000hr).[25] Additionally, the choice of acute and chronic time periods used in the calculation of the ACWR may not have been specific to the basketball competition schedule. The present study used one-week acute and four-week chronic time periods, based on previous research that has applied the ACWR in field sports such as rugby league or Australian football, where games are played weekly.[10,15] To date, there is no clear consensus on the most appropriate acute and chronic periods for use in the ACWR calculation, with one study suggesting a 3:21 acute:chronic period generated better performing injury models,[26] while another study found no difference when using different acute and chronic time periods.[17] This inconsistency suggests that the choice of time periods may be specific to the sample population, and caution should be applied when generalising the results. It is possible that different acute and chronic time windows may better reflect workload in basketball, where multiple games are played each week, however there is currently no research to support this theory. Additionally, when monitoring workload and injury risk, it should be considered that fitness and fatigue have a decaying nature, in that older workload exposures will have less of an impact on injury risk compared to more recent workloads performed by an athlete. It has been suggested that this could be accounted for by using an exponentially weighted moving average, which would give a higher weighting for more recent workloads, however there is currently insufficient research to support this approach.[27]

One of the major limitations of previous studies is that the statistical analyses used may not have been the most appropriate for analysing recurrent or repeated injury data. In team sports, it is common for an athlete to suffer multiple injuries within a season, and it is likely that a player's injury history will have an influence on the risk of subsequent injuries, regardless of injury type. Additionally, depending on the severity of the initial injury, players may continue to train and compete before fully recovering through the modification of movement patterns or biomechanics, further altering their injury risk. As a result, the risk of subsequent injury should not be considered the same as it was for the initial injury. To date, studies investigating the relationship between the ACWR and injury risk have generally used binary logistic regression or Poisson regression models.[9,14,16,17] These statistical models assume that each injury is a statistically independent event, which leads to the assumption that the risk of each subsequent injury is equal, potentially leading to inappropriate findings.[23] The frailty model is more appropriate for analysing recurrent sports injuries as it includes a random effect that accounts for the within-player injury dependency.[23] Using this method of statistical analyses, the present study did not find any of the previously reported links between player workload and injury risk, suggesting that the ACWR is not a useful measure for informing injury risk. It has also been suggested that mathematical coupling exists in the calculation of ACWR, which may result in a false correlation between acute and chronic load.[21] Therefore, the ACWR itself may be misrepresenting the change in workload and could be an unreliable metric for measuring workload.

The main limitation of this study is that the sample size was relatively small, although this is an acknowledged limitation when working with elite athletes, especially in a sport such as basketball where team size is inherently small. Furthermore, a single team was studied over a single season, which inherently limits the amount of workload and injury data available for analysis, as well as the generalizability of these findings. Future research should consider using a larger sample size, incorporating several squads, over multiple seasons. Another limitation is the incomplete match data, which accounted for 26% of all match data. While estimations were made based on previous methods,[16] these are only estimations resulting in some uncertainty in actual payer load. Only one external load variable was used in this study, and it is possible that other sport specific external load variables are more informative of injury risk. Internal training load could also be considered in conjunction with external loads as this may provide a more complete assessment of workload related injury risk. Additionally sensor placement could have affected the specificity of load measures collected. Given that the majority of injuries in basketball occur in the lower limb, it may be more appropriate to place the sensors on the lower leg to more accurately capture lower limb loading, as much of the landing forces will have been attenuated by the time they reach the trunk.[7] Future research should utilise a greater range of external and internal load measures and consider sensor placement to better measure lower limb loading.

CONCLUSION

The results of the present study do not support the use of the ACWR to predict or inform injury risk in a single men's professional basketball team. The lack of significant association between different absolute workload measures also suggests that workload should not be considered in isolation for informing injury risk. This was the first study to investigate the relationship between workload measures and injury risk using a frailty model. While this study provides an initial insight into the relationship between workload measures and injury risk in basketball, further research using a larger sample size or data collected over multiple seasons is needed to give these findings statistical power, and to further validate whether workload is informative of injury risk in basketball.

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AUTHOR AFFILIATIONS

Jasper Wong
Sports Performance Research Institute New Zealand (SPRINZ)
School of Sport and Recreation
Auckland University of Technology
Auckland, New Zealand

Chris Whatman
Sports Performance Research Institute New Zealand (SPRINZ)
School of Sport and Recreation
Auckland University of Technology
Auckland, New Zealand

Kelly Sheerin
Sports Performance Research Institute New Zealand (SPRINZ)
School of Sport and Recreation
Auckland University of Technology
Auckland, New Zealand

Robert Borotkanics
Senior Research Fellow Biostatistics
Faculty of Health and Environmental Sciences
Auckland University of Technology
Auckland, New Zealand

Denny Wells
Sports Performance Research Institute New Zealand (SPRINZ)
School of Sport and Recreation
Auckland University of Technology
Auckland, New Zealand

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A single online education session improves menstrual cycle and hormonal contraceptive knowledge in elite female basketball players and their support staff

BRIANNA LARSEN, CLARE MINAHAN, REBECCA MCLAY-COOKE, KYLIE COX, STEPHEN P BIRD

See end of article for author affiliations.

Correspondence
Brianna Larsen
Sport and Exercise
University of Southern Queensland
Ipswich QLD 4305
AUSTRALIA
+61 7 3812 6045
Brianna.Larsen@usq.edu.au

ABSTRACT

Aim: To assess the effectiveness of an online education intervention in improving menstrual cycle (MC) and hormonal contraceptive (HC) knowledge in elite female basketball athletes and support staff.

Study design: Survey.

Setting: Face-to-face and online survey administration; online education session (Zoom).

Participants/subjects: The Basketball New Zealand Senior Women's National team (n = 12) participated in this study, plus four staff (head coach, assistant coach, physiotherapist, and manager; total n = 16).

Interventions: A 30-min online education session on basic female hormonal physiology and HC options.

Outcome measures: Participants (n = 16) completed a Knowledge Questionnaire to establish their baseline level of MC and HC knowledge. Female participants (n = 15) also completed a Prevalence Questionnaire to characterise their MC history and HC use (past and present). Participants were then invited to attend a 30-min online education session before repeating the Knowledge Questionnaire. Correct responses on each questionnaire were tallied to determine an overall 'knowledge score' (maximum score = 25), allowing for comparisons in knowledge pre- and post-intervention.

Results: Knowledge of the MC and HCs was initially low (10.2 ± 5.6 out of 25 marks) despite most participants being women and 60% currently or previously using HCs. There was a significant improvement in knowledge score post-intervention (19.0 ± 4.0 marks), with a mean change of 8.8 marks (95% CI: 5.9 to 11.7 marks; means only consider those that completed both surveys, n = 10).

Conclusions: Knowledge surrounding the MC and HC options was poor amongst elite female basketball athletes and support staff. However, a 30-min online education session significantly improved knowledge pertaining to athletes' menstrual health. These results encourage focused education interventions surrounding MC and HCs, which may assist athletes in making informed decisions regarding their MC and use (or non-use) of HCs to optimise health and performance.

Keywords: female athletes; contraception; menstrual health; female sex hormones; survey

INTRODUCTION

Female sex hormones play an integral role in many physiological pathways that contribute to exercise capacity, including thermoregulation,[2] cognitive function,[5] and regulation of the immune system.[24] Thus, over recent years there has been increased research interest surrounding the potential influence of the menstrual cycle (MC) on exercise performance (for review see McNulty et al.[18]). This enhanced research interest has been reflected in numerous high-profile media pieces,[10, 11, 15, 23] the development of MC tracking apps/software tailored to female athletes (e.g., FITR Woman, Wild.AI), and an increased motivation from athletes and coaches to understand how the MC may affect sports performance.[3, 27] However, achieving an accurate understanding is complicated by the high prevalence of hormonal contraceptive (HC) use in elite sport, ranging from 28–58% of elite female athletes depending on the sport(s) and geographical location(s) studied.[3, 12, 16, 17, 21] Hormonal contraceptives (such as oral contraceptive (OC) pills, contraceptive implants, intra-uterine devices (IUD), vaginal rings, and contraceptive injections) deliver exogenous sex steroids in order to prevent pregnancy, thus creating a different hormonal profile. The various preparations of HCs may also produce differential physiological responses and side effects between individuals,[25, 28] so a 'one size fits all' approach to athlete menstrual health is not recommended.[18] For female athletes to make appropriate decisions regarding their MC in the face of emerging research and media attention, it is important that they understand basic female hormonal physiology and the HC options available to them. Unfortunately, the scarce existing research investigating athletes' knowledge surrounding the MC and HCs suggests that current knowledge levels are low.[12]

A study by Larsen et al.[12] assessed the knowledge of 189 Australian elite female athletes surrounding the MC and OCs and determined that knowledge was poor, with athletes only answering ~36% of questions correctly. For example, only 16% of athletes were able to correctly identify both oestrogen and progesterone as the female sex hormones that fluctuate across the MC, and only 18% of respondents were able to identify amenorrhea as a condition of the absence of menstruation.[12] Given the high prevalence of Relative Energy Deficiency in Sport (RED-S)-associated amenorrhea in elite athlete populations and the health risks it presents,[4] this finding is very concerning. While this prior study focused only on the MC and OCs (with no knowledge questions relating to long-acting reversible contraceptive (LARC) HC methods such as contraceptive implants and IUDs), the results suggest that elite female athletes possess a low level of understanding around the MC and the most widely used HC option amongst athletes.[9, 12, 16] This poor knowledge, coupled with a high prevalence of HC use and MC dysfunction in female athlete populations, highlights the need for targeted athlete education surrounding menstrual health. This may be particularly pertinent given the sensitive nature of these topics, which may preclude open discussion between athletes and their coaches/medical support staff[1] and lead to athletes seeking information from potentially inaccurate resources (e.g., the anecdotal experience of teammates, friends, or family).[27] It is also important to note that the existing literature suggests differences in athletes' attitudes towards HCs depending on geographical location; for example, elite female athletes from New Zealand report a relatively lower prevalence of HC use (37%)[9] when compared to athletes from countries like Australia (47-58%),[12, 17] the UK (50%)[16] and the Netherlands (57%).[21] Thus, any educational strategies developed for athletes should attempt to accommodate any cultural differences in attitudes towards the MC and HCs. Moreover, it is possible that the results from the single Australian study may not directly predict the knowledge level of athletes from other nationalities and cultural backgrounds.

For female athletes to make evidence-based decisions regarding their menstrual health, a basic understanding of female physiology and the available HC options is paramount. The existing research that suggests that athletes' knowledge of these topics is low[12] is limited by a primary focus on OCs, which precludes understanding of athletes' knowledge and awareness of other HC options. Encouragingly, select studies have demonstrated the effectiveness of education interventions in improving MC and HC related knowledge in the general population,[6, 14, 26] which suggests that it is possible to improve the status quo. To the current authors' knowledge, no such research has been carried out in athletic populations. Thus, the present study aimed to: (1) assess the existing level of knowledge of the New Zealand women's senior national basketball team and their support staff surrounding the MC and HCs (including popular LARC options); (2) collect MC information, as well as information regarding current and historical HC use, from female players and support staff to help contextualise the knowledge data collected (e.g., participants' history of HC use may, at least in part, explain their knowledge of the various HC methods); (3) use the data collected throughout the first two stages of research to develop and deliver an athlete-focused education session on basic female hormonal physiology and HC options, and; (4) assess the effectiveness of the intervention strategy in improving MC and HC-related knowledge.

METHODS

Participants

All 12 athletes in the New Zealand women's senior national basketball team competing at the 2021 FIBA Women's Asia Cup were invited to participate in this study. The head coach, assistant coach, team physiotherapist, and operations manager (n = 4) were also invited to participate in certain aspects of the research (described in subsequent sections). All participants identified as women except for the head coach. Prior to data

collection, one of the authors (SB) attended a training session with the team and support staff whereby the purpose of the research was explained. Prospective participants were made aware that their participation was voluntary and could be withdrawn at any time, and that completion of the study questionnaire(s) constituted their consent to participation. The University of Southern Queensland Human Research Ethics Committee approved all study procedures prior to data collection (HREC H21REA182).

Protocol Overview

Data collection for this study took place over three weeks while the athletes were travelling to, and competing in, the 2021 FIBA Women's Asia Cup in Amman, Jordan. One of the authors (SB) attended the competition with the team in the role of Athlete Health and Performance Lead, which allowed for direct communication with the athletes/support staff and administration of the study questionnaires. Data collection was completed in four stages (Figure 1). All participants (n = 16) first completed a 'Knowledge Questionnaire' (Stage 1; adapted from Larsen et al.[12]) to assess their current level of knowledge surrounding the MC and HCs. Participants completed this questionnaire in paper format in the presence of a researcher (SB) to prevent them from searching the answers online or discussing their responses. Participant demographic information (e.g., age, height, weight, education level, weekly training hours [athletes], and time spent working in high performance sport [coaches/support staff]) were also obtained. Three days after Stage 1, all female participants (n = 15) completed a 'Prevalence Questionnaire' (Stage 2) which comprised questions relating to their MC and HC use (current and historical). Two weeks after completing Stage 2, all participants were invited to attend an online education session on the MC and HCs (Stage 3). Seven athletes and three support staff (n = 10; all women) attended the online education session while in hotel quarantine due to COVID-19 travel restrictions. After the session, the 10 attendees repeated an online version of the Knowledge Questionnaire (Stage 4) while researchers supervised over Zoom, to assess the effectiveness of the education session intervention in improving knowledge.

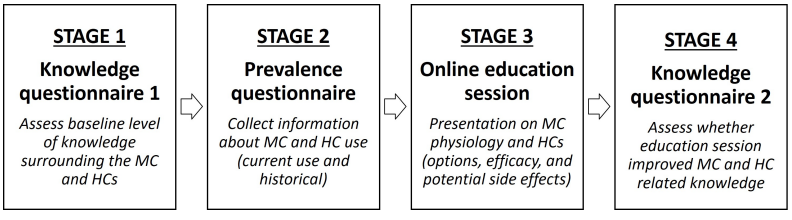

Figure 1. Schematic of the four stages of data collection

Knowledge Questionnaire Development

The Knowledge Questionnaire was adapted from a prior study[12] to include additional questions relating to IUDs and contraceptive implants (these questions were adapted from[7, 13]), as these LARC options have recently been shown to be utilised by elite female athletes[12] (albeit in much smaller numbers than OC pills). The questionnaire comprised multiple-choice questions (MCQs), true/false questions, and questions in short answer format. Questionnaire items are presented in the Results section alongside participant responses (Table 2). Questions 1-8 were MCQs (with four or five possible answers, one of which was correct and one of which was always "I am not sure"), questions 9-14 were presented in short-answer format (i.e., participants were required to write a response), and questions 15-23 required participants to select a response of either true, false, or "I am not sure".

A knowledge score was calculated by allocating a point for each correct answer; all questions were worth one point except for questions 9 and 10 (Table 2) which were worth two points if answered correctly. Thus, the highest knowledge score that could be achieved by respondents was 25. Data were assessed by a single researcher to ensure consistency, using a template of acceptable answers (which were verified using a medical dictionary). Misspelt words were accepted as correct if their meaning was clear.

As previously described, the first Knowledge Questionnaire (Stage 1) was administered in person in paper format. Due to the timing of the online education session (i.e., when the team was in hotel quarantine following the FIBA Women's Asia Cup competition), the second Knowledge Questionnaire (Stage 4) was administered online using an online survey tool (USQ Survey Tool). Participants were not made aware of the knowledge score they achieved in Stage 1 before completing Stage 4. Participants were again instructed to complete the survey without assistance while the researchers supervised over Zoom. The importance of providing 'true' responses was repeatedly highlighted to all participants, and questionnaire completion time was recorded to ensure all participants submitted their responses in a timely fashion while under supervision.

Prevalence Questionnaire Development

Stage 2 involved the female athletes and support staff (n = 15) completing a Prevalence Questionnaire containing questions relating to the MC as well as their past and current experiences with HCs. Participants were first asked the question 'are you currently taking any form of hormonal contraception?'. Depending on the answer to this question, participants were directed to a set of questions. Current HC users were asked the type of HC they used, how long they had been using it, whether they had used another formula/type in the past, their reason(s) for using HC, and any adverse symptoms they experience as a result of HC use. They were also asked about the length and variability of

their MC prior to HC use, and whether they had discussed their HC use with their coach, teammates, and/or family. Oral contraceptive users were also asked about their pill taking regimen (e.g., time of day) and if they ever skip the placebo pills to avoid a bleed. Participants who are not currently using HC provided details about their MC length/variability, as well as whether they had used HC in the past (and if so, what type(s) and the reason for discontinuation). Finally, all respondents were given the opportunity to respond to the question 'Are there any other factors that influence your use (on non-use) of hormonal contraception?'.

Online Education Session

The 30-min online education session was designed to give participants an overview of basic female hormonal physiology and was presented by the lead author (BL). The session comprised information on the MC phases (including female sex hormone fluctuations), 'normal' MC characteristics (i.e., cycle length, duration of menstruation, menstrual fluid volume), common MC issues/conditions (such as pre-menstrual syndrome, dysmenorrhea, oligomenorrhea, amenorrhea, endometriosis, and polycystic ovarian syndrome), HC options (combined OC pills, progesterone only (mini) pills, contraceptive implants, IUDs, contraceptive injections, and vaginal rings; including effectiveness and potential side effects), and general advice for athletes around MC/HC tracking. Participants were also given the opportunity to ask questions during the session.

Data Analysis

All data were analysed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS 24.0). Descriptive statistics were used to describe participant characteristics and the prevalence of HC use and related factors. Knowledge data are presented as frequencies and percentages, and a paired t-test was used to compare knowledge scores pre and post the online education session. Results are presented with 95% confidence intervals and statistical significance was set at $p<0.05$.

RESULTS

Participant demographic information is reported in Table 1.

Table 1: Participant demographics

	Players (N = 12)	Staff (N = 4)
Age (yr)	25.2 ± 2.9	44.8 ± 9.0
Height (cm)	179.0 ± 8.5	177.0 ± 5.1
Weight (kg)	81.3 ± 10.7	78.5 ± 14.8
Education		
High School	1 (8%)	1 (25%)
Bachelor or higher	11 (92%)	3 (75%)
Training load (h/wk)		
11-13	2 (17%)	-
>13	10 (83%)	-
Experience in high performance sport (yr)	-	14 ± 13
Current HC Use		
Yes	3 (25%)	1 (25%)
No	9 (75%)	2 (50%)
N/A	-	1 (25%)
Ever used HC		
Yes	7 (58%)	2 (50%)
No	5 (42%)	1 (25%)
N/A	-	1 (25%)

Values are mean ± SD and frequencies (proportion); N/A = male participant.

Menstrual Cycle Characteristics

The 11 participants who were not currently using a HC reported a typical MC length of 27.8 ± 0.4 days. However, in response to the question "is your menstrual cycle variable?", seven participants (64%) responded 'Yes'. The largest MC length range reported was 27-36 days, with all other participants reporting a MC range between 26-32 days. Five athletes who were not current HC users had used a HC in the past; three had used an OC pill, one had used injectable contraceptives, and one had used an OC pill and injectable contraceptives. The reasons reported for HC discontinuation were adverse side effects (n = 3), inconvenience (n = 2), preferring not to take medication (n = 2), and the benefits no longer being relevant (e.g., contraception, MC control) (n = 2; participants were allowed to select more than one reason). Two participants cited religious beliefs as being influential in their decision not to take HCs.

Hormonal Contraceptive Users

Four participants were currently using a HC; three were using OC pills and one used a contraceptive implant (Implanon NXT). Of the OC users, two used a combined pill (Levelen, Yaz) while one used a progestin-only preparation (Noriday). Two of the OC users (50%) had used a different HC in the past; one had previously taken another brand of OC pill whereas the other had used an IUD. Three participants had been using HC for 1-3 years and one had been using it for 3-5 years, however three participants (75%) reported 'taking a break' from their HC in that time (ranging from 1-6 months). When asked about their MC before HC use, two participants reported a variable MC (of 28-35 days and 28-84 days, respectively), one participant reported a regular 28-day cycle, and one participant was unsure.

The reasons reported for participants' current HC use were pregnancy prevention (n = 3), MC regulation (n = 1), to reduce heavy bleeding (n = 1), to reduce acne (n = 1), relief from headaches (n = 1), relief from painful periods (n = 1), and to manage PCOS (n = 1; participants were allowed to select more than one reason). Three participants (75%) reported adverse symptoms associated with their HC use, including irregular bleeding (n = 3), mood disturbances (e.g., irritability, depressive symptoms; n = 2), and weight gain (n = 1). Only the progestin-only pill user did not report any adverse symptoms. The OC users reported taking their pill 'generally in the morning' (n = 2) or 'within an hour of the same time everyday' (n = 1), and only one OC user reported skipping the sugar (placebo) pills to avoid

menstruation. Finally, all four users of HC reported discussing their HC use with their family, whereas only one participant (25%) had discussed their HC use with their teammates and no participant reported having such discussions with their coach.

Knowledge Score

There was a significant improvement in knowledge score ($p < 0.001$) between Stage 1 (10.2 ± 5.6 marks; 95% CI: 6.2 to 14.2 marks) and Stage 4 (19.0 ± 4.0 marks; 95% CI: 16.1 to 21.9 marks), with a mean change of 8.8 marks (95% CI: 5.9 to 11.7 marks; means only consider those that completed both surveys, n = 10). Changes in knowledge score pre- and post-intervention are presented in Figure 2. During the first attempt of the Knowledge Questionnaire (Stage 1), only 8 out of the 23 questions (35%) were answered correctly by at least 50% of the respondents. Conversely, during Stage 4, all questions with the exception of Question 14 (96% of questions) were answered correctly by at least 50% of the respondents. Responses to individual knowledge questions are presented in Table 2.

DISCUSSION

Even though 60% of participants were current or past users of a HC and the vast majority (94%) were women, the mean score achieved during the first iteration of the knowledge questionnaire was 10.2 out of a possible 25, indicating poor knowledge pertaining to basic female physiology and the available HC options. However, following attendance at a 30-minute online education session, participants achieved a mean knowledge score of 19 marks, indicating a significant improvement in knowledge. These findings highlight the benefit of athlete-focused education surrounding menstrual health in improving knowledge, with the goal of empowering athletes to make informed choices about their MC and use (or non-use) of HCs.

When comparing the percentage of respondents that answered questions correctly between Stage 1 and Stage 4 of the protocol, all but two questions saw an improvement following the education session. Questions 14 and 22 (which related to OC pills and IUDs) saw little improvement (1%) in the percentage of respondents who answered correctly post-intervention, indicating that more time may need to be spent educating athletes on the various HC methods. The 30-min session was designed to encourage attendance and to avoid overwhelming attendees with information; however, it provided limited time for detail when considering the numerous types of HC to be discussed. It is also possible, given the majority of participants were not using HC at the time of study completion, that the MC information was retained better than the HC information as it was considered more relevant. Nevertheless, future education sessions may wish to be extended (e.g., to 45-min) so that key details about the various

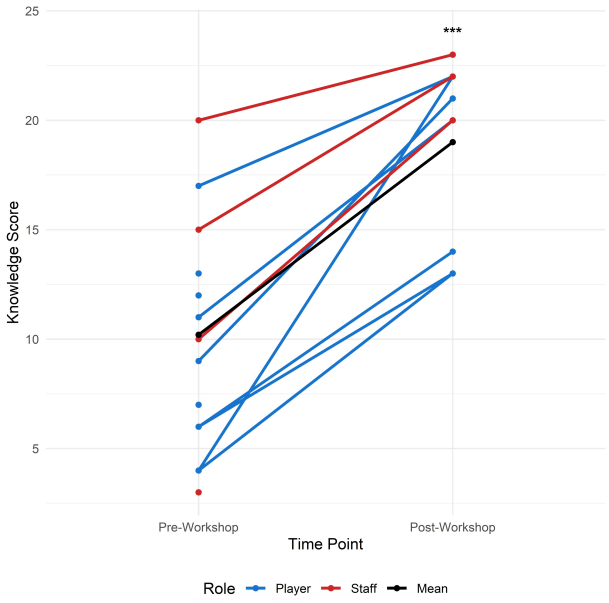

Figure 2. Change in MC and HC related knowledge before and after the online education session. N.B. Means only consider those that completed both surveys, *** indicates $p < 0.001$.

HC methods – particularly OC pills and IUDs – can be expanded upon and/or reiterated.

The percentage of respondents who answered "I am not sure" or gave no answer decreased for all but one question from Stage 1 to Stage 4. It should be noted, however, that Questions 5, 7, 8, 18, 19, 22 elicited a higher percentage of incorrect responses following the online education session when compared to Stage 1. Thus, though participants were less likely to provide no answer or feel unsure after receiving education, in some cases this appears to reflect greater confidence in providing a response rather than an increased accuracy of knowledge. Nevertheless, participants who attended the education session effectively doubled their knowledge score for only a very small investment of time (30 min), which highlights the effectiveness of the session. Prior research has also demonstrated the effectiveness of other forms of MC/HC education in improving knowledge in the general population, such as leaflets[14, 26] and educational text messages[6]. While a presentation was chosen as the intervention in this study to afford athletes and support staff the ability to ask questions, future athlete interventions may wish to engage other approaches to information delivery to value-add to any education session(s). For instance, providing athletes with accurate and relevant resources (e.g., leaflets, websites) on the various HC methods following an education session may be one way to reiterate key information.

The present findings are generally in agreement with the Larsen et al.[12] study investigating Australian elite athletes' knowledge of the MC and OCs, in which athletes answered only ~36% of knowledge questions correctly. As an example,

Table 2. Responses to individual knowledge questions during Stage 1 and Stage 4

Questions	Correct answer	Number of participants correct (%)		Number of participants incorrect (%)		Number of participants that selected "not sure" or gave no answer (%)	
		Stage 1	Stage 4	Stage 1	Stage 4	Stage 1	Stage 4
1. Regarding the menstrual cycle, what may happen to a female who doesn't consume enough energy to support daily living and training activities?	Menstruation may stop	6 (38%)	7 (70%)	1 (6%)	0 (0%)	9 (56%)	3 (30%)
2. What is amenorrhea?	A condition of the absence of menstruation	2 (13%)	8 (80%)	3 (19%)	1 (10%)	11 (69%)	1 (10%)
3. What happens to the natural ovarian hormones produced by the body when you take hormonal contraception (e.g.,	They decrease	7 (44%)	6 (60%)	7 (44%)	3 (30%)	2 (13%)	1 (10%)
4. How many pills are in a standard pack of oral contraceptive pills?	Twenty-eight	6 (38%)	10 (100%)	4 (25%)	0 (0%)	6 (36%)	0 (0%)
5. How many weeks include 'active' pills in a standard pack of oral contraceptive	Three	7 (44%)	8 (80%)	2 (13%)	2 (20%)	7 (44%)	0 (0%)
6. How many weeks include 'inactive' pills in a standard pack of oral contraceptive pills?	One	8 (50%)	10 (100%)	2 (13%)	0 (0%)	6 (38%)	0 (0%)
7. What may happen when 'inactive' pills are skipped and 'active' pills are continuously taken in their place?	Menstrual periods stop	9 (56%)	7 (70%)	0 (0%)	2 (20%)	7 (44%)	1 (10%)
8. Which of the following is not a way in which the combined pill works to prevent pregnancy?	It boosts a woman's immunity so that her antibodies attack sperm	6 (38%)	5 (50%)	0 (0%)	3 (30%)	10 (63%)	2 (20%)
9. Name the female ovarian hormones that fluctuate throughout the menstrual cycle*	Oestrogen, progesterone	3 (19%)	7 (70%)	1 (6%)	0 (0%)	7 (44%)	2 (20%)
10. Name the distinct phases that occur within one typical menstrual cycle#	Follicular, luteal	0 (0%)	6 (60%)	9 (56%)	3 (30%)	5 (31%)	0 (0%)
11. What is the average duration of one complete menstrual cycle (i.e., the number of days from the first day of a period to the start of the next period)?	Twenty-eight days	9 (56%)	8 (80%)	7 (44%)	2 (20%)	0 (0%)	0 (0%)
12. One type of oral contraception is called the combined pill. How many hormones are in this form of	Two	4 (25%)	9 (90%)	2 (13%)	0 (0%)	10 (63%)	1 (10%)
13. Another type of oral contraception is called the mini pill. How many hormones are in this form of	One	4 (25%)	10 (100%)	2 (13%)	0 (0%)	10 (63%)	0 (0%)
14. When taken properly, how effective is the combined oral contraceptive pill at preventing pregnancy? Please write your answer as a percentage	≥99% but <100% accepted as correct	3 (19%)	2 (20%)	10 (63%)	6 (60%)	3 (19%)	2 (20%)
15. IUDs and contraceptive implants are two of the most effective forms of reversible contraception available	TRUE	11 (69%)	9 (90%)	1 (6%)	0 (0%)	4 (25%)	1 (10%
16. An IUD or implant must be inserted and removed by a health care provider	TRUE	14 (88%)	10 (100%)	0 (0%)	0 (0%)	2 (13%)	0 (0%)
17. An implant can protect you from pregnancy for at least 3 years	TRUE	10 (63%)	10 (100%)	1 (6%)	0 (0%)	5 (31%)	0 (0%)
18. An IUD can protect you from pregnancy for 3–10 years	TRUE	6 (38%)	5 (50%)	2 (13%)	4 (50%)	8 (50%)	1 (10%)
19. You can only use an IUD if you have previously given birth	FALSE	8 (50%)	7 (70%)	1 (6%)	2 (20%)	7 (44%)	1 (10%)
20. IUDs and implants contain both oestrogen and progesterone	FALSE	1 (6%)	5 (50%)	4 (25%)	2 (20%)	11 (69%)	3 (30%)
21. IUDs are more effective than oral contraceptive pills at preventing	TRUE	4 (25%)	10 (100%)	4 (25%)	0 (0%)	8 (50%)	0 (0%)
22. An IUD cannot be removed early, even if you change your mind	FALSE	11 (69%)	7 (70%)	3 (19%)	3 (30%)	2 (13%)	2 (20%)
23. IUDs and implants affect your ability to get pregnant in the future	FALSE	6 (38%)	10 (100%)	1 (6%)	0 (0%)	9 (56%)	0 (0%)

Stage 1, n = 16; Stage 4, n = 10. *5 participants in Stage 1 (31%) and 1 participant in Stage 4 (10%) received one point for including oestrogen but not progesterone in their response; #1 participant in Stage 1 (6%) and 1 participant in Stage 4 (10%) received one point for responding with follicular or luteal but not both.

the question 'what is amenorrhea?' was answered correctly by 18% and 13% of respondents in the Larsen et al.[12] study and the present study, respectively. These findings are concerning given amenorrhea is a key component of RED-S, which is associated with deleterious health effects such as osteopenia/osteoporosis, recurrent illness/injuries, and reduced performance and wellbeing.[20] This emphasises the need for education if athletes are to make appropriate decisions about their menstrual health, such as knowing to talk to a doctor if their MC changes or stops. Encouragingly, 80% of attendees at the online education session answered the amenorrhea question correctly during Stage 4 of the protocol, which suggests that the information presented in the education session relating to MC issues was well absorbed. Providing evidence-based education on historically sensitive topics such as the MC and HCs may begin to encourage open conversation between athletes and their support staff, which may be an important factor in the timely identification and treatment of MC-related issues such as RED-S associated amenorrhea.

One possible reason as to why the initial level of knowledge surrounding the MC and HC options was low in this cohort is that the majority of participants had a natural MC (i.e., didn't use a HC) and were, according to their self-reported MC data, eumenorrheic (i.e., experiencing regular MCs). Moreover, HC use was low in this cohort (25%) compared to other NZ studies[9] and certainly abroad.[16, 17, 21] It seems reasonable that women may be less likely to seek education about HCs and MC issues if they are not currently using HCs or experiencing issues with their MC. However, one of the participants had a highly variable MC (up to 84 days) prior to HC use, which is indicative of menstrual dysfunction [8]. In addition, 75% of the current HC users experience adverse symptoms as a result of their HC use, and 60% of the prior HC users discontinued their HC use due, at least in part, to adverse side effects. These findings suggest that athletes could benefit from additional knowledge about the MC and the available HC options, so that current and future HC users are able to choose the HC option that best suits their individual needs, and so that athletes with a natural MC can comprehend the implications of MC disruptions if they occur. Interestingly, in the present study only the participant taking Noriday (a progestin-only OC pill) reported no adverse symptoms associated with their HC use, which contradicts previous research that showed a higher prevalence of adverse symptoms in athletes using progestin-only HCs compared to athletes taking combined HC methods.[16, 22] Of course, the experience of a single participant does not dispute the previous findings; rather, it lends credence to the idea that athlete menstrual health is not a 'one size fits all' approach.

None of the athletes in the present study had previously discussed their HC use with their coach, which supports recent research by Brown et al.[1], who reported that most elite female athletes' do not discuss their MC with their coaches. While the authors are not suggesting that female athletes must divulge everything about their personal life to their teammates and coaching staff, it is important that issues affecting female athletes' menstrual health are not ignored simply due to feelings of embarrassment or awkwardness. However, it is also important that any education intervention is evidence-based and informative but not instructive; participants should be left with the ability to make informed decisions regarding their menstrual health that best aligns with their own individual circumstance (e.g., health status, contraceptive needs, religious beliefs etc.).

A limitation of the current study was a small sample size within one sport (basketball), so it is possible that the results do not directly apply to elite female athletes across all sports. However, it is reasonable to assume that the findings would apply to other female athletes irrespective of sport, as the health information obtained/presented was not basketball-specific. Another limitation of the study is that not all participants attended the education session and therefore not all participants completed Stage 4 of the protocol. While attendance was strongly encouraged, the online education session was held when participants were in hotel quarantine (across different countries) following their competition, and although care was taken to select a time that would suit everyone, only 10 participants completed Stages 3 and 4 of the protocol. Nevertheless, the effectiveness of the session was confirmed by a significant improvement in knowledge score ($p < 0.001$) in those that received the education, with a mean improvement of almost nine marks. Finally, Stage 4 was completed directly after the online education session, which provides little insight into how the information will be retained by the athletes and their support staff. However, it is hoped that even if the breadth of information is not retained, that those who attended the education session will feel more empowered to ask questions and seek additional information from their physician about their MC and/or HC options.

CONCLUSION

Knowledge surrounding the MC and HC options was initially poor amongst elite female basketball athletes and their support staff, with less than half of the Knowledge Questionnaire items answered correctly. However, a 30-min online education session was able to significantly improve knowledge pertaining to menstrual health, with respondents effectively doubling their knowledge score post-intervention. While the MC and HCs can undoubtedly be difficult conversation topics, it is imperative that an open environment is fostered within high-performance sport that allows female athletes to discuss their MC, particularly if issues arise. The results from this study encourage athlete-focused education interventions surrounding the MC and HCs, which will assist athletes in making informed decisions regarding their MC and

use (or non-use) of HCs to optimise their individual health and performance. It is hoped that providing evidence-based education on the MC and HCs also encourages more open conversation between athletes and their support staff regarding menstrual health.

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AUTHOR AFFILIATIONS

Brianna Larsen PhD
School of Health and Medical Sciences
University of Southern Queensland
Queensland, AUSTRALIA
Clare Minahan PhD
Griffith Sports Science
Griffith University
Gold Coast, Queensland, AUSTRALIA
Rebecca McLay-Cooke PhD
High Performance Sport New Zealand
Christchurch, NEW ZEALAND
Kylie Cox BPhty, MSS
Basketball New Zealand
Wellington, NEW ZEALAND
Stephen P Bird PhD
School of Health and Medical Sciences
University of Southern Queensland
Queensland, AUSTRALIA
Basketball New Zealand
Wellington, NEW ZEALAND

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Is there a link between alcohol use and long-term cognitive or neuropathological outcomes in athletes with a history of mild traumatic brain injury? A systematic review

TARA MUNRO, PATRIA A HUME, STEPHEN T CASPER, DOUG KING, JAMES WEBB, ALICE THEADOM
See end of article for author affiliations.

Correspondence
Professor Alice Theadom
Traumatic Brain Injury Network
Faculty of Health and Environmental Sciences
Auckland University of Technology
Private Bag 92006
Auckland 1142, New Zealand
Email alice.theadom@aut.ac.nz

ABSTRACT

Background

Alcohol has been proposed as a risk factor for brain health in sport and is a known risk factor for dementia in the general population. However, any link between alcohol and long-term health effects observed in athletes who have experienced multiple mild traumatic brain injuries (mTBI) remains unclear.

Objective

This systematic review explored links between alcohol use and clinical presentation of cognitive and neuropathological outcomes in athletes with a history of mTBI.

Methods

Systematic searches of library databases from 1970s' using search terms related to contact sports, athletes, traumatic brain injury/concussion, neurodegenerative diseases, and alcohol. Studies needed to present results on: 1) Sportspeople engaged in at least one competitive season of sport; 2) Alcohol use or alcoholism; 3) Participants with a history of mTBI or repeated head impact sustained from sports participation; 4) At least one cognitive or neuropathological outcome; 5) Published in English in a peer-reviewed journal. Data were extracted into a standardised spreadsheet. Included studies were appraised using the British Medical Journal Appraisal Tool for Cross-Sectional Studies.

Results Only five articles presented results directly linking alcohol use with a cognitive or neuropathological outcome despite 101 articles discussing possible links. Quality of evidence in the five studies was moderate. One study reported an association between alcohol use and immediate memory (cognitive functioning). Brain scanning results showed an association between alcohol use and glutamate in athletes, however, more associations with white and grey matter were observed in controls. Only one study revealed higher rates of antemortem alcohol use in chronic traumatic encephalopathy (CTE) cases.

Conclusions There was minimal evidence showing the relative contribution of alcohol on cognitive and neuropathological outcomes specifically in athletes with a history of mTBI.

Key Points

- Only five articles presented results directly linking alcohol use and cognitive and neuropathological outcomes in athletes with a history of mTBI.
- There was little evidence to suggest a link between alcohol and longer-term cognitive functioning in athletes with a history of mTBI.
- There was minimal evidence from studies exploring links between alcohol use and neuropathological outcomes including magnetic resonance imaging, magnetic resonance spectroscopy and CTE diagnosis. Based on one study there was slight evidence of alcohol use as a modifier for tauopathy or increased likelihood of CTE for athlete cases.
- No studies were identified examining a link between alcohol and dementia in athletes with a history of mTBI.
- There was minimal evidence on the relative contribution of alcohol on long-term brain health in athletes with a history of mTBI

INTRODUCTION

Athletes involved in contact sports including American football, soccer, rugby, boxing, wrestling, and hockey, are prone to experiencing multiple mild traumatic brain injuries (mTBI) over their career.[1] A mTBI is defined as a pathophysiological process in which an impact or force to the head or body transmitted to the head disrupts brain function.[2,3] MTBI's cause neurological impairments and symptoms impacting cognitive, behavioural and physical function[3] and long-term detrimental brain health effects.[3-7] A review[5] on cognitive and neuropsychological outcomes for retired athletes identified evidence of decreased cognitive performance on visual and verbal memory, attention, information processing and motor speed when compared with controls.[8] Repetitive mTBI is associated with increased risk of progressive diseases such as chronic traumatic encephalopathy (CTE) and dementia.[9] CTE is a progressive disease and represents one (of many) possible causes of dementia. Dementia is a clinically defined construct, meaning that a patient has objective cognitive/behavioural impairment sufficient to interfere with their ability to perform instrumental activities of daily living independently. Dementia is therefore not a disease per se but is the result of an underlying disease (like CTE, Alzheimer's disease, etc.).

Being informed about potential risks for cognitive, psychological, and neuropathological outcomes that impact on the wellbeing and quality of life post TBI is integral for an athletes' decision-making process. There may be several potential modifying factors between repetitive mTBI and longer-term outcomes that athletes may need to consider (e.g., decision to play, decision to return to play post-concussion) in addition to pre-professional factors (e.g., age at playing, sustaining concussion, initial exposures), game-related exposure (e.g., seasons played, number of concussions and injuries), and post-retirement outcomes (e.g., impairment in cognitive functioning and mood, neurodegenerative disease among others).[10] Behaviour modifying factors may underlie mid- and long-range outcomes such as socio-economic status, stress levels, exercise, alcohol, and tobacco use.[10] The rationale for the interest in alcohol use as a modifier is explained broadly by several factors: (1) The higher prevalence of hazardous drinking behaviour shown in former sports participants than the general population;[11,12] (2) The effects of alcohol on the brain, cognitive functioning, and recovery from a mTBI;[13] and; (3) The question of who, and why, individuals develop CTE, while others do not.[14,15]

In sports such as rugby, athletes report frequent episodic drinking episodes at elite and community levels.[16] High alcohol use has been associated with difficulties in problem-solving, attention and working memory. Symptoms of cognitive impairment following alcohol misuse have been attributed to altered regional brain activation and decreased grey/white matter volumes.[14] Impairment in cognitive functioning in older age may be related to high alcohol use, with a potentially higher risk of developing dementia. World Rugby has recently proposed that alcohol was one of 12 factors influencing long-term brain health. Consequently, cognitive impairment and neuropathological outcomes following mTBI may be exacerbated by, or due to, high alcohol use.[14]

Objective

This systematic review investigated the evidence for the potential role of high alcohol use on long-term cognitive functioning, neurodegenerative outcomes, and likelihood or diagnosis of post-mortem diagnosis of CTE for athletes with a history of mTBI.

METHODS

The systematic review was approved by the International Prospective Register of Systematic Reviews (PROSPERO) on 21/5/2021 (ID: CRD42021250409). To be included in the study, articles needed to meet the following criteria: 1) Published in English language in a peer-reviewed journal; 2) Full text available; 3) Recruited sportspeople engaged in at least one competitive season of sport; 4) Cross-sectional, retrospective or prospective cohort design; 5) Presented results on alcohol use and at least one neurocognitive or neuropathological outcome including CTE; 6) Inclusion of participants with history of mTBI. Neurocognitive outcomes could be assessed via neuropsychological assessment, computerised tests of cognition or self-reported cognitive functioning.

Cognitive functioning encompassed a range of cognitive domains including memory loss/deficits, attention difficulties and executive function.[7] For neuropathological outcomes, the clinical diagnosis of Alzheimer's disease, dementia, mild cognitive impairment, or chronic traumatic encephalopathy were included as well as studies looking at changes in the structure of the brain such as Magnetic Resonance Imaging (MRI).

To ensure a comprehensive view of the evidence of the effects of alcohol, all forms of alcohol use in participants were considered. Due to the heterogeneity in terms used by authors, 'alcohol use' 'alcohol abuse', 'alcoholism', 'alcohol use disorder' and 'alcohol dependence' were all included. Cases of TBI were determined based on self-report and/or medical history as defined by the study authors and cases referred to as concussion were included.

Search Strategy for Identification of Databases

Online databases were searched until 6th July 2021 for relevant literature included CINAHL Complete, MEDLINE and SPORTDiscus, Scopus, Web of Science and PsycINFO. The

search strategy was developed to include terms relevant to the population, variables, and outcomes of interest:

- Group 1 (abstract/title): sport* OR athlet* OR play* OR "sports person" OR sportswom* OR contact sport* OR box* OR football OR rugby
- Group 2 (abstract/title): concuss* OR traumatic brain inj* OR head impact* OR brain inj* OR Head inj* OR TBI OR "skull fracture" OR mTBI
- Group 3 (abstract/title): Alzheimer OR dementia OR "mild cognitive impairment" OR CTE OR neurodegenerative OR "tau pathology" OR "dementia pugilisitica" OR "punch drunk" OR "traumatic encephalopathy" OR tau* OR "major neurocognitive disorder" OR "neurofibrillary tangles" OR "serum tau" OR "senile plaques" OR presenile OR pre-senile OR cogniti*
- Group 4 (whole text): alcohol* OR drink* OR etoh (where etoh is ethanol)

Inclusion-Exclusion Criteria

Identified citations were downloaded into Endnote. Duplicates were removed. Details of remaining citations and abstracts were copied into an Excel spreadsheet. Titles and abstracts were reviewed against the inclusion criteria for population, study design and outcomes by two reviewers (TM, AT) independently with reasons for exclusion recorded in the spreadsheet. For potentially eligible articles the full text articles were obtained and reviewed against the criteria by two authors independently (TM, AT). The alcohol use inclusion criteria were only applied at the full text article stage as alcohol was not always the primary research question of the study and did not feature in the abstract. Throughout the selection process, decisions were compared between the two authors and any disagreements were resolved through discussion. A third author (DK) was required to check one article where there remained uncertainty between the two authors. Following discussion, it was decided that this article did not meet the inclusion criteria.

Data Extraction

To ensure consistency of data extraction by the two authors (TM, AT), data collection headings were used in the excel spreadsheet to guide the data extraction process: 'Lead author surname', 'Year (published)', 'Sport(s) included', 'Cases', 'Controls', 'Number of participants', 'Gender of participants', 'Age range of participants', 'Alcohol assessment', 'Cognitive outcome assessment', 'Concussion history assessment', 'Key findings', 'Country (research was conducted)', 'Funder of research', 'Cognitive/neurodegenerative outcomes linked with alcohol data' (Y/N).

Assessment of Publication Quality

Quality of individual studies was appraised using the British Medical Journal Appraisal Tool for Cross-Sectional Studies (BMJ AXIS) [17] to determine reliability, value, relevancy, and risk of bias [18, 19]. The BMJ AXIS contains 20 items surrounding study design, reporting quality, ethical quality, and potential conflicts of interest - the latter item of which was highlighted for its importance in the review due to its political and societal context [19, 20]. To be rated as being of good quality through this tool, studies must have met most of the questions with a 'yes' response. Two authors (TM, AT) independently rated study quality based on the tool. All disagreements were quickly resolved through discussion and a third reviewer was not required.

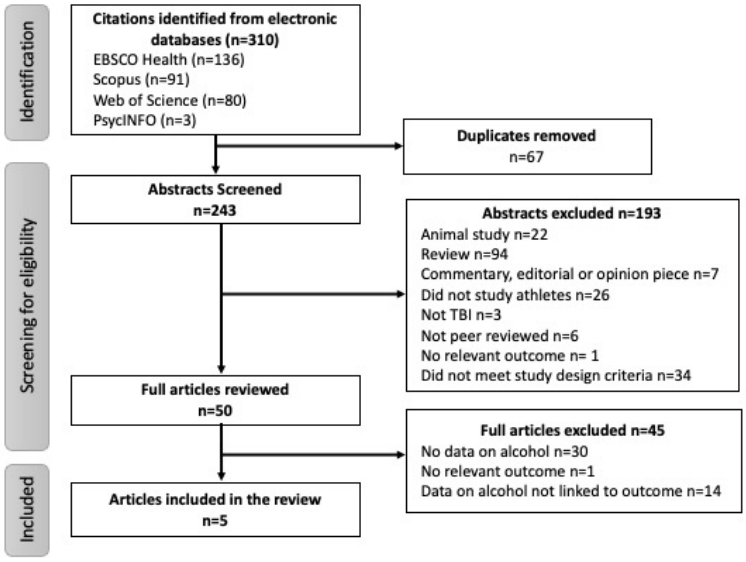

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) flow diagram for the identification, screening, eligibility, and inclusion of studies. *n* = number.

Analysis

There was considerable diversity in methods of assessing TBI history, alcohol use and cognitive and neuropathological outcomes and study designs. Consequently, findings were synthesised using narrative analysis.

RESULTS

For the 310 citations identified from the initial search, figure 1 shows the flow of the selection of studies and review against the inclusion/exclusion criteria. A high proportion (n=101, 52.3%) of articles were excluded as they were a literature review, commentary, editorial or other opinion piece. Of the five articles[3,21-24] that met the inclusion criteria and linked alcohol and cognitive and neuropathological outcomes, four were of a cross-sectional design[3,22-24] and one was a retrospective cohort study[21] that involved post-mortem examinations (Table 1).

Table 1 Characteristics of included studies reporting on alcohol and the long-term neurocognitive or neurodegenerative outcomes

Study; Design; Funding	Country; Sport; Cases; Controls; Participant characteristics (sex, age)	Assessments: 1) Alcohol; 2) Cognitive/neuropathological; 3) Concussion History	Key Findings
Hume et al., 2016 (23) Cross-sectional; World Rugby, AUT and NZ Rugby.	NZ; Rugby: 103 Elite-rugby group; 193 community-rugby group, 65 Non-contact-sport group; male; mean 43.3 yr.	1) Alcohol Use Disorders Identification Test (AUDIT); 2) CNS Vital Signs neuropsychological test battery; 3) Questionnaire: concussion frequency, evaluation for concussion, loss of consciousness or other symptoms, reporting concussion.	More hazardous alcohol use in the rugby players compared with the non-contact players. No significant correlations observed between alcohol use and neuropsychological variables,
Bieniek et al., 2020 (21) Retrospective cohort study (autopsy); Florida Department of Health Ed and Ethel Moore Alzheimer's Disease Research Program, Mayo Clinic Younkin Scholars Program on Synaptic Biology and Memory, Mayo Clinic Alzheimer's Disease Research Center Pilot Project Grant and National Institutes on Aging.	USA; Contact sports: Donated brains - Autopsy sample population; 300 athletes, 450 Non-athletes; male and female; mean age at death athletes 68 yr, non-athletes 64 yr.	1) Alcoholism Diagnostic codes - The Rochester Epidemiology Project; 2) presence of tau-pathology or post-mortem diagnosis of CTE; 3) Medical record query, sports participation assessment	Cases with CTE had higher frequencies of antemortem alcohol abuse compared to cases without CTE.
Gardner et al., 2017 (22) Cross-sectional; New South Wales Sporting Injuries Committee – Sports Research and Injury Prevention Scheme Grant, and Brain Foundation, Australia – Brain Injury Award.	Australia; Rugby: 16 Retired professional rugby league players; 16 age and education-matched controls with no participation in contact sports neurotrauma history; male; 30-45 yr.	1) Alcohol Use Disorders Identification Test (AUDIT); 2) magnetic resonance spectroscopy; 3) concussion history interview	Retired athletes had greater levels of alcohol use than non-injured education matched controls. Significant association between alcohol use and glutamate in retired players not in controls. However, there were more associations between alcohol use in other white and grey matter constructs in controls.
Jordan et al., 1996 (3) Cross-sectional; United States Soccer Federation.	USA; Soccer: 20 Soccer Team training camp members; 20 Age-matched elite track athletes; male; mean 24.9 yrs	1) CAGE questionnaire; 2) MRI imaging; 3) Scale of soccer participation: length of season, frequency of heading.	No significant difference in current or past alcohol use between the groups. There was no correlation between the MRI findings and alcohol consumption.
Mathias et al., 2014 (24) Cross-sectional; National Health and Medical Research Foundation of Australia.	Australia; Sports: 26 sporting-athlete TBI patients; 36 Orthopaedic control group (OC); 27 Physical assault TBI patients and male and female; Sport 28.5 yr, assault 34.3 yr, OC control 34.4 yr.	1) Alcohol Use Disorders Identification Test (AUDIT); 2) WAIS, WASI and COWA; 3) TBI severity score.	TBI sport group had lower levels of alcohol use than the TBI assault group or orthopaedic controls. Alcohol use only correlated with immediate memory on the WAIS assessment but not with delayed memory, vocabulary, block design, similarities, matrix reasoning or the COWA.

The studies largely involved male participants (two studies included female participants), a range of ages (18 to 68 years) and encompassed current professional athletes and retired athletes. A range of contact sports (rugby, soccer, American football, baseball, basketball, boxing, hockey, and wrestling) were included. All studies had a control group with matched participants who were either involved in non-contact sports or had no history of mTBI.

The range of assessments for cognitive functioning included the CNS Vital Signs neuropsychological test,[23] and tests from the Wechsler Adult Intelligence Scale (WAIS) and Controlled Oral Word Association Test (COWA).[24] In terms of neuropathology, Bieniek et al.[21] involved post-mortem examination of participants. Jordan et al.[3] utilised magnetic resonance imaging scores and screening for past neurological illness. Gardner et al.[22] looked at magnetic resonance spectroscopy.
mTBI histories were determined through questionnaire/interviewing. For example, Hume et al.,[23] recorded the number of times participants self-reported they had experienced a concussion during sport and symptoms experienced, or who had received a medical evaluation from a physician for mTBI. Jordan et al.,[3] utilised a scale of 'potential heading' sustained through a participant's sports career through a grading system. Mathias et al.,[24] utilised a grading scale for TBI severity based on the Glasgow Coma Scale (GCS), loss of consciousness and post-traumatic amnesia. Gardner et al.,[22] utilised the 'Rivermead Post Concussion Symptoms Questionnaire' to determine experience of mTBI symptoms in their participants. Bieniek et al.,[21] used medical record query and assessment of sports participation to determine the severity of concussion in addition to presence of tau pathology or chronic traumatic encephalopathy.

Alcohol use assessment in participants was determined through medical record query for the retrospective and prospective cohort autopsy studies. For the other studies, standardised questionnaires were used such as the Alcohol Use Disorders Identification Test (AUDIT)[25] by Hume et al.,[23] Mathias et al.,[24]

and Gardner et al.,[22] while Jordan et al.,[3] utilised the CAGE questionnaire for determining alcohol dependency.

Two studies explored the link between alcohol and cognitive functioning, with only one study showing a link with the single cognitive domain of immediate memory. There was no significant association with other cognitive domains across both studies.[23,24] The one magnetic resonance imaging study showed no association with alcohol use.[22] One study found a significant association between alcohol use and glutamate in athletes, but more associations were found between alcohol and white and grey matter in non-injured controls.[22] One study[21] exploring neuropathological outcomes found cases with CTE had a higher frequency of high alcohol use over the lifetime.

The five studies were rated as of moderately good quality (75-80% met criteria with 'yes' responses) with scores ranging from 14/20 to 15/20 as illustrated in Table 2. The most common methodological weaknesses were a lack of sample size justification (item 3) raising potential issues of a statistically underpowered study and very small sample sizes. All studies had possible selection bias in their participants (e.g., participants self-nominating or selected based on given characteristics). Three studies identified potential conflict of interest either within authorship or via funding source.[3,21] There was insufficient information to determine the role of potential influence of conflict on results. One study involved athletes and patients with TBI who were in the subacute phase of their recovery (5-months post-injury for athletes and 7-months for assault population), with many who were still experiencing incomplete recovery per the GOSE scores reported, which could be considered short-term outcomes.[24]

DISCUSSION

Excessive or problematic alcohol use has been established as a risk factor for a range of adverse biological (lower grey matter brain volume), functional (lower cognition), and clinical (dementia diagnosis) outcomes in the general population. In order to better understand whether alcohol use uniquely influences long-term outcomes in former athletes, it is critical to determine: 1) If the prevalence of problematic alcohol use is higher within this population compared to the general population; 2) If problematic alcohol use interacts with the effects of repetitive head impacts/history of multiple concussions; and 3) What is the nature of these associations (concussion history and head impacts result in executive dysfunction/decreased inhibition which can increase alcohol use vs. alcohol use as a moderator vs. an independent effect of alcohol use). While the results from five studies indicated there is minimal evidence showing a relative contribution of alcohol consumption on the examined outcomes, this conflicts with well-replicated results in the general population. Given that alcohol use is a well-established risk factor for the adverse outcomes observed in the general population, the mixed results observed in our review are likely more reflective of the limitations of cross-sectional research into alcohol consumption (as opposed to recording the cumulative effects of chronic hazardous drinking) than the fact that there is a unique absence of effect of alcohol on former athletes. Without the necessary epidemiological studies, and ability to quantify problematic drinking longitudinally, there is not enough evidence to definitively state rates of hazardous drinking are higher in former athletes. These are critical issues that need to be addressed if we are to better understand the influence of problematic alcohol use and adverse long-term outcomes in former athletes.

High alcohol use within a person's lifetime has been associated with long-term brain health such as dementia in the population.[26,27] Long-term brain health issues observed in athletes who have experienced multiple mTBI may be due to alcohol rather than the mTBI(s). Asken et al.[14] stated that long term effects of alcohol may look like CTE and that clinical symptoms of CTE are non-specific. Alcohol may *moderate* the relationship between trauma and clinical symptoms. The early 1973 Corsellis et al. study[28] noted a high level of alcoholism in their small (n=15) sample of dementia pugilistica. The quite high rates of alcohol abuse in contact sports continue to raise the issue of alcohol as a confound or correlate. Iverson[9,29,30] who has frequently noted high levels of alcohol intake in those with clinical symptoms of CTE (also depression and other psych issues) has never said the disease is due to alcohol. It has consequently been proposed that the long-term brain health issues observed in athletes who have experienced multiple mTBI may be complicated by historical alcohol use rather than the mTBI(s).

This systematic review evaluated evidence for alcohol use influencing risk for later-life neurodegenerative disease in collision sport athletes (a population with most of their head trauma occurring many years prior to onset of progressive clinical decline). Whilst there were over a hundred reviews or opinion pieces discussing a link between alcohol use and longer-term brain health in athletes, there were only five studies of moderate methodological quality that met inclusion criteria. Therefore, there was minimal evidence of a link between alcohol use with cognitive and/or neuropathological outcomes. Further research is urgently needed.

Many narrative reviews and opinion pieces were identified within the review, yet minimal empirical evidence highlights an assumption that the relationship observed in the general population between high alcohol use and increased risk of longer-term brain health issues directly applies to athletes and the development of CTE. A wide range of factors have been identified that may influence long-term brain health including cardiovascular health,[31] diet,[32] physical activity and sleep disturbances.[31] However, many factors will present differently

Table 2 British Medical Journal Appraisal Tool (BMJ-AXIS) analysis of studies in this systematic review

British Medical Journal Appraisal Tool (BMJ-AXIS) item	Lead Author, Year				
	Hume, 2016 (23)	Bieniek, 2020 (21)	Gardner, 2017 (22)	Jordan, 1996 (3)	Mathias, 2014 (24)
1	Y	Y	Y	Y	Y
2	Y	Y	Y	Y	Y
3	N (not provided)	N (not provided)	N (not provided)	N (not provided and very small N)	N (not provided and very small N)
4	Y	Y	Y	Y	Y
5	Y	Y	Y	Y	Y
6	Y	N (differences between excluded and included in sample observed)	Y	Y	Y
7	NA (self-selecting)	N	NA (self-selecting)	NA	NA
8	Y	Y	Y	Y	Y
9	Y	Y	Y	Y	Y
10	Y	Y	Y	Y	Y
11	Y	Y	Y	Y	N (Not all methods clearly specified)
12	Y	Y	Y	Y	Y
13	U	U	U	U	U
14	NA	NA	NA	NA	NA
15	NS	NS	NS	NS	NS
16	Y	Y	Y	Y	Y
17	Y	Y	Y	Y	Y
18	Y	Y	N (limitations not comprehensively discussed)	N (limitations not comprehensively discussed)	Y
19	Y (conflicts documented, potential influence unclear)	Y (no conflicts identified)	Y (conflicts documented, potential influence unclear)	Y (Potential conflict identified, influence unclear)	Y (no conflicts identified)
20	Y	Y	Y	Y	Y
Total Score /20	15	14	14	14	14

Y Yes, N No, U Unclear, *NA* Not Applicable, *NS* Not stated

within an athletic population particularly at an elite level where characteristic profiles will be markedly different to the general population, e.g., diet and levels of physical activity are carefully managed. This review highlighted a significant gap in existing literature exploring relationships between potential influencing factors on brain health specifically within sports populations to explore their relative contributions so athletes can be adequately informed.

Methodological Quality

All five studies were rated to be of moderate quality. A key contributor to reduced quality rating was sample size. Researchers have difficulties collecting enough data to enable testing of hypothesis[33] when the target group is small, there is data sparsity, participants are hard to access, data collection entails prohibitive costs or participants come from a population base prone to drop-out.[33] Three of five studies in this review reported small participant samples. Small sample sizes raised questions of validity and reliability of outcomes in the studies and potential of generalisability to larger populations. Of greater concern was no study reported a statistical power calculation to justify sample size and ensure the study was sufficiently powered. Sample sizes need to be considered carefully.[34] For moderate-to-strong associations, between 20 to 50 cases are needed to identify associations. For small-to-moderate associations that may enable generalisablity, the sample size would need to be 200 participants.[34] Based on this information, the small number of participants in the studies within this systematic review may have limited any likelihood of discovering small-to-moderate true effects.[35]

Three studies reported potential conflicts of interest. Whilst conflicts of interest were clearly stated in the acknowledgements or funding sections of the articles, it was difficult to determine potential influences of conflict. Such clarity is essential for confidence in studies reporting conflicts.

Participants

The studies had a range of ages (18-68 years) and encompassed current professional and retired athletes. Asken et al.[14]

discussed the effects of developmental and environmental variables on cognition, emotional and behavioural changes for contact-sports athletes with a history of repeated mTBI; including socio-cultural factors, ethnicity, and socio-economic status. In addition to physiological factors, these environmental/developmental variables need to be considered to increase understanding of who develops clinicopathological changes following repeated head injury in sport and while others do not.[14] The studies included in the review all provided details of the sociodemographic characteristics of their samples, however these factors were rarely considered in analyses exploring links between alcohol and cognitive and neuropathological outcomes.

Most of the samples within the review recruited self-selecting samples which could bias the results. McKee et al.[36] described this as ascertainment bias in autopsy-based studies, with brain donation being influenced by the health of the individual. The impact of this potential bias was illustrated by Bieniek et al.[21] where a high proportion (16% of athletes and 20% of non-athletes) had 'alcoholism'.[21] In comparing these statistics to the larger U.S. population according to the 2019 National Survey on Drug Use and Health (NSDUH) Annual National Report, 5.3% of people aged 12 and over had an alcohol use disorder[37] suggesting a potential limitation of the generalisability of the study sample. Additionally, of interest in Jordan et al.'s 1996 study[3] was the finding that three of the soccer players had cavum septum pellucidum. Participants in this study[3] were young (soccer mean age 24.8 years old; track athletes mean age 26.4 years old) and actively involved in sport. The authors acknowledged[3] that the possibility of delayed presentation of CTE clinicopathology could not be excluded due to this limitation. The small study sample size possibly limited generalisability of findings to the larger population of athletes. Cavum septum separations have been reported for other sports participants.[38]

Alcohol Use Assessment

Four of five studies in our review used validated assessments of alcohol use.[3,22-24] Three of five included articles[22-24] used the Alcohol Use Disorders Identification Test (AUDIT) [39] developed by the World Health Organisation [40], and validated by authors in different countries. AUDIT has been regarded as the 'gold standard' tool for assessing alcohol use behaviours.[40-43] AUDIT provides scoring cut offs indicative of hazardous alcohol use levels.

Jordan et al.[3] used the CAGE alcohol tool to assess current and past alcohol use and dependency in their participants.[3] The CAGE tool has demonstrated high validity and test-retest reliability in past studies.[44] However, a limitation of the CAGE is that it is less suitable for individuals with low alcohol intake or a moderate form of 'problem drinking'.[44,45] McCusker et al.[46] found that CAGE was most effective in determining lifetime prevalence of alcohol use disorder, and AUDIT was advantageous in identifying 'hazardous' drinkers who had reached a severe level of harm by their alcohol use [46]. These assessments examined recent alcohol use rather than lifetime alcohol use as considered by Bieniek et al.[21] Lifetime patterns of alcohol use may be more relevant to this population than their current drinking pattern. There may be many nuances that could be important on the role of alcohol use and long-term outcome such as whether frequency of binge drinking, alcohol dependency and duration of high alcohol use over the lifetime that need to be explored. People with a history of TBI may well use alcohol to self-medicate leaving individuals who have problems with alcohol misuse and play contact sports professionally at higher risk for further problems. Alcohol misuse is a strong 'predictor' of TBI, potentially putting individuals at a risk of further head injury (an observation made in clinical medicine for well over a century). Exploring alcohol use as a single variable and in a single directional manner could mask more specific influences on longer term brain health. A potential limitation to consider with self-report includes reluctance to self-report honestly due to social stigma with alcohol use disorder.[47]

The long-term effects of excessive alcohol use may look like the symptoms associated with CTE (e.g., memory loss), rather than alcohol use resulting in neuropathological changes that look like CTE. This is an essential distinction that needs to be evaluated. There needs to be further studies to evaluate evidence for any association of alcohol with neuropathological changes which will increase the risk for cognitive/behavioural impairment, and studies to evaluate the association of alcohol with the cognitive/behavioural changes themselves, regardless of presence/absence of neuropathological changes.

Concussion/TBI Measures

Across the five studies, a range of measures determined the participants TBI history. Fadnes et al.[48] described potential issues in self-reporting of TBI history, including social desirability bias, selective recall, issues with question phrasing, and decreased accuracy over time in a 'recall period'. Question phrasing in surveys, and written questionnaires have potential to alter the responses from participants.[48] Selective recall and issues with recall period may be particularly relevant when considering reporting of head injury and TBI, and its impacts of cognitive functioning (including memory). The implications of memory recall issues may be exacerbated by the effects of heavy alcohol use on cognition.[14] Several studies used techniques to assist with participant recall; for example, Hume et al.[23] provided a definition of concussion for the participants to assist with recall and Jordan et al.[3] asked about resulting post-concussion symptoms or loss of consciousness[3] as well as determining first age of head injury, number of head injuries reported, and not reported, and severity of injuries sustained. No reliable biomarker or objective measure of mTBI has been

identified and, given many sports injuries are not reported and mTBI has become better documented in recent times, medical records can often underestimate mTBI history. Despite limitations of self-report, it is currently a key method in ascertaining mTBI history although future research may benefit from strategies to optimise recall and address potential misconceptions that could affect reporting.

Neurodegenerative Outcomes via Medical Imaging Techniques

Studies within the review included participants engaging in a range of sports and included a range of methods of assessing cognitive and neuropathological outcome. A broad definition of outcome was used to ensure capture of potentially relevant literature. If a finding is replicated using different methodologies within different populations, there can be increased confidence that the finding is true. However conversely the heterogeneity of the ways the variables were assessed between studies, and participant characteristics, meant the ability to make inter-study comparisons through statistical analysis was restricted. Data were consequently synthesised using a narrative approach. There did not appear to be consistent findings across the five studies included within this review.

Limitations

Whilst a wide range of search terms used to encompass the different aspects of the research question, it is possible that the search strategy did not elicit all relevant articles. Through initial scoping searches, it became apparent that the role of alcohol was often a secondary research question and thus did not feature in the abstracts of relevant articles and consequently the alcohol search terms were searched across the whole article text rather than restricted to title and abstract. Potentially relevant articles published past the search strategy date, and articles solely published in databases that this study did not include, would have been removed from consideration. As there were only five articles that met review inclusion criteria the impact of excluding relevant studies may have been of importance, albeit all five articles showed minimal evidence of alcohol use as a modifier for outcomes.

A further limitation was the inability to make direct inter-study comparisons between the five articles, particularly with statistical data, due to heterogeneity of outcome measures (i.e., how terms were defined, measured, and interpreted). Different assessments of alcohol use (the AUDIT, CAGE and medical record query), different ways of questioning to determine concussion/TBI history, a broad range of outcomes including imaging and brain pathology. The two studies exploring cognitive functioning used different measures meant that different cognitive domains were explored, further reducing the ability to make comparisons.

Summary of Key Findings

There are political and societal implications given the research results. Synthesis of existing evidence of alcohol use as a modifier for cognitive and neuropathological impacts on athletes with a history of TBI has highlighted key gaps in the evidence base.

The literature review of the five included studies demonstrated that alcohol use was not associated with cognitive function impairment in athletes except on the domain of immediate memory identify by one study.[24] Alcohol use has not impacted MRI findings.[3] However, one study did indicate that hazardous alcohol use was observed in higher frequencies in CTE cases.[21]

The need to understand risk factors and clinicopathological correlation of CTE is required and could be achieved via prospective longitudinal studies.[49] Whether alcohol is a risk factor for clinicopathological correlation of CTE requires a more standardised research approach be undertaken specifically looking at alcohol use and longitudinal changes post head injury. An appropriate methodological approach needs to include reliable and valid measures of alcohol use over time, larger sample sizes to enable moderate to strong correlations to be established, bias in participants (e.g., with autopsy studies) to be addressed, and accounting of additional external variables (other behavioural health-modifying variables).

If alcohol proved to be a modifier for outcomes in neuropathology of CTE, recommendations could be made to reduce its potentially harmful impact. While this review has shown there is no clear evidence linking hazardous alcohol use to long term brain health in athletes (current, retired, or deceased), it may remain a serious co-morbid condition that requires clinical intervention. Education for current players may be needed to reduce any potential long-term detrimental impacts. Further research specifically focusing on the role of alcohol use in athletes with a history of mTBI including female participants in relation to other potential factors is urgently needed.

CONCLUSIONS

This systematic review aimed to identify and critique the literature to explore whether alcohol use is linked in clinical presentations of neuropathology and cognitive functioning of athletes with a history of mTBI. Studies were rated as being of moderately good quality (75-80% met criteria with ‘yes’ responses) through the BMJ AXIS tool. Four of the five studies were based on cross sectional designs preventing exploration of associations over time. The small sample sizes of participants, different alcohol assessment tools, concussion history assessment and various cognitive functioning and psychological measures utilised raised questions of the validity and reliability of the reported outcomes and potential for generalisability to the larger population. There was no conclusive evidence linking

alcohol use to long-term cognitive functioning, neuropathological outcomes, or possible increased likelihood of post-mortem diagnosis of CTE for athletes with a history of TBI. Although it appears unlikely that heavy alcohol use produces a tau pathology that is CTE-like, alcohol may appear as a confounder for CTE for numerous reasons. Given the paucity of included studies and minimal empirical evidence, it is recommended a more standardised methodological approach to further research reporting alcohol use and longitudinal changes following mTBI is warranted.

DECLARATIONS

Data Availability

Data have been presented within the article. Further details can be obtained within the published articles of studies included in the review

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Contributors' Statement

According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed qualify for authorship based on making one or more substantial contributions to the intellectual content of the manuscript. Tara Munro and Alice Theadom were responsible for conducting the literature search, extracting, and analysing the data, interpreting the results and co-editing the manuscript. Professors Alice Theadom, Patria Hume and Stephen T Casper were responsible for the original conception of the project. Patria Hume, Stephen T Casper, Doug King and James Webb provided interpretation of data, provided interpretation of results, and co-edited the first draft of the manuscript. All authors take responsibility for the paper.

Conflict of Interest

Tara Munro, Patria A Hume, James Webb, Doug King and Alice Theadom declare that they have no conflict of interest. Stephen T Casper discloses that he is retained by plaintiffs in concussion litigation pending against sporting organisations.

Compliance with Ethical Standards

This review did not require institutional ethics approval as published literature only were reviewed.

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AUTHOR AFFILIATIONS

Tara Munro

Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

Patria A Hume

Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand

Stephen T Casper

School of Arts and Sciences, Clarkson University, New York, USA

Doug King

Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand

Wolfson Research Institute for Health and Wellbeing, Department of Sport and Exercise Sciences, Durham University, Durham, United Kingdom

School of Science and Technology, University of New England, Armidale, NSW, Australia

James Webb

Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

Webb Psychology, Auckland, New Zealand

Alice Theadom

Traumatic Brain Injury Network (TBIN), Auckland University of Technology, Auckland, New Zealand

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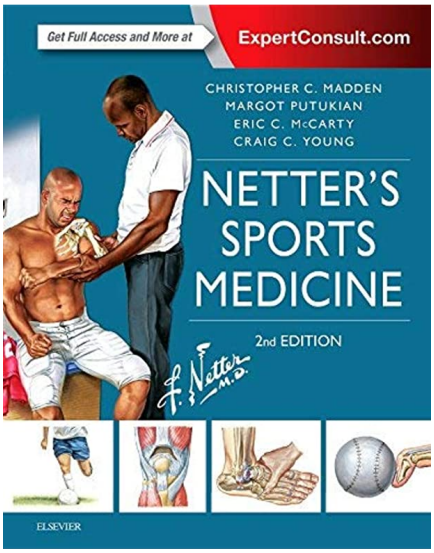

Netter's Sports Medicine

Second Edition 2018

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CHRIS MILNE

I have long been an admirer of the medical illustrations by Frank Netter and regard him as the greatest medical artist since Da Vinci. Having used my copies of a Netter Atlas of Medical Illustrations for the past 25 years, particularly volume 8, the musculoskeletal system, I was intrigued to see how they could be integrated into a sports medicine textbook.

This volume is the spiritual successor to the Team Physician's Handbook by Morris Mellion, published in 1990. This has been a valued reference over the thirty years since then.

So how does this new book stack up? Well, the list of contributors is impressive, with many of those listed being very prominent in the field. It has a heavy USA bias, with only six of the more than 100 contributors being from outside the fifty states. This needs to be borne in mind when reading as recommendations reflect clinical practice in the USA, which may differ from that in New Zealand.

The book is split into several sections, with early chapters devoted to athletic care and environmental issues. Then follows chapters on psychological problems plus general medical conditions. These are followed by chapters on injuries to specific body sites. Possibly the most useful part of the book are the chapters occupying the final 200 odd pages, which cover issues relating to specific sports. These chapters provide a valuable overview for a doctor or physiotherapist who is newly appointed to provide care for athletes from a sport with which they are not familiar. When it came to rugby, I was heartened to note that the chapter had been co-authored by Jon Patricios, a prominent South African sports physician, as knowledge of rugby medicine in the USA could best be described as patchy. The chapter on rowing is written by Jane Thornton and Connie LeBrun; both acknowledged authorities on the sport and rowers themselves. Common rowing injuries are covered well. The various martial arts also received good exposure, which is fortunate as combat sports have a relatively high incidence of injury.

Throughout its length, the book is peppered with illustrations from the famed Netter collection. These enhance the text and are particularly valuable for visual learners like myself.

So overall an excellent textbook and a worthy successor to the Team Physician's Handbook of the last millennium. It has well deserved its place on my rather large medical bookshelf.

Chris Milne
Sports Physician

Disclosure: I bought this book myself and therefore have no reason to promote it inappropriately.