NEW ZEALAND
Journal of Sports Medicine

SPORTS MEDICINE NEW ZEALAND INC

Vol 43 • No 1 • 2016

Official Journal of Sports Medicine New Zealand Inc.

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NEW ZEALAND
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Web: www.sportsmedicine.co.nz

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

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NZ JOURNAL OF SPORTS MEDICINE
Author Information

GENERAL
The New Zealand Journal of Sports Medicine is the official journal of Sports Medicine New Zealand, publishing material relevant to sports medicine and related disciplines. The New Zealand Journal of Sports Medicine welcomes submissions of original manuscripts from both members and non-members of Sports Medicine New Zealand in the following areas: sports medicine, sports physiotherapy, clinically relevant sports science, rehabilitation, coaching issues as they relate to sports medicine, exercise prescription and training, sports chiropractic, sports podiatry, and sports psychology.

Manuscripts must not have been published elsewhere except in abstract form. Manuscripts will be reviewed by the editorial board and/or experts in the field of interest. Submissions are in the following categories: original research, case reports, review articles, editorials, letters to the editor, sports medicine tips, policy statements.

SUBMISSION DETAILS
Manuscripts are to be submitted to:

The Editor
New Zealand Journal of Sports Medicine
Sports Medicine New Zealand Inc
PO Box 6398
Dunedin, New Zealand
Phone +64-3-477-7887
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Corn, Kirk, and the Nature of Innovation in Sports Medicine

BRUCE HAMILTON

Given that Star Trek is one of the most recognisable science fiction franchises, it is surprising to note that the original 1966 television series survived only 3 years before being abandoned due to critically poor ratings. However, so popular did the Star Trek phenomenon subsequently become, that in addition to a number of spin off movies and series, there have been two documentaries dedicated entirely to chronicling the cult-like fan base of self-styled "Trekkies"! Led by Captain James T Kirk, the original Starship Enterprise five year mission was "to boldly go where no man has gone before", and as a result the crew (and script writers) were constantly challenged to provide innovative solutions to complex scenarios. Medical advances did not miss the attention of the Starship script writers, with the charismatic Doctor McCoy serendipitously "discovering" a form of "instant tissue regeneration, coupled with some perfect form of biological renewal", (Episode 19, Series 3,1969) - somewhat akin to descriptions of platelet rich plasma (PRP) found in the medical literature fifty years later. In the microcosm of the sports medicine world, it sometimes feels like we too have to go where no man (or woman) has gone before, constantly challenged by Athletes and Coaches to be innovative, and to push the boundaries on evidence based practice.

During the 2015 Sports Medicine NZ conference (an excellent conference by the way), key-note speaker and Physiotherapy legend Craig Purdam presented on the challenges of balancing innovation and evidence in Sports Medicine. One of the many concepts that I took away from this excellent talk, was that of "Diffusion of Innovation" and I jotted this down, along with the references cited. (Figure One).

Particularly appealing to me was the reference to "innovators" and "laggards" and so I went in search of the 1943 Ryan and Gross manuscript published in the journal "Rural Sociology"- an unusual source for those of us working in sports medicine.[1] The manuscript, entitled "The Diffusion of Hybrid Seed Corn in Two Iowa Communities" documents the systematic uptake of drought resistant hybrid corn in 1930's Iowa. While as far as I can tell this particular corn has no intrinsic relationship with sports medicine "as we know it" (sorry for that, but Trekkies may recognise this not-so-subtle reference to Star Trek), it is a fascinating read. Briefly, in the 1930's following the Great Depression in the USA, a series of droughts and in search of potential fiscal rewards, scientists developed a corn seed which produced higher crop yields. Between 1933 and 1939, land planted with the new hybrid corn increased from 40,000 to 24 million acres (for comparison, the total land area of NZ is 66 million acres). Hoping to understand the process of how new products become integrated into common usage, the researchers interviewed 345 farmers and found that while commercial advertising influenced those farmers who first started using the new technology, ultimately it was farmer to farmer communication that led to the greatest overall uptake. While this was one of the first manuscripts in the field of innovative process (now a recognised academic discipline), they did not use the terminology of "laggards" presented by Purdam – this was from the reference of "Rogers 1962".

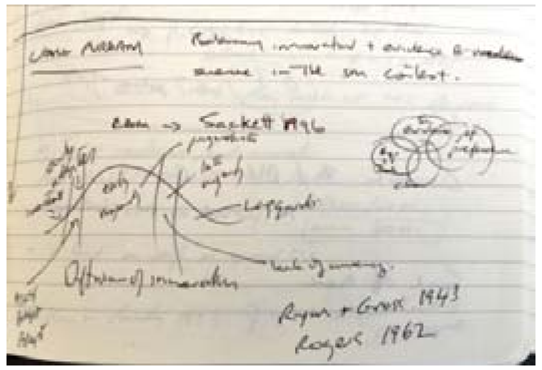

Figure 1: Notes made from the Craig Purdam keynote address 2015.

Written by Everett Rogers (1931-2004) the book "Diffusion of Innovations" is now in its 5th edition and has won numerous awards, including in 1990 being designated a "citation classic" by the Institute for Scientific Information (based on citations numbering more than 7000!).[2] I had never heard of it before. Like Ryan and Goss, Rogers was a graduate student from Iowa state University, completing his PhD in 1957 (again for Trekkies, it is worth noting that it is likely only a coincidence that Iowa in the 1950's was a hotbed of innovative process research, but was also the designated birthplace of Captain James Tiberius Kirk, champion of innovative practice). While it is this text that first defines different groups of adopters of new technology as innovators, early adopters, early majority, late majority and laggards, it does so much more. In the latest edition published in 2003, Rogers summarises thousands of articles published on this topic since the ground breaking work of the 1940's, and outlines concepts highly relevant to "cutting edge" sports medicine practice. Two particular concepts that I liked were the challenges of "preventive innovation" and the "characteristics" of innovations that influence the uptake of novel processes. The former establishes an academic rationale for the difficulties observed in disseminating novel innovations related to prevention, which invariably have a very slow rate of uptake into mainstream use. This difficulty allegedly results primarily from the invisibility of prevention outcomes (that is, how do we know if we have actually prevented an injury or illness), and may account for the challenges encountered in the global implementation of injury prevention programmes.[3] By contrast, the characteristics of innovations that facilitate the rapid adoption of new technology include the relative advantages of the new technology (to patients and/or Doctors), compatibility with current practice, complexity of the technology (easier is better), trial-ability (how expensive is it to get the kit to "have a go") and observability (how easy it is to see the process). Each of these factors will influence how quickly a novel technique will be taken up by practitioners. However, over and above all of these factors, the most powerful influence on the rate of adoption of new technology is peer-peer inter-personal communication and this is likely a truism in Sports Medicine practice. Intriguingly, the most innovative members of (sports medicine) communities may often be perceived by their peers as "deviant" and have marginalised credibility due to their extreme views. By contrast, true opinion leaders are characterised by being both technically competent and socially acceptable due to their tendency to conform to the norms determined by their peers.

This is all very well and good, but so what?

Over the last 15 years or so, a range of novel sport medicine and rehabilitation innovations have come and gone. Very few of those innovations have achieved practitioner saturation that would be expected when a novel approach is shown to be effective. While many novel techniques appear to find a level of usage from individual practitioners, very few achieve universal acceptance (eccentric tendon loading may be an example of overwhelming adoption, but even this is now challenged on multiple fronts). Reflecting on my own (somewhat concerning) history of innovation adoption may well reflect a process that many of us have experienced or observed during our careers.

In 1998, on the basis of a single manuscript reporting the benefits of autologous blood injections into rabbit tendons,[4] Craig Purdam, myself and other colleagues at the Australian Institute of Sport, began trialing the injection of recalcitrant patellar tendinopathy cases with autologous blood. Anecdotally, the results were mixed but encouraging enough that I became very enthusiastic about this novel technology and its (il-) logical extrapolation PRP. Subsequently, I became a strong advocate for the application of these techniques in my various work-places, and was encouraged enough to research and publish on this topic.[5] PRP is now heavily promoted (and if we believe the propaganda, utilised) for a range of sports medicine related injuries. However, at the same time that I was actively utilising this tool, I was becoming increasingly skeptical of its purported "magical" ability and increasingly questioned the approach of those companies promoting its use. Indeed, while acknowledging the limitations of our research, our team's best efforts failed to show any benefit of PRP in an acute hamstring injury, over high quality physiotherapy care.[6] As a result of critically evaluating our outcomes, I became increasingly disillusioned with the use of PRP as a mainstream intervention, while others have remained convinced of its utility. This experience has influenced my attitude to much of clinical medicine, with an increasingly skeptical view of new and novel interventions and a reality check on what we actually understand of how the body works. Applying the principles of Rogers 1962 to my personal experience, it appears that over my career I have likely migrated from being an innovator / early adopter (and probably being considered a deviant) to being a laggard (and probably being considered deviant). Does this make me a better or worse practitioner? – I'm not sure.

Beyond the observation that Iowa was both a hub of innovative research in the 1950's and the birthplace of James T Kirk, its most famous fictional son and icon of innovation, what can we conclude from this ramble through the corn fields of Iowa? I would contend that innovation is critical if sports medicine is going to continue to develop as a specialist field, but that innovation without critical evaluation will never result in universal adoption. We must embrace innovators and early adopters (including those we may perceive as deviants), but at the same time challenge and expand the evidence base. As clinicians we must actively seek opportunities to perform research in all its varying forms, (and publish this in esteemed journals such as this….), in order to challenge both historical and novel dogma. Only by taking this critical approach do we avoid the trap of confirmation bias that pervades uncritical clinical practice. Finally, we must not shy away from change as that will ultimately render us irrelevant to the individuals we are here to help. The field of Sports Medicine requires innovators and early adopters, but also high quality research, and (with respect to Jean Luc Picard from Star Trek's Next Generation) we all have a responsibility to "make it so".

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Rio de Janeiro Olympic/Paralympic Games 2016

With only a few months to go until the opening ceremony of the Rio Olympic and Paralympic Games, it is a great opportunity to wish our athletes the best. The Olympics is an incredibly difficult event in which to be successful, and New Zealand's athletes will be under immense scrutiny over the coming weeks. Given what we know about Rio, the 2016 Olympics will be both exciting and challenging for all involved.

It's also appropriate to acknowledge the large number of Sports Medicine New Zealand members who will either be involved on the ground in Rio, or who have contributed to the athletes' preparation over recent years. Anonymously supporting athletes and coaches can seem to be a thankless task at times, but seeing NZ's athletes competing to the best of their ability on the international stage truly is inspirational to the broader NZ community. The key role that SMNZ members play in the preparation of NZ athletes should be not be overlooked or minimised.

To those travelling to Rio as part of the team – good luck, go hard and may you form many good memories.

Sports Medicine New Zealand - Who are we?

STEPHEN KARA

My recent election to Chairman of Sports Medicine New Zealand (SMNZ) may have many members wondering who I am and what does this mean for our organisation. So firstly let me introduce myself - I am an Auckland based sports doctor, currently working solely in rugby medicine, have been a member of our organisation for over 20 years and am the current president for the Auckland Branch of SMNZ.

SMNZ has operated as a not for profit organisation benefiting its members, primarily focusing on post-graduate education and collegiality. Key functions listed on SMNZ website under What Are Sports Medicine NZ Functions? (www.sportsmedicinenz.co.nz/about) state some of our functions to be cooperation with national bodies, advisory roles with local and national bodies and community health matters especially related to recreational and physical activities of all age groups (points 5 – 7). But how much have we really focused on these? The recent national conference held in Christchurch was themed 'Life is Movement' and produced an excellent turn out, linking well with the community. This was an excellent start to pave the way for discussion around exercise as a prescription/treatment for health conditions at a community level. So how can we foster this further? Following the lead by our Australian counterparts needs to be considered. Rebranding may be required to incorporate the importance of exercise in the organisational name to allow us to claim this space. I believe this will signal to advisory bodies and the community that we acknowledge the need to adopt a wider role and that we are not just concerned with sports. As an example we have the expertise to advise those funding and guiding the management of chronic medical conditions.

SMNZ should be the flagship for sport and exercise health in New Zealand and must become a recognised stakeholder amongst health boards and funding agencies, with our branding evident on policies and guidelines plus membership representation on various national working groups.

The strength of our conference has been the quality of the international speakers and local researchers, with attention to scheduling to ensure smaller clinical practical sessions. The success is an acknowledgement of the hard work from the national executive and the international collegial relationships they maintain. This format has been attractive and should be retained. Whilst our identity is important, we should consider a more collaborative approach with other professional bodies. Our discipline requires a multi-disciplinary approach and the maintenance of relationships is critical. We can achieve this formally with conference collaboration or integration and in a country of our size, economy of scale makes a lot of sense to me. The additional fostering of informal communication between providers at such events is immeasurable and at present, I believe we are missing these aspects.

Finally we must address membership value. What are we providing for our members and what is the attraction to belong to our organisation? Financial constraints have limited us in this respect and in order to provide more we must be able to secure more. Looking for alternative financial avenues outside of our traditional income stream will be necessary to provide attractive membership benefits. This will require thinking outside of the box.

I challenge all members to be represented at the Annual General Meeting (coincidentally held in conjunction with the annual national conference) to provide direction for the national executive as to the future function of SMNZ. Are we to be a conduit for educational purposes or are we to be a visible face in the exercise and medicine arena? We must not let apathy be a cause for stagnation and we must be constantly looking for a sustainable future.

Stephen Kara
National Chairman
Sports Medicine New Zealand

BEST OF BRITISH - HIGHLIGHTS FROM THE BJSM

CHRIS MILNE

This column covers 12 issues of BJSM from July to December 2015 so coverage will necessarily be highly selective.

The July 2015 issue published in conjunction with the IOC contained a consensus statement on youth athletic development.[1] It covers issues such as physiological and performance changes occurring across maturation, plus injury and health concerns of systematic training and competition. It argues against early sport specialisation and in favour of increasing the opportunities for children to discover the sports that they enjoy and and at which they may possibly excel.

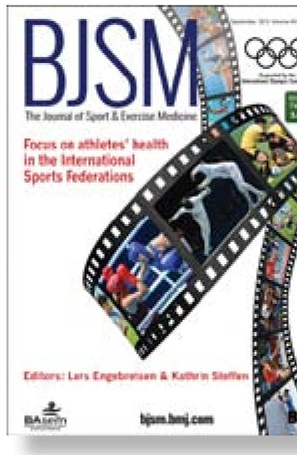
Issue 14 was edited by two senior New Zealand sports physiotherapists, Hamish Ashton and Anthony Schneiders. It included a best practice guide to the conservative management of patellofemoral pain, with the lead author Christian Barton from University of London, UK.[2] The guide recommends an individually tailored, multi-modal intervention programme including gluteal and quadriceps strengthening, patella taping and emphasises education and activity modification. Evidence also supported the use of foot orthoses and acupuncture.

Later in the same issue was an article entitled 'Platelet rich plasma does not enhance return to play in hamstring injuries: a randomised controlled trial'.[3] This is an open access article with the lead author being none other than Bruce Hamilton, our editor. The randomised three arm parallel group trial enrolled 90 professional athletes and established that there was no benefit of a single PRP injection over intensive rehabilitation in athletes who sustained acute MRI-positive hamstring injury. They concluded that intensive physiotherapy remained the primary means of ensuring an optimal return to sport following hamstring injury.[1]

Also in the same issue was a prospective cohort study of 76 New Zealand representative rowers looking at the prevalence, incidence and severity of low back pain.[4] Led by the HPSNZ and Rowing NZ health team physiotherapist, Craig Newlands, they found a high correlation between new episodes of low back pain and total training hours, with increasing age also being a risk factor for development of low back pain.

Issue 15 examined the controversy surrounding physical activity, diet and obesity. One editorial written by Malhotra and Tim Noakes was entitled 'It is time to bust the myth of physical inactivity and obesity: you cannot outrun a bad diet'.[5] Their conclusion was that the junk food industry, with its use of celebrity endorsements of sugary drinks, had increased commercial profit at the cost of population health. However, some of their conclusions were attacked in an editorial which immediately followed it written by Steven Blair, well-known researcher from the USA.[6]

Post-traumatic arthritis after ACL injury is a common phenomenon. A systemic review by van Meer and colleagues from Rotterdam concluded that medial meniscal injury after ACL rupture increased the risk of post-traumatic arthritis.[7] Lateral meniscal injury did not. Importantly, they also concluded that the time to an injury and reconstruction did not influence development of later arthritis. One minor pedantic point is that they refer to this as osteoarthritis, whereas a more accurate term would be post-traumatic arthritis; this can have implications when insurers are involved in the management of such cases.



Issue 16 included an article with the rather inaccurate title 'Ultrasound guided shoulder girdle injections are more accurate and more effective than landmark guided injections: a systematic review and meta analysis'.[8] As a fan of selective use of technology, I read this article by Aly and colleagues from Edmonton with some scepticism. Sure enough, when one delves further into the article, they explain that subacromial injections can be performed just as accurately using landmark guidance as opposed to ultrasound. Given the greater costs involved with use of ultrasound guidance, plus the fact that many people receiving ultrasound guided injections are not seen by clinicians who later organise rehabilitation, I would argue that in the first instance a subacromial injection should be performed by a clinician who is experienced in the procedure, and can ensure that appropriate rehabilitation is arranged following such an injection.

It is always good to read studies that indicate that clinicians follow evidence-based guidelines. One such study emanated from Finland recently.[9] Mattila and co-authors found that there had been a decrease of 42% in men and 55% in women who were treated surgically following acute achilles tendon ruptures since 2008 and 2007 respectively. I suspect the findings in New Zealand would be similar in that same timeframe.

Issue 17 published in association with the IOC focused on athletes' health, with articles contributed by senior figures from the international sports federation. An article by McIntosh and Patton examined boxing head guard performance in punch machine tests.[10,11] They found head guards reduced linear and angular accelerations by almost half. Therefore, it is rather ironic that the International Boxing Association banned the use of head guards in selected competitions. This ban has been carried over to the Olympic boxing competition in Rio this year. To my mind, this is hardly an example of a sporting body acting rationally to protect the health of their athletes. I suspect that over time the decision will be reversed, but it will be an uphill battle.

Pre-participation health questionnaires have been a controversial tool. An article by Juan Manuel Alonso and colleagues from the International Association of Athletics Federations found that the questionnaire was an effective screening tool prior to the Moscow 2013 IAAF World Championships.[12] Athletes who reported a pre-participation injury complaint were at double the risk for an injury during the championship itself.

Exercising in the heat is a challenge for athletes in most summer sports. Issue 18 contained a consensus statement with up to date recommendations for athletes.[13] The most important intervention is heat acclimatisation, with repeated exercise heat exposures for one to two weeks prior to the competition. In addition, athletes should train and compete in a euhydrated state. Event organisers should plan for large shaded areas and provide cooling and rehydration facilities plus schedule events in accordance with minimising the health risks to athletes. Longer recovery periods between enduring events to allow opportunity for hydration and body cooling are also recommended.

As we get older, we pay more attention to articles relevant to our age group. One such was review of an article by Uthman and colleagues regarding exercise for lower limb osteoarthritis. They found that comprehensive programmes combining strengthening, exercise, flexibility and aerobic exercise provided the greatest probability of benefit.[2]

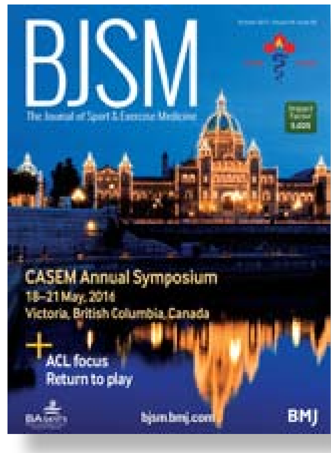
Arthroscopic surgery for degenerative knees has been performed commonly, despite the evidence base being known to be weak. Two linked editorials by Andy Carr[14] and John Orchard looked at this issue. Orchard concluded that doctors often make non-rational decisions, possibly because they use their 'fast' brain in a purely reactive manner rather than taking the time to go through the options in a more considered manner.[15] One can see how this happens in busy clinics, and we need to be on our guard to prevent it happening in our own consulting rooms.

If you are looking for a concise article on prevention and treatment of hamstring injuries, it is hard to go past that written by Peter Brukner in Issue 19 of BJSM.[16] Multiple hamstring injuries are the same and those that are a slow stretch type of injury and/or involve the central tendon require longer times to return to play. Recurrence rates remain high, and strength deficits may be an important factor in this.

There is increasing evidence of tools to predict hamstring injury and Nordic hamstring exercises have been shown to reduce the incidence of these injuries in season. They recommend three sessions per week during the 10-week pre season programme, and one session per week during the competitive season.

Thomson and colleagues examined the lower extremity risk with varying shoe surface traction coefficients.[17] They found that high levels of rotational traction were associated with 2.5 times the risk of non-contact lower limb injury and that rotational traction was affected by the ground surface as well as the athlete's shoe. In essence, a little bit of slippage is no bad thing.

Finally in this issue was an article entitled 'Isometric exercise induces analgesia and reduces inhibition in patella tendinopathy'. The lead author Ebonie Rio spoke at the SMNZ Conference in Christchurch in late 2015. In essence, a single resistance training bout of 5x 45 second isometric exercises with 2-minute recovery at a resistance of 70% 1RM reduced pain and increased maximal voluntary isometric contraction. This gives us something to offer our patients with problematic tendons that can help them through a competition season.



Issue 20 in October featured an article by Benno Nigg and colleagues entitled "Running shoes and running injuries: myth busting and a proposal for two new paradigms: preferred movement path and comfort filter'.[19] This article challenges a lot of the prevailing dogma regarding biomechanics and running shoes. It proposes that a runner intuitively selects a comfortable product using their own comfort filter that enables them to remain in their preferred movement path. This may automatically reduce the injury risk and could go part of the way to explaining why the frequency of running injury has not changed over the past 40 years. The authors conclude that there is little evidence for pronation and impact forces as being risk factors, despite these being considered primary predictors of running injuries.

Does running protect against knee osteoarthritis or promote it? These questions were debated by Richard Leech and colleagues in an editorial in the November issue of BJSM.[20] The authors conclude that a prospective longitudinal observational study is required to identify known and novel risk factors for knee OA amongst recreational runners. At present they conclude that the definitive answer to the question remains elusive.

The hazards of physical inactivity are well documented. Buckley and co-workers provide expert guidance for employers to promote the avoidance of prolonged periods of sedentary work. Their consensus statement was entitled 'The sedentary office: an expert statement on the growing case for change towards better health and productivity'.[21] They propose that desk based workers should initially progress towards accumulating at least two hours a day of standing and light activity and then progress to sit-stand adjustable desk stations and that employers should be actively involved with the process.

Patellofemoral pain is the commonest musculoskeletal problem in most sports medicine practices. Simon Lack and colleagues conducted a systematic review and meta analysis of proximal muscle rehabilitation.[22] They identified 14 studies and found strong evidence that rehabilitation of proximal muscles, principally gluteus medius, was effective in the rehabilitation of patellofemoral pain.

Exercise and pregnancy has long been a controversial area. Barakat and colleagues provided a narrative review asking, what do we know about this topic?[23] They concluded that in the absence of obstetric complications, the healthy pregnant body is able to cope with the physiological demands imposed by moderate exercise, and that moderate exercise was not a risk factor for adverse foetal and maternal pregnancy outcomes. They go further and suggest that a supervised programme of moderate exercise throughout pregnancy may be recommended by health professionals to attenuate the risk of pregnancy complications.

Issue 20 included an article near to my heart entitled 'Can you feel the real paper'.[24] Borjesson and colleagues argue that although electronic journals have made significant progress in the past few years, there are a few advantages of the old 'paper journal'. These included better visibility in sunny situations plus less adverse effects from the odd drop of rain on paper compared with electronic devices. Also, they comment that paper journals cannot be lost due to hard disc failure, or unavailable due to a failed internet connection. Worth a read, whatever your views on this topic.

Later in the same issue was a personal viewpoint entitled 'Stop hunting for zebras in Texas: and the diagnostic culture of "rule out"'.[25] Suarabh Jha, a radiologist in Philadelphia, comments that we need to make the most of clinical context rather than order every investigation, to which I say 'hear hear'. He comments that conquering uncertainty is impossible and that 'rule out' philosophy begets more tests and more uncertainty. Yet another advocate for selective application of technology and all it involves.

Finally in the same issue was the statement of the Third International Exercise Associated Hyponatraemia Consensus Development Conference held in Carlsbad in 2015.[26] This[3] consensus built on the two earlier conferences and the bottom line is drinking to thirst to maintain plasma volume within the normal range for the activity and prevent excessive dehydration whilst maintaining plasma osmolality within the normal range. This, in turn, will minimise the risk of hyponatraemia.

Issue 23 could be called the exercise genomics issue. It contained a consensus statement by Nick Weborn and colleagues regarding direct to consumer genetic testing for predicting sports performance any talent identification.[27] These authors express concern over the lack of clarity of information over which specific genes or variance are being tested and the lack of appropriate genetic counselling for the interpretation of the genetic data to consumers. In essence, this resting is usually commercially driven and cannot be regarded as having the athlete's health as a high priority.

Is a higher serum cholesterol associated with altered tendon structure or tendon pain? Ben Tilley, Jill Cook and colleagues looked at this issue and concluded that the answer was yes. Meta analysis of 17 studies showed significantly higher total cholesterol, LDL and triglyceride and lower HDL cholesterol in individuals with tendon pain or structural abnormalities.[28] Statin use was associated with achilles tendon rupture in women but not in men.

Issue 24 included an article on prediction of time to return to sport after acute hamstring injury.[29] Wangensteen and colleagues looked at 180 male athletes with acute hamstring injuries and concluded that MRI scanning only explained 2.8% of the variants in time to return to sport. You can bet that it contributed a good deal more than 2.8% of the total cost. Therefore, this is yet another reason for coaches to trust their clinicians rather than what is reported on an MRI scan.

Exercise has long been thought to favourably improve mental health. Cooney and colleagues conducted a Cochrane review of 39 randomised controlled trials looking at exercise in the management of depression. They concluded that exercise reduced depression symptom severity, but it was unclear if the effect remained after participants stopped exercising. However, trial reports did not provide precise details on how the exercise was implemented, e.g. type, duration, frequency or supervised. Nevertheless, given the positive effects of exercise on circulating endorphin levels, the evidence for a positive link in treatment of depression is highly plausible.[30]

My selection for most valuable article over this six month period would be that entitled 'Stop hunting for zebras in Texas'. This article, plus the article on MRI and its low predictive value in time to return to sport, should be required reading for coaches and administrators plus medicolegal practitioners. They provide compelling reasons for selective application of technology, which should benefit both patients and the health system budget.

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A previous ankle sprain does not influence the balance of netball players

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ABSTRACT

Aim

Netball is a sport known for its high incidence of ankle sprains. Owing to the specific rules of the game, balance is an important skill in netball. The current study aimed to determine whether a prior ankle sprain influenced the balance of netball players. A secondary aim was to determine whether the competitive level of netball players had any effect on their balance abilities.

Study Design

Cross-sectional

Setting

University sport halls and community rooms.

Participants

Ninety-six female netball players from club and inter-district teams.

Interventions

Self-reported lifetime ankle sprain history.

Outcome Measures

Dynamic balance was measured using the Star Excursion Balance Test in the anterior, posterior-lateral and posterior-medial directions. Static balance was assessed with the demi-pointe balance test and the number of footlifts during 30 seconds of unilateral stance.

Results

Seventy-two percent of participants reported previously sustaining an ankle sprain. There were no differences in any balance measure when comparing participants with, and without, a previous ankle sprain ($p \geq 0.05$). The competitive level of netball players was shown to have no effect on balance ability, with club and inter-district participants achieving similar results across all balance measures ($p \geq 0.05$).

Conclusions

Neither the static or dynamic balance of netball players was influenced by a history of ankle sprain. Even though inter-district players are chosen in their teams for displaying heightened netball abilities, their balance was similar to club players and provides a theory that these balance measures are not suitably sports specific to the balance skills required for netball.

Key Words

Athletic performance, Ankle injuries, Postural control, Sport

INTRODUCTION

Netball is a fast paced, multi-directional ball sport that involves running, sprinting, jumping, cutting and shuffling.[4] Although the sport originated from basketball, netball has a unique set of rules that differentiate it from its predecessor; competitors must remain within specific areas of the court based on their playing position, defenders must remain three feet from an attacking player in possession of the ball, and the ball cannot be dribbled.[19] Furthermore, netball has a footwork rule in which a player, once in possession of the ball, is not allowed to take any further steps with their landing leg until the ball is released,[19] often resulting in a netball player balancing on one leg.[14]

As a result of netball's unique rules, balance is thought to be an important skill for a netball player.[16,23] It has been suggested that the assessment of balance within a netball cohort should incorporate both static and dynamic measures.[15] In a static sense, balance allows players in shooting positions to remain stable and aim for goal, and allows defenders to obstruct a pass, or shot at goal, by holding a defensive pose in a plantar-flexed position whilst maintaining the ground distance rule. It is also important for a netball player to be able to maintain dynamic balance in order to avoid violating the footwork rule when in possession of the ball and/or remain within specific areas of the court.

Amongst netball players, the ankle is the most commonly reported site of injury.[3] Between 30 % and 84 % of all netball injuries affect the ankle,[13,17,18] with sprains making up the large majority of injuries to the joint.[3] Irrespective of the exact percentage values, research has highlighted that ankle sprains within this sporting group are a concern. Court sports have the highest ankle sprain incidence rate within all sporting categories[2] and the main population group participating in netball – women – have a higher incidence of ankle sprains compared to males.[2]

Balance deficits in the form of centre of pressure area, centre of pressure velocity and postural sway index are observed in both the acute and chronic phase following an ankle sprain;[27] however, the effect of a prior ankle sprain on more field based measures of balance are not as widely investigated. Owing to the rules of netball, and the common occurrence of ankle sprains during participation, it is important to identify whether a previous ankle sprain influences the balance abilities of netball players.

The characterisation of balance skills in regards to previous ankle sprain history within a cohort of netball players has not, to the authors' knowledge, been previously investigated. The primary aim of the current study was to determine the impact of prior ankle sprain history on the balance of netball players. It was hypothesised that individuals with a history of previous ankle sprain would perform worse in all balance tests compared to uninjured players. A secondary aim was to profile differences in the balance abilities between club level and inter-district level netball players. Due to both increased speeds of play and agility requirements at higher levels of netball competition, it was hypothesised that the inter-district netball players would perform better across all balance tests compared to the club players.

METHODS

The study received ethical approval from The University of Sydney Human Research Ethics Committee. After being informed of procedures and providing their written consent, a total of 96 female netball players participated in the study – fifty-four participants played netball at an inter-district level and 42 played netball at a club level. The majority of inter-district participants were netball players from the Sydney University Netball Club/City of Sydney Netball Association Elite Development Squad, while additional inter-district and all club players were conveniently sampled. Participant demographics are presented in Table 1. To determine previous ankle sprain history, each player completed a self-administered form to report the location and number of previous lifetime ankle sprains that had resulted in immobilisation and/or a cessation of activity.

The current study analysed pre-season cross-sectional data from a longitudinal study aimed at identifying risk factors for ankle sprain during a netball season. To be included, each participant was required to have had at least one year of experience playing netball and be registered to play in the following netball season. Furthermore, participants were required to be at least 15 years old at the time of pre-season data collection. Participants with a history of ankle fracture or ankle surgery were excluded, as were participants with any lower limb injury sustained within the six months prior to the study.

Each of the three balance tests selected for the current study have previously been shown to be affected by past ankle injury[10] and/or acknowledged as tests that can identify individuals at risk of sustaining an ankle sprain.[1,21] Two measures of static balance were assessed - the number of footlifts during unilateral stance[10] and the demi-pointe test.[10] Dynamic balance was quantified with the Star Excursion Balance Test (SEBT).[23]

For the first static balance test, the number of 'footlifts' during a 30 second test period were counted. With the test assessing stability, a larger number of footlifts is indicative of poorer balance. The participant assumed a unilateral stance with the medial aspect of her contralateral foot resting lightly on the calf of her stance leg. She was instructed to keep her eyes closed and her hands by her side. If the eyes of the participant were opened at any point of the test then the test was started again. A footlift was defined as the elevation of any part of the foot from the ground, such as the toes or metatarsal heads.[10] If the contralateral foot came in contact with the floor then one count was added to the footlift score – as was an additional count for every second the contralateral foot remained grounded on the floor. The test has been reported to have good intra-rater reliability.[10]

The demi-pointe balance test provides a measure of static balance by assessing the ability to balance unilaterally on the ball of the foot for five seconds in a maximally plantar-flexed position.[10] After assuming a unilateral position, the participant initially steadied herself with her hands on a wall. The stopwatch was started when the participant removed her hands from the wall. During unilateral stance, the medial aspect of the contralateral foot rested lightly on the calf of the stance leg. Participants were given three trials of the test and were failed if balance was not maintained for two of the three trials.

Due to a redundancy in assessing all eight reach distances of the original SEBT test,[8] reach distances were only collected in the anterior, posterior-lateral and posterior-medial directions.[1,11,21] For the anterior direction, the participant stood barefoot with the distal aspect of her second toe at the centre of the SEBT grid, and for the posterior-medial and posterior-lateral directions, the heel of the stance leg was positioned at the centre of the grid.[6] The participant was instructed to place her hands on her hips, balance on her stance leg and reach as far as she could with her contralateral leg in the direction being assessed. The protocol has been shown to have excellent inter-rater reliability.[7] The reach leg had to lightly touch the testing grid and return to the bilateral stance position without any loss of balance. To standardise any potential learning effects, participants were given three practice trials in each direction before any measures were recorded.[25] A trial was deemed unsuccessful if:

1. the heel of the stance leg lifted during the reach,
2. the hands of the participant were removed from her hips
3. unilateral stance was compromised
4. the reach limb was used to transfer weight at the maximal excursion distance in order to maintain balance, or
5. the movement back to the starting bilateral stance position was not controlled. The average of three successful trials in each reach direction was calculated for each participant.

In order to compare between groups, SEBT reach distances were normalised to leg length.[5] To determine leg length, participants lay supine and the distance from the anterior superior iliac spine to the distal point of the medial malleolus on the same leg was measured with a tape measure.[5]

The measures for one limb of each participant were analysed. For participants with no history of ankle sprain, the stance limb used for analysis was randomly selected. For participants with a history of ankle sprain, the stance limb used for analysis was the limb with the highest number of previous ankle sprains. If an equal number of previous sprains were reported for each ankle then the stance limb used for analysis was randomly selected.

Comparisons between previously injured and uninjured players, as well as between the club and inter-district players, were assessed with SPSS version 22. Differences in age, height, mass, SEBT reach distances and the number of footlifts during unilateral stance were analysed with a two-way analysis of variance. Differences in demi-pointe test results were analysed with chi-square tests. All tests were conducted with a level of significance set at 0.05.

RESULTS

Seventy-two percent of the cohort reported a previous ankle sprain. Netball players with a previous history of ankle sprain were older than the netball players with no history of ankle sprain (p=0.005). Previous ankle sprain history had no effect on any balance measure (p≥0.05). The SEBT results, the number of footlifts during unilateral stance and the demi-pointe test results are presented in Table 1.

Twenty-six (62%) of the club players and 43 (80%) of the inter-district players reported previously sustaining an ankle sprain. The inter-district players were younger (p=0.001) and taller (p=0.005) than the club level participants. No differences between the two competitive levels were found for any of the balance test results (p≥0.05).

Table 1. Demographic and balance test results for the netball cohort split into previous ankle sprain history and skill level. Mean ± SD

	Total Cohort	No Previous Ankle Sprain	Previous Ankle Sprain	Club Players	Inter-District Players
n	96	27	69	42	54
Age (years)	21.4 ± 6.3	19.5 ± 3.4	22.2 ± 7.0[a]	24.1 ± 7.9	19.4 ± 3.5[b]
Height (cm)	170.3 ± 6.7	169.7 ± 5.5	170.5 ± 7.2	167.6 ± 5.4	172.8 ± 6.9[b]
Mass (kg)	70.3 ± 14.4	69.0 ± 16.3	70.8 ± 13.7	68.5 ± 15.9	72.0 ± 12.7
SEBT Ant[c]	65.8 ± 5.6	65.8 ± 6.6	65.8 ± 5.2	66.5 ± 5.6	65.3 ± 5.6
SEBT PL[c]	71.0 ± 10.3	69.9 ± 9.2	71.4 ± 10.7	68.7 ± 10.7	72.8 ± 9.6
SEBT PM[c]	76.8 ± 8.9	75.9 ± 7.2	77.2 ± 9.6	75.7 ± 7.7	77.7 ± 9.7
Footlifts (n)	29.1 ± 11.6	28.0 ± 11.4	29.5 ± 11.7	27.5 ± 10.1	30.3 ± 12.6
Demi-pointe (pass:fail)	66:30	20:7	46:23	28:14	38:16

SEBT= Star Excursion Balance Test. Ant=anterior reach direction. PL=Posterior-lateral reach direction. PM=Posterior-medial reach direction. [a]Statistically different to previously uninjured (p<0.05). [b]Statistically different to netball club players (p<0.05), [c]Values are normalised to leg length.

DISCUSSION

In contrast to the original hypothesis, the balance of netball players with a prior history of ankle sprain was found to be similar to the netball players with no history of ankle sprain. A similar finding has been reported in a soccer cohort, with a prior ankle sprain showing no influence over the ability to control balance.[24] A post-hoc analysis on the balance data of the netball players found no balance differences between individuals reporting one previous ankle sprain compared with individuals reporting two or more previous ankle sprains. Recurrent ankle sprain is an aspect of chronic ankle instability[9] and, although the current study focused only on ankle sprain history, previous literature has reported balance deficits in populations with chronic ankle instability.[8,10,12]

Results of the demi-pointe test revealed that 31% of the total netball cohort could not maintain balance on the ball of the foot – a higher percentage than the 21% of test failures found in previous research investigating the balance of individuals with unilateral instability following an ankle sprain.[10] Owing to the rules of netball, stance in a demi-pointe position is sometimes necessary to minimise the distance between a defensive player's hands and an attacking player with the ball, whilst maintaining the required 3 foot ground distance between the players. Whilst the demi-pointe test is performed on a single leg, perhaps players strategically adopt a bilateral demi-pointe stance during netball participation in order to maintain their balance in this position. Furthermore, whilst the demi-pointe test is a five second assessment of static balance, it has been reported that netball players defend an opposing player in possession of the ball for an average of only 1.7 seconds outside the goal circle and 2.5 seconds inside the goal circle.[4] This suggests that the ability to maintain balance for an extended period of time might not be a necessary requirement for netball players and that a more sport specific measure of balance needs to be considered.

Ankle sprain history was not found to influence the result of the footlift test in the current study. Thirty seconds of unilateral stance without visual input resulted in an average of 29 footlifts for all participants - similar to the figure of 27 footlifts reported in a cohort of university students.[1] The results for the netball players are also comparable to similarly aged individuals from a general community/university population with perceived ankle instability[10] – notably larger, however, than the score of 13 footlifts reported by individuals in that same study with no history of ankle sprain.[10]

The current study had aimed to determine the effect of a prior ankle sprain on the balance capabilities of netball players, but perhaps, poor balance is a reason that netball players are sustaining ankle sprains. Balance deficits in the form of single leg balance test failures[26] and Star Excursion Balance Test results[1,21] have been identified as risk factors for sustaining an ankle sprain. Plisky et al. (2006)[21] reported that female high school basketball players had a 6.5 times higher chance of sustaining a lower limb injury if

composite reach distances were less than 94 % of an individual's leg length. The largest mean normalised reach distance for the SEBT in the current study was achieved in the posterior-medial direction and was only 77% of leg length. A comparison between these findings suggests that all netball players within the current study may be at risk of sustaining a lower limb injury. Upon further examination of the methodologies used, the protocol used by Plisky et al. (2006)[21] required basketball players to watch an instructional video demonstrating the task before any trials were attempted. The instructional video likely equipped the players, either consciously or subconsciously, with task learning strategies to better execute the test and achieve greater reach distances. Furthermore, the positioning of the stance leg on the testing grid in the Plisky et al. (2006) study incorporated the length of the foot in the posterior directions which would have resulted in larger distances reached. To enable accurate comparison between studies, balance protocols must be standardised and, until then, care should be taken when comparing results from protocols that are inconsistent. Future research should focus on determining whether field based balance measures, like that of the SEBT, can be used to identify netball players at risk of sustaining ankle sprains.

As a secondary hypothesis, it was proposed that the inter-district netball players would perform better across the range of balance tests compared to the club level players because, in theory, the inter-district players were chosen in their representative teams for possessing greater netball ability across a range of sport specific skills compared to individuals who participate at a club level. Furthermore, inter-district netball players are likely to have more hours dedicated to training and, as a result, a greater opportunity to refine their skills through drills and simulated match play. The results of the current study demonstrate that there were no differences in any of the balance tests between club and inter-district participants in the current study. These findings may encourage inter-district teams to increase the amount of balance training in their programmes in order to maintain the competitive edge that they have over club players in terms of overall netball skill.

Although no balance differences between groups were found in the current study, it is still believed that balance is necessary for the sport of netball. It is possible that the balance tests chosen for this study (based on their previously reported ability to detect differences between individuals with and without ankle instability within general community cohorts)[10,20] may lack functional specificity and therefore be unrepresentative of on-court netball skills. This theory would also act to explain the similar balance scores of club and inter-district players when, theoretically, the inter-district netball players should be outperforming their club counterparts due to their more fast paced, dynamic and skilled netball exposure.

There were differences in height and age between the club and inter-district netball players of this cohort. As standing height is correlated to leg length,[5] to which reach distances were normalised, the differences in height between the groups of participants are not thought to have affected the interpretation of the SEBT results. There is the potential that taller individuals, due to a higher center of mass, may have had greater difficulty performing the footlift and demi pointe tests. The participants who reported a previous ankle sprain were older than those in the non-injured group. This finding could easily be attributed to the greater number of years these players had to sustain an ankle sprain. The differences in mean age between both groups analysed within this study was less than five years and were therefore not considered to be a confounding factor for the performance of any of the balance tests. Despite this, future research should consider matching participants for height and age.

A limitation of the current study is reflected in the reliability of the demi-pointe balance test – of which there is no available data. Additionally, it is noted that a two-way analysis of variance assumes equal sample size among groups and, in the current study, the number of participants with a previous ankle sprain was higher than the number of participants with no history of ankle sprain. Despite this, parametric tests (such as the two-way analysis of variance) are generally considered to be robust enough in their design to tolerate violations to assumptions without affecting the statistical results.[22]

CONCLUSION

Within the current cohort of netball players, a prior history of ankle sprain was not found to be associated with the three balance tests chosen for assessment. Furthermore, each balance measure was found to be similar between the club and inter-district player subgroups. The results of this study provide a theory that, to accurately assess the balance skills of netball players, a more sports-specific balance assessment protocol needs to be considered.

ACKNOWLEDGEMENTS

This research was funded under the NSW Sporting Injuries Fund Research Programme. The conclusions in the final report are those of the authors and any views expressed are not necessarily those of the NSW Sporting Injuries Fund.

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Use of load and strength training modalities for management and rehabilitation of tendinopathy

PAUL GAMBLE

"You must load a tendon, otherwise it will forget it is a tendon"

Michael Kjaer

INTRODUCTION

There is growing recognition of the merits and applications of load and specific strength training modalities in the treatment and rehabilitation of tendinopathy. The need to explore novel approaches with this condition is apparent: the variable outcomes of current methods and the frequency of recurrence indicates that existing treatment regimens for tendinopathy may be lacking or incomplete.[1] The potential of strength training interventions to positively impact symptoms are particularly significant given the negative sequelae that are otherwise observed with tendinopathy, which can serve to further reduce function and load tolerance. In particular this is highly pertinent to athlete populations for whom the need and motivation to continue to train and compete is naturally greater.[2]

A characteristic of tendinopathy is that individual cases often vary widely in how they present and respond to treatment. Thus the prevailing view in the literature at present is that tendon pathology represents a continuum.[3] The nature of this condition further varies according to anatomical location, such that tendinopathy of the upper limb (eg, rotator cuff and elbow) presents quite differently to common forms of lower limb tendinopathy (Achilles tendinopathy and patellar tendinopathy being the most prevalent). The specific location of the tendinopathy (for instance, mid-portion versus insertion) is another important consideration that affects both presentation and response to treatment. Due to the multifactorial nature of tendinopathy and its presentation, different cases can also react very differently to a particular stimulus. Moreover the response can vary at different times even for the same individual.

Definitive recommendations are therefore difficult and are probably not advisable. This clearly calls for management on a case by case basis and a responsive approach guided by ongoing monitoring and assessment. Keeping these caveats in mind, some guidance can nevertheless be offered, based upon the findings from the literature to date.

1 Strength Training as a Treatment Modality

There is growing awareness of the potential application of strength training modes to help manage and treat a variety of musculoskeletal injuries and chronic conditions. Benefits associated with strength training as a treatment modality include ameliorating symptoms and eliciting positive changes in function. In particular, there is increasing empirical support for strength training as a valid treatment modality and tool for injury management that positively influences treatment outcomes, particularly for chronic conditions and overuse injuries such as tendinopathy.[4]

The favourable effects of heavy resistance training modalities in relation to conventional therapeutic rehabilitation modes have been demonstrated.[5] Strength training, alongside various forms of neuromuscular training, has a role to play in each of the following outcomes during rehabilitation and injury management:[6]

- i increasing capacity to generate force and tolerate load
- ii restoring central drive and sensorimotor control
- iii improving mobility or range of motion
- iv correcting or remodelling movement mechanics

A related aspect of the application of load and strength training modalities during rehabilitation and when managing tendinopathy in a competing athlete concerns maintaining the athlete's overall function whilst their ability to fully participate in their normal training is impaired. Whilst restrictions might be placed on the injured area, it is clearly important to avoid detraining of the uninjured contralateral limb, and this may confer a cross over effect to the injured limb.[7] In addition, training the contralateral limb may confer a cross-over effect to the injured limb. Appropriately modified strength training also offers a potential means to provide a training stimulus at segments adjacent to the injured area.

2 Mechanisms of Load Application and Strength Training for Tendinopathy

The use of heavy resistance strength training modes for tendinopathy is an illustrative example of the application of 'advanced' training modes for injury management and rehabilitation.[8] The therapeutic application of loading and mobilisation exercise, described as 'mechanotherapy', is relevant not only to muscle injuries, but also to collagenous connective tissues such as tendon.[9]

Two of the major stimuli for tendon adaptation are loading intensity and duration of load application.[10] Modalities that elicit higher tendon strain appear to be have the greatest effect in terms of eliciting adaptation. For instance, there is some evidence that heavy resistance training is more potent in eliciting gains in tendon cross sectional area and changes in stiffness measures in comparison to equivalent training with light loads.[11] It follows that different forms of strength training offer a potent means to elicit the requisite level of tendon strain to promote adaptation. In addition, strength training modes can produce a variety of other favourable changes, as has been demonstrated with early stage tendinopathy, termed 'reactive tendinopathy',[3] and chronic tendinopathy.

2.1 Modifying Pain Response and Symptoms

It has been identified that there is likely both peripheral (nociceptor-mediated) and central components to the clinical presentation of pain symptoms experienced by those suffering with tendinopathy.[12] A consequence of this central sensitisation that has been demonstrated among individuals suffering with tendinopathy is that the presentation of symptoms can become uncoupled with the tissue damage that is observed.[13] Essentially, in such chronic cases of tendinopathy the pain reported may no longer correspond to what is occurring with the tendon structures involved.[12] A recent review on this topic reported such findings of central sensitisation and 'mechanical hyperalgesia' were particularly prevalent in investigations of upper limb tendinopathy.[13]

Moreover, there is a link between athletes' experience of pain symptoms and the functional impairments they demonstrate. This has further implications in the form of related behaviour modifications that often develop over time, such as movement adaptions and avoidance of load.[13] Clearly there is a need to resolve these factors in order that the symptomatic athlete is able overcome this cycle of mechanical hyperalgesia and resulting avoidance and aversion to load.

Addressing any centrally-mediated mechanical hyperalgesia that may be present would appear to be a critical first step in order that the athlete is ultimately able to tolerate the remedial exercise required to return to full training and competition. Appropriate application of load via strength training interventions such as isometric training has been shown to be highly potent in modifying symptoms of tendon pain.[14] For instance, there is an acute effect whereby pain responses are modified for a period following isometric contraction. This phenomenon is described as 'mechanical hypoalgesia', and in cases of reactive tendinopathy the altered pain response may persist for hours at a time.[2] Once more, the application of load, and isometric training in particular, represents an important tool to overcome these barriers to rehabilitation and return to sport.

2.2 Training 'Mechanotherapy' to Support Healing, Repair and Remodelling

Chronic tendinopathy has been characterised as a condition that is the result of failed healing rather than simply an inflammatory condition.[15] Whilst protecting and unloading the injured region has traditionally been advocated during the period following injury, excessive or prolonged unloading can conversely serve to blunt the repair and remodelling that occurs, and thereby inhibit recovery.[16] Essentially, in the absence of appropriate mobilisation and activity during the critical phases of repair and remodelling the repair that occurs spontaneously following injury may result in disorganised collagen fibre formation. As a result, the healed and remodelled tissue may not have the same structural integrity and mechanical properties of healthy tissue.[17]

Early mobilisation and load-bearing is therefore increasingly advocated as an integral part of injury management for soft tissue injuries, ie, ligament sprains and muscle and tendon strains.[18] In addition to providing a general stimulus to promote regeneration, directed application of mechanical loading can also serve to direct the adaptation and remodelling that occurs, for example with respect to the orientation and alignment of new collagen fibres. Appropriate mobilisation can also help to combat the adhesions to the tendon sheath associated with tissue scarring that can occur during the repair process of tendons.[17] This is an example of the maladaptation that can occur which is particularly problematic for impairing the function of flexor tendons post injury. Once more, early introduction of appropriate passive and active mobilisation in combination with modified loading during the acute phase provides a means to avoid these unwanted structural and functional changes.

Finally, it has been emphasised that even in cases of chronic tendinopathy where extensive tissue pathology is evident, there is nevertheless generally still enough 'normal' tendon to maintain function. The recent clinical guidance for treating Achilles and patellar tendinopathy from leading authorities in the field is therefore to 'treat the donut, not the hole' – ie, focus on building capacity and load tolerance of the surrounding normal tendon tissue.[19]

2.3 Preventing Maladaptation and Deconditioning

Paradoxically, immobilisation and disuse are associated with unfavourable physiological and morphological adaptations. For example, when mechanical stress is removed or restricted, adverse changes to tendon structure and function can occur quite rapidly.[17] The effect of unloading the tendon essentially serves to weaken the structural integrity of the tissues, due to a combination of withdrawing the anabolic stimulus and increased catabolism.[17] These physiological and structural changes ultimately serve to further reduce the functional limits of the tendon.

Excessively restricting or withdrawing the mechanical loading placed upon tendon structures is therefore clearly not advisable for an athlete who wishes to continue to train and compete, even with overload-related conditions such as tendinopathy.[2] In this instance imposing the load via strength training modalities offers a means to avoid a catabolic or detraining response, whilst minimising the risk aggravating the symptomatic tissues.

Various strength training modalities offer a potent means to stimulate healing and elicit positive adaptation in 'mechanoresponsive' tissues such as tendon.[17] Positive effects of actively loading the connective tissue structures in this way include increased collagen turnover and greater net collagen synthesis; both of which favour remodelling and repair.[20] Once more the use of appropriate strength training modes is therefore supported in helping to safeguard the tendon and maintain tolerance to load.

2.4 Restoring Motor Activation

In addition to helping to maintain structural integrity, the adaptations elicited via the appropriate application of load include favourable changes in the function of the muscle-tendon unit. This is another critical factor in view of the adverse changes in motor control that may be observed in those suffering with tendinopathy. These changes alter the interaction between the muscle and tendon, and in turn affect both mechanical properties and the relative strain placed upon tendon structures.[21] For instance, it has been demonstrated that the relative strain placed on the aponeurosis is greater among those suffering with Achilles tendinopathy.[21]

A favourable effect following appropriate application of loading is a reduction of inhibition associated with tendinopathy (i.e. 'disinhibition') to restore central drive to the muscle-tendon unit. The restoration of motor drive to the muscle-tendon unit in response to isometric strength training has been observed with patellar tendinopathy, for example.[22]

3 Approach in Relation to Site of Tendinopathy

There are a number of different sport and exercise related tendinopathies.[23] In general, the most common of these for the majority of sports are Achilles and patellar tendinopathy. It has been identified that the presentations and therefore what is optimal for injury management may differ for Achilles versus patellar tendinopathy.[8] In the following section we will explore the key factors identified with these two different conditions, and corresponding approaches to management and treatment.

3.1 Achilles Tendinopathy

As has been outlined, leading authorities in the field of tendon research have postulated that tendon pathology represents a continuum.[3] In accordance with this model, individual cases of 'loading-induced' Achilles tendinopathy can vary widely in how they present. The mechanical properties of the Achilles tendon aponeurosis is altered in those suffering with Achilles tendinopathy.[21] The variability in clinical presentation is likewise reflected in diverging responses to particular treatment protocols demonstrated by individuals.

Due to the integrated function of the muscle-tendon unit, the strength and flexibility of the plantarflexors are important considerations when managing overuse injury to the Achilles tendon and guarding against reinjury. In accordance with this, a variety of loading regimens have reported effectiveness with Achilles tendinopathy.[8] For instance, training interventions designed to provide some manner of eccentric overload have been employed with some success to relieve symptoms of Achilles tendinopathy and restore function.[24] Equally, individual cases vary widely and in some instances the response to eccentric training during the initial management or rehabilitation process may not be favourable.

It has been argued than the success of conventional eccentric rehabilitation body-weight exercise as a treatment modality for Achilles tendinopathy can be ascribed in part to providing flexibility training for the plantar flexor muscles and associated connective tissues.[25] Finally, proximal control of the lower limb is also implicated with Achilles tendinopathy. Recent evidence indicates altered neuromotor control of gluteal muscles is associated with this condition.[26]

3.2 Patellar Tendinopathy

Lower limb control during jumping and landing movements has been implicated as a factor in the aetiology of patellar tendinopathy, particularly in sports that involve repetitive jumping such as volleyball and basketball.[27] Deficits in neuromuscular function and dynamic control of lower limb alignment are identified as a factor contributing to the high incidence of patellar tendinopathy in these sports.[28] Such issues have similarly been implicated in the greater incidence of patellofemoral pain syndrome among females.[29]

Similarly, aberrant hip and knee mechanics running gait are implicated with both the aetiology and sequelae observed with patellar tendinopathy in runners. There is some suggestion that the specific mechanics involved may differ between females and males.[30] Female runners often demonstrate greater hip adduction and internal rotation at initial contact particularly, leading to a valgus lower limb alignment, and this is even more pronounced in female runners suffering with patellofemoral pain.[31] Symptomatic male runners appear to demonstrate greater contralateral pelvic drop, indicative of impaired dynamic lumbopelvic control, in comparison to healthy male runners.[30]

A common focus during clinical assessment is the strength and function of the vastus medius oblique (VMO) due to its role as the primary stabiliser of the patella, and the observation that those with conditions such as patellar tendinopathy may exhibit specific VMO atrophy.[32] On the other hand, recent findings indicate that atrophy is not restricted to VMO, but is in fact present in all parts of the quadriceps. This would suggest that the traditional focus on VMO might be misguided. Deficits in function of the proximal musculature have been implicated in those suffering patellofemoral pain.[33] Muscles of the hip girdle and the gluteal muscles in particular have therefore been a focus for recent investigations.[34,35]

Eccentric strength training is often employed for specific development of medial quadriceps (VMO) and patella tendon as part of the rehabilitation for patellar tendinopathy.[36] A range of training modes have been employed, including controlled eccentric knee flexion movements as well as rapid drop squats or drop jump landings.[37] Unilateral single-leg squat protocols have proven efficacy as a rehabilitation tool. These exercises are often performed on a decline surface, maintaining an upright posture with minimal forward torso lean and neutral lower limb alignment so that the supporting knee remains in line with the toes.[37]

A biomechanical analysis identified that employing a decline surface with a minimum angle of 15-degrees serves to specifically load the patella tendon, which appears to explain the superior effectiveness of decline squats in comparison to eccentric squats performed on a flat surface.[36] There does appear to be an optimal range of motion for the exercise – descending to a knee flexion angle of 60-degrees. Beyond this range forces placed upon the patellofemoral joint increase to a greater extent than patellar tendon forces.[36]

In symptomatic athletes, the depth will initially be governed by pain experienced during the movement – it is typically recommended to work just into the range where the movement becomes painful.[37] Within the specific range of motion, progression can be achieved by adding external load, for example using dumbbells held at the sides or supported upon the shoulders. For instance, the addition of a 10kg load via a backpack was shown to increase knee moment of force by 23%.[36]

Despite the effectiveness generally reported with eccentric training modalities as a rehabilitation tool for those suffering symptoms of patellar tendinopathy, data from one study suggests that standard rehabilitation eccentric training interventions may be less effective for players who are asymptomatic but exhibit abnormalities on ultrasonograph tendon scans indicative of increased risk for developing tendinopathy.[38] Furthermore, the data from studies to date does not indicate that the standard eccentric training regimen reduces the initial incidence of signs and symptoms of patellar tendinopathy.

4 Key Parameters for Training Prescription

Current recommendations advocate a relatively high level of loading when employing strength training to manage tendinopathy. The stimulus-response relationship would suggest that a threshold load will need to be reached in order to elicit structural adaptation, alongside the therapeutic effects of mechanotherapy. This marks a departure from traditional approaches to tendinopathy rehabilitation that have typically employed high volumes and repetitions of particular eccentric training modes (eg, heel drops and decline squats) performed with only body weight resistance.

Another consideration when selecting treatment protocols and training modes to manage tendinopathy is the degree of compression placed upon the symptomatic tendon. For instance, current guidelines in the literature include operating within a mid- to inner-range of motion.[2] Other recommendations include avoiding particular postures in order to reduce compression and shear at the tendon. One example in relation to patellar tendinopathy is that some leading clinicians increasingly recommend avoiding excessive dorsiflexion at the ankle during weight bearing training modes – so that the knee does not travel over the toe.

Once more, the latter recommendation marks a major shift in the clinical recommendations for patellar tendinopathy – specifically in relation to the use of the decline squat exercise. Having previously been advocated as a therapeutic modality for patellar tendinopathy,[39] some leading authorities now suggest that the decline squat should be used primarily as a provocation test, and its use should perhaps be avoided in the management and rehabilitation training interventions for symptomatic individuals.

That said, a key consideration may be the degree of incline employed. It has been established that quite modest decline angles (greater than 15-degrees) can achieve the desired increase in patellar tendon load.[36]

4.1 Training Modes

There are a number different training modes that have potential applications for managing tendinopathy. Conceptually, these different training modes can be considered to form a continuum, and such an approach might be used to guide progression. Isometric training modes appear to be tolerated best during the initial stages, and offer a means to provide the requisite level of load upon the muscle-tendon unit to elicit positive adaptation and the associated benefits of mechanotherapy with respect to symptoms and function.

4.1.1 Isometric Training

Broadly there are two approaches to isometric training. The first of these employs immovable apparatus against which the athlete develops force. Examples of this form of isometric training include squats and pulls performed against a fixed bar in a squat rack. The second approach is isointertial isometric training, whereby the athlete performs static holds against an external resistance in the form of free weights or a resistance machine. This method can also be used with body weight resistance exercises, with or without external resistance.

The Spanish Squat that is employed to manage patellar tendinopathy is an example of the former approach to isometric training. The apparatus involved comprises an inelastic strap tethered to a fixed immovable anchor; the athlete develops tension against this strap as they hold a 3/4 squat position.

4.1.2 Heavy Resistance Training

Heavy slow resistance (HSR) approach has been used successfully as an alternative to the more conventional eccentric training protocols employed to treat tendinopathy.[8] This method has shown to be effective in the treatment of patellar tendinopathy particularly, but is also seeing increasing use to treat Achilles tendinopathy.[15] With this approach a set duration is implemented, so that the participant has a set time (eg, 3 seconds) to move through the full range of motion for the concentric and eccentric portion of the exercise, respectively (so in this example the total duration of each repetition is 6 seconds).

As symptoms improve the practitioner might consider progressively removing the restriction on the duration of eccentric and concentric phases, so that the participant is permitted to increase contraction velocity during repetitions as tolerated.

4.1.3 Eccentric Strength Training

The majority of eccentric training interventions employed in the treatment and management of tendinopathy involve body weight resistance only. However, a less conservative approach featuring higher eccentric loading and more progressive selection of exercise modes can elicit a greater level of adaptation and might therefore serve a greater protective effect. Marked adaptations to both muscle fascicle architecture and tendon mechanical properties are observed following heavy resistance eccentric strength training.[40]

An investigation of tendon loading during eccentric training exercises identified a fluctuating pattern of loading and unloading on the tendon, which differed to the constant pattern observed during concentric training.[41] It has been speculated that these fluctuations in tendon load which differentiate eccentric training from conventional training modes might be the specific stimulus that elicits remodelling of tendon structures. In addition, the fluctuations in tendon loading were attributed to greater difficulty in controlling muscle tension during the eccentric action.[41]

4.1.4 Coupled Eccentric-Concentric Ballistic Resistance Training

Specific changes in muscle activation during the eccentric phase of loaded jumping movements have previously been documented following training.[42] It could therefore be speculated that exposure to coupled eccentric-concentric ballistic training that imposes significant eccentric loading under appropriate conditions might serve a protective effect by enhancing the capacity to control muscle activation and tension during the eccentric phase, thereby sparing the tendon. It also follows that the training stimulus provided should ultimately aim to replicate the loading conditions and movements encountered during athletic activities, which often involves the coupling of rapid eccentric and concentric actions.

4.1.5 Plyometrics

Plyometric training is associated with beneficial changes in mechanical properties of the muscle-tendon unit.[43] Changes in dissipative properties of the Achilles tendon have been reported following plyometric training, in the absence of any significant change in cross sectional area.[44] Clearly this will depend on tolerance as stretch-shorting cycle movements tend to be provocative

in symptomatic individuals. The initial reintroduction to plyometics is therefore likely to be in the form of low-amplitude stretch-shortening cycle movements, performed bilaterally in the first instance.

The relative strain placed upon the muscle-tendon unit does vary according to the intensity of the stretch-shortening cycle activity employed. For instance, the degree of length changes at fascicle versus tendon during eccentric and concentric actions, and in turn the magnitude of stretch and recoil that occurs at the tendon, differs according to the drop height employed.[45] Practically this can be used to regulate the degree of stretch load placed upon the tendon by selecting appropriate plyometric exercises (e.g. bilateral movements and longer ground contacts initially) and employing low amplitude drops and jumps.

4.1.6 Neuromuscular Training

Neuromuscular training interventions for overuse conditions of lower limb and upper limb require consideration of the kinetic chain as a whole. Investigations of both Achilles tendinopathy and patellar tendinopathy demonstrate the importance of proximal control. For instance, aberrant motor control of the hip musculature has been implicated in runners suffering with Achilles tendinopathy.[26] This suggests a need for remedial strength training modalities to help restore function of muscles that provide proximal control of the lower limb.

For instance, a recent investigation of patellar tendinopathy employed a neuromuscular training intervention that comprised strength training for the hip extensor muscles.[46] The need for movement skill training alongside strength training modalities for the lower limb kinetic chain is supported by a recent study highlighting an apparent link between the kinematics employed at take-off and landing and the development of patellar tendinopathy.[27]

4.2 Prescription of Repetitions, Volume, Frequency

It has been suggested that the limited effectiveness of conventional rehabilitation regimens for tendinopathy such as eccentric training protocols may be attributed in part to shortcomings in the loading parameters employed.[41] For example, the standard approach for Achilles tendinopathy is the Alfredson heel drop protocol, which comprises 12 sets of 15 repetitions (including both straight-leg and knee-flexed variations) with body weight resistance performed daily. Whilst this approach has produced favourable results with midportion Achilles tendinopathy in a number of studies, equally a significant proportion of cases fail to respond to standard eccentric loading regimens. Different authors have highlighted that there is not a strong rationale or empirical basis for the frequency and volume prescribed in many eccentric rehabilitation protocols.[15,41] Indeed, the standard Afredson protocol would appear contrary to a number of fundamental principles of training, not least progressive overload.[47]

For instance, rather than daily frequency employed with rehabilitation schemes such as the Alfredson protocol, interventions comprising heavy slow resistance training performed three times per week have also been shown to be effective for both patellar tendinopathy[48] and midportion Achilles tendinopathy.[15] These findings suggest that an approach to programming more akin to what is employed with strength training for athletic preparation might be more appropriate. There is also some indication that the reduced frequency and more modest training volumes involved may also improve compliance.[15]

Similarly, a recent study also demonstrated that the number of repetitions prescribed with this protocol were not in fact necessary to elicit a favourable response in those suffering with mid-portion Achilles tendinopathy. The treatment group that adopted ‘do as tolerated’ approach, whereby the participant was allowed to self-select repetitions performed each day, which eventuated in markedly lower volumes of repetitions performed, did not adversely affect treatment outcomes in terms of symptoms or satisfaction.[49]

4.3 Time Course and Progression

A ‘functional rehabilitation’ approach is increasingly recommended during the initial period following ligament sprain and tendon injuries that involves the application of load and introduction of strength training modalities at an early stage.[16] It should also be recognised that there can be negative consequences if mobilisation or loading is applied prematurely or progressed too rapidly. The practitioner must therefore strike a delicate balance, which has been termed ‘optimal loading’ in the sports medicine literature.[16]

Ultimately what constitutes optimal loading must be judged on a case by case basis.[16] Similarly, decisions on the timing and rate of progression will be determined from monitoring how the athlete responds on a day-to-day and week-to-week basis. In general, the initial introduction of loading will typically involve the application of moderate-intensity isometric training, as this tends to elicit positive changes with the least risk of aggravating the tendon. As training advances and symptoms and load tolerance improves, exercise selection can progress to other forms of heavy resistance training, and this includes the introduction of plyometrics at a later stage.

5 Summary

Tendinopathy is a notoriously difficult condition to treat and manage. Tendinopathy is not only recalcitrant with regards to treatment, but also in the sense that it defies generalisation. As described, anatomical location (upper versus lower limb) and specific site (eg, mid-portion versus insertion) are important factors that will have a profound effect on how the condition presents and treatment approaches. When dealing with a particular type of tendinopathy the practitioner must take account of not only what is occurring at the site, but also centrally mediated factors that can have a marked influence on symptoms and associated responses. The multifactorial nature of this condition, and the variable nature of its presentation, also extends to how it presents and responds in different individuals and different time points.

The various potential benefits of load application and specific strength training modalities to address the respective factors associated with tendinopathy have been detailed. Within the constraints described, and remaining mindful of these caveats and considerations outlined in this paper, we have outlined a range of different training modalities that merit consideration when approaching the treatment and management of each individual case. Some guidance regarding training parameters, prescription and progression have also been offered to aid the practitioner, albeit the variable nature of tendinopathies necessitate that any plan must be adapted and refined on a day-to-day and week-to-week basis.

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commentary

Efficacy of injury prevention programmes in sport

JESSICA MEYER, DUNCAN REID

ABSTRACT

Aim

To systematically review the literature to evaluate the efficacy of primary injury prevention programmes in reducing injuries in sport.

Data Sources

Electronic databases including MEDLINE, SPORTDiscus, CINAHL, Health Source: Nursing/Academic Edition, Biomedical Reference Collection & MESH headings were searched to identify relevant studies.

Study Selection

The inclusion criteria were; randomised controlled trials, clinical controlled trials and prospective cohort trials investigating the efficacy of injury prevention programmes at reducing injuries in sport. Articles not written in English, those not available in full text and those published before 2000 were excluded.

Data Extraction

Twenty four articles were assessed for eligibility, 11 were excluded as they did not meet the inclusion criteria, leaving 13 studies to be included in the review.

Data Synthesis

Eleven of the 13 studies found positive results for their injury prevention programme.

Conclusions

Based on the results of this review, there is level one evidence for the efficacy of injury prevention programmes in reducing injuries in sport. Programmes involving running, active stretching, strengthening exercises, balance exercises, plyometrics and sport-specific drills appear to be effective in reducing ACL injuries and overall injuries in soccer players. Programmes including eccentric strength straining for the hamstrings also appear to be effective at reducing the risk of hamstring muscle strains. Further research is required to establish the effectiveness of different programme parameters such as programme duration and frequency as these were variable.

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INTRODUCTION

Epidemiological studies have shown that sport and recreation injuries constitute a major public health burden in many developed countries.[1-2] Recent Accident Compensation Corporation (ACC) statistics indicate that in 2012 there were 21,471 new and 27,697 existing claims relating to sports injuries alone. The total cost of these claims was over $247 million. Treating sports injuries is often difficult, expensive and time consuming, therefore preventive strategies and programmes are justified on medical as well as economic grounds.

Developing an effective injury prevention strategy or programme can be seen as an ongoing process of surveillance, implementation and monitoring. The 'sequence of injury prevention' model developed by Van Mechelen (1992) describes this four step process. The first step is to establish the extent of the injury problem. This includes identifying the number of injuries, incidence, trends, severity and consequences (impairments, disabilities and costs). The second step is to identify the aetiology, risk factors and mechanisms of injuries. Following this, an injury prevention strategy or programme is introduced. This is based on the previously identified etiological factors and mechanisms of injuries. The final step is to measure the effectiveness and cost effectiveness of the programme. This is achieved by repeating the first step, monitoring the extent of injuries.[3] Risk factors associated with sports injuries can be extrinsic or intrinsic. As intrinsic risk factors such as physical fitness, joint mobility, muscle flexibility and strength, motor abilities and sport-specific skills are modifiable they are often incorporated in injury prevention programmes.

In 2001 a systematic review was conducted investigating the effectiveness of injury prevention measures and programmes in sport with positive results.[4] Since this review, a number of new studies investigating injury prevention have been conducted. Another systematic review investigated the efficacy of injury prevention programmes in soccer alone and found conflicting evidence for the effectiveness of exercise based programmes.[5] A recent systematic review conducted in 2014 investigated anterior cruciate ligament and knee injury prevention programs for soccer players.[6] They found a statistically significant reduction in injury risk for knee injuries, but did not find a statistically significant reduction of ACL injuries.

Overall, to date, there is conflicting results for the effectiveness of injury prevention programmes at reducing injuries in sport. Hence, the purpose of this review is to undertake a more up-to-date systematic review to see if more recent studies can reduce this conflicting result.

METHODS

Search Strategy

A search to identify literature relevant to the efficacy of injury prevention programmes was conducted using the electronic databases subscribed to by Auckland University of Technology. These included MEDLINE, SPORTDiscus, CINAHL, Health Source: Nursing/Academic Edition, Biomedical Reference Collection & MESH headings. Keywords used in isolation or combinations were: (injur* N5 prevent*) OR (injur* N5 reduc*), efficacy OR effect* OR intervention* OR program* OR strateg* OR outcome*, ("high perform*" N5 sport*) OR ("high perform" N5 athlet*) OR (elite N3 sport*) OR (elite N3 athlet*) OR (elite N5 basketball) OR (elite N5 soccer) OR (elite N5 football) OR (elite N5 rugby) OR (elite N5 volleyball) OR (elite N5 netball) OR (elite run*). The search was performed in September 2013. The references from each paper were also reviewed to identify any other relevant studies missed in the database search. See Figure 1.

Study Selection

The inclusion criteria for studies were randomised controlled trials, clinical controlled trials and prospective cohort studies investigating the efficacy of injury prevention programmes at reducing injuries in sport, where the primary outcome measure was the number of injuries and/or injury incidence. Type of intervention was injury prevention programmes aimed at improving strength, flexibility, co-ordination, balance or agility. Articles not written in English, those not available in full text and those published before 2000 were excluded.

Review and Analysis of Methodological Quality

Since non-randomised studies were included in the review, the Down's and Black tool was utilised to assess the methodological quality of each paper. The tool consists of 27 items distributed between five-scales; reporting, external validity, internal validity -bias, internal validity -confounding and power.[7] This tool is useful for reviewing studies where randomised and non-randomised and prospective studies are included. Each study was then categorised as being of strong, moderate, limited or poor methodological quality depending on its score. The following levels of evidence were then used to interpret the overall strength of the evidence:

Level one: strong evidence - when provided by generally consistent findings in multiple RCT's of strong quality

Level two: moderate evidence - when provided by generally consistent findings in one RCT of strong quality and one or more limited quality RCT

Level three: limited evidence - when provided by generally consistent findings in one RCT of moderate quality and one or more low quality RCT

Level four: insufficient evidence - when provided by generally consistent findings of one or more RCT's of limited or poor quality, no RCT's available, or conflicting results.[8]

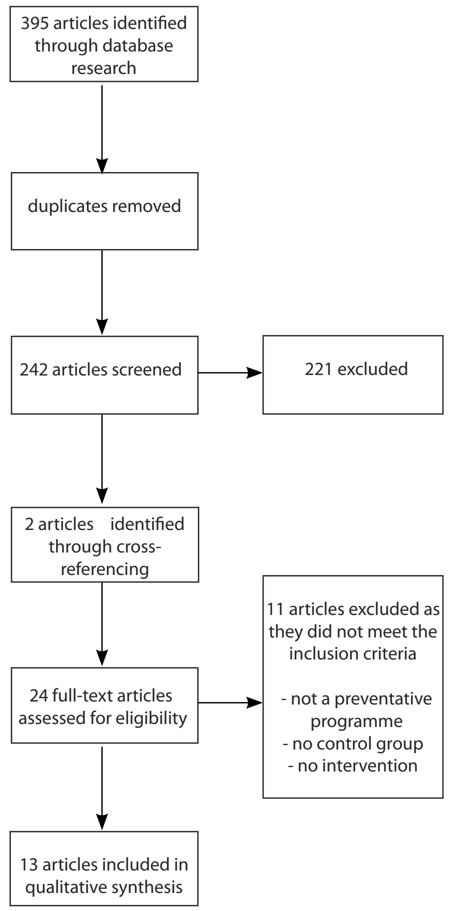

Figure 1. Flow diagram of study selection process.

RESULTS

The search identified 24 articles that were assessed for eligibility. Following the exclusion process 13 studies met the selection criteria. Seven of the studies were RCT's and six were CCT's. The characteristics and main outcomes are summarised in Table 1 (at end of article).

Methodological Quality

Two studies had a limited level of methodological quality,[9,10] seven studies had a moderate level,[11-17] and four studies were considered to be of strong methodological quality.[18-21] The overall mean quality score for the 13 reviewed studies is 17.62 (SD +/- 3.92) and range from 12-23. See Table 2 for study design and methodological scores and variation.

Eleven of the 13 studies found a significant difference between the intervention and control groups and only two studies found no significant difference between groups. Given that the majority of the studies were of a moderate to strong level of quality, there is level one evidence for the effectiveness of injury prevention programmes.

Interventions

Nine of the studies involved interventions that included a multi-faceted programme (a combination of stretching, strengthening, education, plyometrics and sport-specific drills). One study involved balance board training only,[14] while another involved teaching and practicing landing and falling strategies.[16] The other two studies both involved strengthening programmes for the hamstrings.[12,20] The majority of the interventions were untaken during team training. The duration of the intervention programmes ranged from ten weeks to two full seasons of play.

Control/Comparison Groups

The majority of the studies involved a control group that continued with their usual warm up. These were not standardised and simply consisted of the warm up the team normally completed. As there was variability between teams, the content of the warm up was not detailed in any of the studies. One study had no true control group[10] instead the two intervention groups completed specific technical training or a proprioceptive training program, while the third group wore a sport-stirrup orthosis as an ankle injury prevention strategy. Three studies[9,11,13] also had no control group, but rather compared intervention scores to baseline measures.

Table 2 - Study design and methodological scores and variation.

Study	Authors	Reporting	External Validity	Internal Validity - Bias	Internal Validity - Confounding	Power	Total Quality Score	Quality Mean Score	Quality Score Range
Design		(/10)	(/3)	(/7)	(/6)	(/1)	(/26)	(+/-SD)	
RCT	Petersen et al. (2011)	9	3	5	5	1	23		
	Emery & Meeuwisse (2010)	8	2	6	6	1	23		
	Longo et al. (2012)	8	3	5	5	1	22		
	Holmich et al. (2010)	8	3	3	6	1	21		
	Soderman et al. (2000)	8	2	3	5	1	19		
	Gilchrist et al. (2008)	8	3	3	3	0	17		
	Stasinopoulos (2004)	5	2	2	3	0	12	19.57 (+/- 4.00)	12-23
CCT	Scase et al. (2006)	9	3	5	2	1	20		
	Mandelbaum et al. (2005)	6	3	5	2	0	16		
	Askling et al. (2003)	6	2	4	3	0	15		
	Owen et al. (2013)	7	2	3	2	0	14		
	Verrall et al. (2013)	6	2	4	2	0	14		
	Arnason et al. (2008)	6	3	3	1	0	13	15.33 (+/- 2.50)	13-20
Mean		7.23	2.54	3.92	3.46	0.46	17.62		
(SD)		(+/- 1.30)	(+/-0.52)	(+/-1.19)	(+/-1.71)	(+/- 0.52)	(+/-3.93)		
Range		5-9	2-3	2-6	1-6	0 - 1	12-23		

Outcome Measures

All the studies reported injury incidence as the primary outcome measure. This was generally reported as injury incidence per 1000 hours of exposure (to overall training and playing time, or playing time only). The majority of the studies reported injuries on a daily to weekly basis via team staff (coaches, managers, athletic trainers or physiotherapists). Three studies[11,12,13] did not detail how injuries were reported. Secondary outcome measures included muscle strength, running speed, range of motion and muscle flexibility, balance and postural sway of the lower extremities.

DISCUSSION

Due to the diverse nature of the studies included in this review, the findings have been summarised below by sports, anatomic region or type of injury prevention programme.

Soccer

There have been a number of previous studies investigating the effects of injury prevention in soccer. Van Beijsterveldt et al, (2013) conducted a systematic review on the efficacy of exercise-based injury prevention programmes for soccer players. They reviewed six RCT and CCTs, involving over 6,000 participants. The results of the included studies were variable and their overall conclusion was that there is conflicting evidence for the effectiveness of exercise-based programme to prevent soccer injuries. They gave a number of potential reasons for the contradictory findings including; different study samples (gender and soccer type), differences between the intervention programmes implemented (for content, training frequency and duration) and compliance with the programme. Two of the studies from their systematic review have been included in this systematic review. Grimm et al, (2015) recently conducted a systematic review and meta-analysis of ACL and knee injury prevention programmes for soccer players. They stated that while the analysis supports the use of injury prevention programmes for preventing overall knee injuries in soccer, a non-significant reduction in ACL injuries was observed through meta-analysis techniques.

In the current review there were nine studies that involved injury prevention programmes for soccer players. Six of the eight studies of a moderate to strong level of methodological quality found a positive result for injury prevention programmes within their study. Only one study utilised the FIFA 11+ injury prevention programme, which showed positive results (Longo et al, 2012). However, another study utilised a 'soccer-specific' neuromuscular training programme similar to the FIFA 11+ (Emery & Meeuwisse, 2010) and two studies utilised the PEP programme (Mandelbaum et al, 2005 and Gilchrist et al., 2008) all finding positive results for the intervention group at reducing injuries in soccer players.

Hamstring Injuries

There were four studies in this review that involved interventions that were specifically aimed at reducing hamstrings injuries. Three of the four studies were of a moderate to strong methodological quality and show positive results for their interventions at reducing hamstring injuries.[12,13,20] The other study also showed a positive result, however is of limited methodological quality.[9] These positive findings for the effectiveness of injury prevention programmes reveal advancements in the understanding of injury prevention for hamstring injuries. A review conducted in 2005 investigated the evidence based prevention of hamstring injuries in sport. At the time they noted that the evidence base was small and while there was evidence surrounding the rehabilitation

of hamstring injuries, there was very little research carried out on prevention of hamstring injuries.

ACL injuries

There were two studies that investigated the effect of training programmes aimed at reducing ACL injuries in soccer players. Both studies involved utilising the PEP Programme with female soccer players, were of a moderate level of methodological quality and found positive results for their interventions.[15,17] The results from this review are reasonably consistent with a similar previous review conducted by Padua & Marshall (2006), which evaluated the evidence supporting ACL injury prevention programmes. Their review included nine studies that investigated the use of an exercise training program aimed at reducing knee and/or ACL injury risk. They found that there was moderate evidence to support the use of specialised exercise programs incorporating proprioception-balance and/or plyometric-agility exercises to decrease the rate of ACL injuries. Based on the studies they reviewed, they concluded that the most successful injury prevention programmes incorporated a multi-faceted exercise approach (proprioception-balance, plyometric-agility, strength and flexibility) and promoted proper technique and injury-risk awareness above performance. Padua & Marshall (2006) also commented that while a multi-faceted programme seems most beneficial, there was no research that clearly identified the most important components of an effective ACL injury prevention programme. These findings are consistent with the findings of this review.

General Findings

With regard to programme parameters, the frequency at which the injury prevention programmes were performed varied across the studies. The two studies that found positive results with a strengthening-based programme varied from one to two times a week (Askling et al, 2003) to two to three times a week (Petersen et al, 2011). Frequency also varied in the studies that utilised a multi-faceted injury prevention programme, ranging from two times per week (Owen et al, 2013) to three to four times per week (Longo et al, 2012).

The duration of the programmes was consistent in the two studies investigating strengthening-based exercises, both completing them for ten weeks (Askling et al., 2003 and Petersen et al, 2011). However, Petersen et al (2011) also completed a weekly seasonal programme following the initial ten weeks. With regard to the multi-factorial programmes there was a larger variation in duration. The majority of the studies completed their programmes over their respective sports' seasons. Therefore, the variation in duration was dependent on the length of the season for that sport, which ranged from 12 weeks (Gilchrist et al, 2008) to nine months (Longo et al, 2012).

The time of the season in which the programmes were untaken was reasonably consistent within the multi-factorial programmes. With the exception of Verrall et al (2005) all of the programmes were completed as a warm up and were therefore completed during the competition season. With regard to the strengthening-based programmes, Askling et al (2003) completed their ten week programme pre-season, while Petersen et al (2011) completed theirs during a mid-season break and then continued with a weekly programme for the rest of the season. Completing an injury prevention programme pre-season doesn't appear to be any more effective than completing it during the competition season.

CONCLUSIONS

The results of this review indicate that there is level one evidence to support the use of injury prevention programmes at reducing injuries in sport. Multi-faceted injury prevention programmes including running, active stretching, strengthening exercises, balance exercises, plyometrics and sport-specific drills appear to be effective in reducing overall injuries in soccer players and ACL injuries.

Programmes involving strength training for the hamstrings also appear to be effective at reducing the risk or hamstring muscle injuries.

Further research in this area is required to establish the effectiveness of different programme parameters such as programme duration, frequency and time of implementation for practical application.

Practical Implications

- Injury prevention programmes should be multi-faceted and include the following key components:
  - running
  - active stretching
  - strengthening exercises
  - balance exercises
  - plyometrics and
  - sport-specific drills
- An injury prevention programme can be effectively completed as part of a warm up and does not require any additional equipment.
- While there is no definite consensus on optimal programme length or frequency, findings suggest they should be completed at least twice a week for the duration of the sporting season.
- Programmes involving strengthening-based exercises are effective at reducing soft tissue injuries. These programmes need to be completed at least one to two times a week for at least ten weeks in duration.
- The majority of multi-faceted injury prevention programme studies have been conducted within soccer and there is evidence of their effectiveness in reducing overall injuries. These programmes may be effective in other team sports.

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Study	Participant Demographics	Intervention	Control	Outcome Measures	Results
Petersen et al. (2011)	N= 942 Male soccer players from 50 professional and amateur teams	N= 461 Progressive eccentric training programme followed by a weekly seasonal program Duration: one season	N= 481 Usual soccer training programme	Incidence of overall, new and recurrent hamstring injuries	Acute hamstring injury rates per 100 player seasons were 3.8 in the intervention group compared to 13.1 in the control group. New injury rates per 100 player seasons were 3.1 compared to 8.1 and recurrent injury rates were 7.1 compared to 45.8 per 100 player seasons.
Emery & Meeuwisse (2010)	N= 744 Male and female indoor soccer players	N= 380 Soccer-specific neuromuscular training programme including dynamic stretching, eccentric strength, agility, jumping and balance (including a home-based balance training programme) Duration: two seasons	N= 364 Standardised warm up (static and dynamic stretching and aerobic components) and a home based stretching programme	Number of injuries, defined as all soccer injuries resulting in medical attention and/or removal from a session and/or time loss	Significant reduction injury rate in intervention group (2.08 injuries/1000 hours) compared to control group (3.35 injuries/1000 hours).
Longo et al. (2012)	N=121 Male club level basketball players	N= 80 FIFA 11+ program 3-4 x week Duration: nine months	N= 41 Normal training program	Primary: injury to athlete; including type of exposure (match or training), location on injury, type of injury (acute or overuse) Secondary: injury to lower extremity (foot, ankle, lower leg, knee, thigh, groin and hip)	23 of the 121 players in the study sustained 31 injuries. Injury rates per 1000 athlete exposures were lower in the intervention than those in the control group with statistical significance for overall and severe injuries. Intervention group also had statistically significant lower injury rates for trunk, hip and groin compared to control group.
Holmich et al. (2009)	N= 1211 Football players	N= 27 clubs Exercise program aimed at preventing groin injuries. Six exercises including: strengthening (concentric and eccentric), coordination and core stability exercises for the muscles related to the pelvis	N= 28 clubs Standard warm up	Time until the first groin injury	Risk of groin injury was reduced in the intervention group, but this was not significant. Having a previous groin injury almost doubles the risk of developing a new groin injury and playing at a higher level almost triples the risk of developing groin injuries.
Scase et al. (2006)	N= 723 Junior elite male football players	N= 114 An intervention programme teaching players six landing, falling and recovery skills Duration: eight sessions	N=609 No training sessions	Injury incidence rates	Intervention group showed a significantly longer time to the first injury and significantly fewer injuries resulting from landing and falls. No significant differences between groups for; injury incidence, prevalence, injury nature/diagnosis, injury site or injury severity.
Soderman et al. (2000)	N= 221 Female soccer players	N= 121 Training program consisting of 10–15 min of balance board training in addition to their standard soccer practice and games Duration: one season	N=100 No balance board training	Injury incidence, including number and type of traumatic injuries of the lower extremities	No significant differences between the groups with respect either to the number, incidence, or type of traumatic injuries of the lower extremities. Incidence rate of "major" injuries was higher in the intervention group than in the control group.
Gilchrist et al. (2008)	N = 1435 Collegiate division one female soccer players	N= 583 Alternative warm up (PEP Program) completed 3x week consisting of: stretching, strengthening, plyometrics, agility, and avoidance of high-risk positions Duration: one season	N= 852 Standard warm up	Injury incidence rates as the number of injuries per 1000 player-hours (PH)	Overall ACL injury rate among the intervention athletes was 1.7 times less than in control athletes. Non-contact ACL injury rate among intervention athletes was 3.3 times less than in control athletes. No ACL injuries occurred in the intervention group during practice, compared to 6 among the control athletes. Game related non-contact ACL injury rates in intervention athletes were reduced by more than half.
Mandelbaum et al. (2005)	N = 2946 Female soccer players	N= 1041 Alternative warm up (PEP Program) consisting of: education, stretching, strengthening, plyometrics and sports-specific agility drills Duration: two seasons	N= 1905 Standard warm up	ACL injury incidence	An 88% decrease in ACL injury in the intervention group compared to control in the first season. During the second season, there was a 74% reduction in ACL injury in the intervention group compared to controls.
Askling et al. (2003)	N=30 Male soccer players in premier-league division	N= 15 16 sessions of specific hamstring strength training Duration: 10 weeks followed by 10 months observation	N=15 No specific hamstring strength training	Hamstring injury incidence, hamstring isokinetic strength and maximal running speed	Occurrence of hamstring strains was lower in the training group (3/15), than the control group (10/15). In addition, there were significant increases in strength and speed in the training group.
Owen et al. (2013)	N= 26 and 23 (season one and two) elite male professional soccer players	Training programme consisting of balance, functional strength, core stability and mobility exercises, performed twice weekly Duration: one season	None	Overall injury incidence	Increase in the total number of injuries within the intervention season (88 compared to 72), however this was largely due to the greater number of contusion injuries sustained within the intervention season (44) when compared to control season (23). Significantly less muscle injuries were observed during the intervention season.
Verrall et al. (2005)	N= One team Australian rules football players	Intervention programme performed during pre-season conditioning period including: high intensity running/ acceleration drills, hamstring stretches, specific football training drill and instructions regarding weight training for the lower limb	None	Number of athletes with hamstring injury, competition days missed and incidence of hamstring match injuries per 1000hrs of playing time	In the seasons prior to intervention, 20 athletes sustained hamstring injuries compared to only six following intervention. Competition days missed reduced from 31 and 38 to 5 and 16 following intervention and match incidence decreased from 4.7 to 1.3 per 1000 hours of playing time.
Arnason et al. (2008)	N= 17-30 Male soccer teams, player numbers varying from 18 to 24 players per team	The program consisted of warm up, stretching, flexibility training and eccentric strength training Duration: two seasons	Baseline measures	Hamstring injury incidence rate	No difference in the incidence of hamstring strains between teams that used the flexibility training program and those who did not, nor was there a difference compared with the baseline data. The incidence of hamstring strains was lower in teams who used the eccentric training program compared with teams that did not use the program, as well as compared with baseline data for the same intervention teams.
Stasinopoulos (2004)	N = 52 Female volleyball players	Group 1 (N=18) Specific technical training programme Group 2 (N=17) Proprioceptive training programme Group 3 (N=17) Sport-Stirrup orthosis Duration: one season	None	Number of ankle injuries	Of the 18 players in group one, two suffered ankle sprains the next season; of the 17 players of group two, three suffered ankle sprains the next season; and of the 17 players of group three, six suffered ankle sprains the next season. Technical training was slightly more effective than the other two methods. Orthosis was not effective in players that had suffered ankle sprains more than three times during their careers.

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When clavicular fractures become a pain in the a*!m

REBECCA LONGHURST, TONY EDWARDS, BRUCE HAMILTON,
JESSICA MEYER, CHELSEA LANE, LOUISE JOHNSON

INTRODUCTION

Thoracic outlet syndrome (TOS) is characterised by a complex of symptoms that arise from the compression of both the subclavian artery and vein, and the brachial plexus within the thoracic outlet (TO).[1,2] The TO is the anatomical space between the first rib, clavicle, subclavius muscle, costoclavicular ligament and the anterior scalene muscle.[1,2,3,4] While well recognised, TOS remains a contentious diagnosis, with some authors questioning its very existence. A recent Cochrane review highlighted that no globally accepted diagnostic criteria exists.[3,5]

Notwithstanding the recent Cochrane review that highlighted that no globally accepted diagnostic criteria exists,[3,5] Twaij et al[1] describe three distinct means of classifying TOS:

1 by event (trauma, repetitive stress or postural abnormalities)
2 by affected structure (neurogenic, arterial or venous)
3 by cause of compression (scalenus anticus or cervical rib syndrome)

Compression of the neurovascular contents of the TO is described as occurring at three potential sites. Firstly, the lower roots of the brachial plexus and subclavian artery may be compressed as they pass over the first rib (or a cervical band/rib if present), and travel between the anterior and middle scalene muscles. Secondly, the lower trunk of the brachial plexus and/or the subclavian artery and vein may be compressed beneath the clavicle in the costoclavicular space. Finally, compression of the brachial plexus cords and/or the axillary artery and vein may occur in the sub-coracoid tunnel.[2]

While a range of causes of TOS have been reported in the literature (Table 1), TOS secondary to mal-union of a clavicular fracture has only rarely been reported[6,7,8,9] Notwithstanding the limited literature, it is intuitive that malunion of a fractured clavicle with associated soft tissue swelling may compress elements within the TO.

The following report illustrates a case of TOS in an elite athlete that began following a benign appearing clavicle fracture.

Table 1: Causes of Thoracic Outlet Syndrome

Identifiable Cause	
Congenital Anomalies	Transverse process of seventh cervical vertebrae, cervical rib, first rib, enlarged scalene tubercle, enlarged scalene muscles.[2,3,11,12]
Trauma	Motor vehicle accident, sporting accident.[1,2,12]
	Bony remodelling post fracture of first rib or clavicle or posterior subluxation of the acromioclavicular joint.[2,12,13,14]
	Post traumatic soft tissue pathologies including muscle hypertrophy, muscle atrophy, muscle spasm, muscle fiber type adaptive transformation, excessive contraction and altered scapula biomechanics and positioning.[15,17,18,19,20,21,22,23]
Posture	Poor posture with protracted shoulders and forward head.[1,12,24,25,26,27,28]
	Soft tissue adaptations to repetitive occupational or athletic activities and postures.[1,2,11,12,14,29]
Miscellaneous	Space occupying lesions such as lung tumour or osteochondroma of the first rib.[23,16,28,30]
	Arteriosclerosis.[11]

CASE REPORT

Athlete X is a Women's Black Sticks Hockey player who received a direct blow to the left clavicle from a powerfully struck hockey ball. Despite wearing routine protective equipment, simple radiography revealed an undisplaced mid clavicular fracture with 25 degrees angulation. Initially athlete X was treated conservatively with simple analgesia and a collar and cuff. Athlete X was noted to have a kyphotic thoracic spine with protracted scapulae. On two occasions during the first week of her rehabilitation, Athlete X felt a "crack" with a "shifting" sensation in the clavicle, associated with an increase in localised clavicle pain. Repeat radiographs revealed caudal displacement of the lateral fragment of the fracture and cranial angulation of the medial fragment. Eight days post-fracture, left arm pulses and sensation were normal but the left clavicle was asymmetrical without skin tenting or tension. An orthopaedic opinion supported the continued conservative management.

Athlete X had a 2 week break from training and rehabilitation, and returned to therapy three weeks post fracture in a sling having been maintaining cardiovascular fitness on a stationary bike. The deformity in left clavicle remained and there was ongoing pain in the fracture site at 45 degrees of active and passive glenohumeral flexion. There were no neurovascular symptoms or signs. She was able to perform pain free pendular exercises, leaning forward letting the arm hang and performing small circles, table wipe exercises with hand supported on a table, and scapula stabilised performing small clockwise and anti-clockwise circles only. Dynamic tape was used to re-inforce an appropriate posture and the sling was replaced with a figure of 8 brace to minimise thoracic kyphosis and to retract her scapula.

Athlete X progressed unremarkably until week 5 post fracture where attempts to elicit further gains in shoulder range of motion were accompanied by a 'nervy pull' radiating into the arm. At 6 weeks post injury, athlete X began to experience numbness over a glove-like distribution in the hand not respecting identifiable dermatome or peripheral nerve distribution. She was also experiencing headaches with end of range arm movements, light-headedness, faintness and tachycardia during exercise and with rapid standing. She was unable to maintain abduction (Roos test), for longer than 5 seconds before her symptoms began.

An MRI to assess the integrity of the thoracic outlet illustrated a healing, minimally displaced clavicle fracture, with no observable impingement or compression between the fracture callus and the subclavian vessels or brachial plexus (in both a neutral and abducted-externally rotated position). No cervical rib or band, were detected.

Given the inability to identify a source of compression, it was postulated that soft tissue could be causing the congestion within the TO. A cardiothoracic surgeon specialist was consulted and continuation of conservative management was advocated.

Physiotherapy for athlete X aimed to; restore glenohumeral function, increase use of the arm, re-introduce arm loading and decrease neural symptoms in the arm. Athlete X's gym based rehabilitation programme was integrated into her normal strength and conditioning programme and she was reviewed weekly (Table 2). Movements and loading in the frontal plane which reproduced neural symptoms in the arm were initially avoided then gradually introduced.

Athlete X returned to hockey training and competition at 16 and 20 weeks post injury respectively. However, athlete X continued to experience symptoms attributed to TOS. Abduction past 30 degrees continued to induce transient numbness in athlete X's arm which dissipated as soon as the arm was moved out of the frontal plane. Following further consultation with several vascular surgeons, it was decided that Athlete X would be re-examined 9 months post injury with the option of a first rib resection at that time should symptoms persist. As a result of ongoing symptoms 9 months post injury, resection of the first rib was performed. At 3 weeks post-resection, Athlete X was not experiencing any TOS symptoms and was able to attain 100 degrees of abduction which was not accompanied with transient numbness. Athlete X is on track to return to full training at 12 weeks post-resection and full competition at 16 weeks post-resection.

Table 2: Weekly Rehabilitation Plans for Athlete X

Week	Exercises
3 weeks post fracture	Cardiovascular fitness on exercise bike Pendular movements of the shoulder Table wipes
5 weeks post fracture	As above with addition of Active assisted elevation, external rotation and abduction Neural glides
6 weeks post fracture	As above with addition of: Running on Alter-G (monitoring heart rate and arm symptoms) Core strengthening
8 weeks post fracture	Treadmill intervals (monitoring heart rate and arm symptoms) Barbell upright rows Leg Press Standing half medicine ball slams Barbell bench press Kettle bell goblet squat Kettle bell squats Prone bridge Half dead bug Dish/spoon abdominals
10 weeks post fracture	Triceps dips on the bench Double cable row Chest press Standing full medicine ball slams Upright row with in standing with Olympic bar Theraband external rotation Tricep crawl/piston in plank position on a bench Modified half Turkish get ups from sitting to standing holding weight at chest Squat Lateral lunge Leg press
11 weeks post fracture	As above with the following additions and modifications: Chest press: added eccentric component on the lower Full modified Turkish get ups from supine to standing pressing weight above head once in standing Skipping 3 x 30 second intervals (5 repetitions) Diving laterally onto high jump mats landing on both sides with arm out-stretched overhead
12 weeks post fracture	As above with the following additions and modifications: Skipping 3 x 30 seconds with 30 rest only x 5 Modified burpie: three press ups off knees with small counter movement jump x 3 per set Diving laterally onto mat super-setted with diving for ball thrown to random sides and heights
13 weeks post fracture	As above with the following additions and modifications: Chin ups Back squats with the bar Return to goal keeper training resumed

DISCUSSION

Due to the proximity of the TO, fractures to the clavicle can result in a diverse array of symptoms. Although infrequent, the development of TOS post clavicular fracture, is reported in the literature including three case studies,[12,30,31] and one clinical article.[21] Each case study identified a mechanical compression in the thoracic outlet via either hypertrophic callous formation, clavicular mal-union/non-union, or significant clavicle displacement.[12,30,31] However, athlete X had no radiological evidence of a space occupying lesion in her TO. It was surmised but unproven that soft tissue swelling associated with the initial and subsequent trauma with post traumatic muscle spasm, potential hypertrophy of her scalene muscles, and protracted shoulder posture may all have been involved in the development of TOS.

Although several objective and provocation tests are utilised in the diagnosis of TOS (Table 3), none have been shown to be valid or reliable.[32,33] This lack of validity may be due to the unique presentation of each individual's TOS symptoms.[14,34] The absence of specific and valid tests requires that a high index of suspicion be maintained in patients presenting with neurogenic hand and arm symptoms.

Delayed diagnosis, or reluctance to accept TOS as a diagnosis may lead to hand atrophy, chronic pain syndrome and unnecessary cervical and hand operations.[21]

Surgical intervention for TOS symptoms are more frequently reported in the literature than conservative management, Dubisson found that the absence of an identifiable mechanical block to the TO from the clavicular fracture eliminated any immediate need for surgical intervention.[35] However, conservative treatment is still recommended as the initial management of choice, unless severe vascular compromise is in situ.[5] A systematic review[4] showed that physical treatments can reduce the pain in patients with TOS. The lack of consensus in the literature regarding best practice may be the result of the various presentations and aetiologies of TOS being considered under the one umbrella term.

Injection of botulinum toxin into anterior and middle scalene muscles has been advocated in the treatment and management of some cases of TOS.[37] However, any improvement in symptoms from botox injection are short lived, with symptoms returning by three months.[37]

Table 4 collates the current research looking specifically at TOS in the athletic population. Of interest 8 of the reported 10 cases involved surgical intervention for resolution of TOS.

Table 3: TOS Provocation Tests

Provocation Test	Description	Positive Test
Roos Stress Test.[2,5,12]	Patient seated with arms abducted and externally rotated to 90 degrees and elbows flexed to 90 degrees. Patient opens and closes hand for 3 minutes	Patient is unable to maintain arm position or symptoms are reproduced
Adson's Manoeuvre[2,5,12]	i) Patient seated with arm in lap, head is rotated and extended to the tested side. Patient is instructed to breath in and hold for 30 seconds as examiner palpates for changes in radial pulse ii) Modification: shoulder is held in 15 degrees abuction and head position is maintained for 1 minutes whilst the patient breathes normally	Dimunition/elimination of pulse or reproduction of symptoms
Wright's test (Hyper-abduction manoeuvre). [2,5,12]	Patient seated with head forward. Examiner brings arm passively into abduction and external rotation to 90 degrees with elbow flexed to 45 degrees. Arm is held for 1 minutes whilst pulse is palpated. The test is then repeated at end of range abduction.	Decrease in radial pulse or reproduction of symptoms
Costoclavicular Manoeuvre[2,5,12]	Patient assumes an exaggerated military position; arms by sides, scapulae retracted and depressed and chest protruded. This is held for 1 minute whilst the examiner palpates the radial pulse.	Changes in pulse and reproduction of symptoms

CONCLUSION

TOS is a rare complication of a minimally displaced clavicular fracture but when signs and symptoms do not fit with expected recovery from a simple clavicle fracture, other causes should be considered. When dealing with elite athletes the complexity of meeting the conflicting imperatives of a rapid return to sport and long term health and function, needs to be acknowledged and managed. In this case, a conservative approach, allowed the Athlete to function adequately on the field but ultimately surgical intervention was required to address residual deficits in daily living.

Key lessons from this case study:

- An index of suspicion for TOS must be maintained when working with athletes
- The presentation and causative factors of TOS vary greatly between individuals
- TOS is difficult to diagnose because of a lack of definitive diagnostic criteria and accepted objective measures
- Typically conservative treatment should be trialled first, unless vascular compromise is present. Surgical intervention should be considered if the conservative treatment fails.
- Meaningful measureable objective measures may need to be selected and adapted for the individual to measure change until reliable valid measures are found.
- TOS may be a diagnosis of elimination until valid and reliable objective measures are established.

Appendum

Athlete X returned to full training and playing as expected and continues to be symptom free following surgery.

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Table 4: Reports of TOS in the athletic population.

Paper	Type of Study	Type of Athlete	How TOS developed?	Management	Outcome
Fujita et al[31]	Case report and review of the literature	Professional Keirin cyclist	Secondary to mal-union of fractured clavicle	Surgical intervention: resection of the inferior protruding part of the clavicle	Return to full sport 1 month post-surgery.
Park et al[29]	Case report	Olympic gold medallist archer	Gradual onset, CT scan confirmed reduction in costoclavicular space in full draw position	Surgical intervention: clavicle osteotomy and first rib excision	Return to 90% of shooting ability, but withdrew from national team as an athlete to begin coaching
Ligh, Schulman & Safran[40]	Case report	College baseball player	Gradual onset non-specific posterior shoulder pain with documented axillary artery compression	6 months of graduated conservative treatment	Return to similar level of activity pain free
Esposito et al[41]	Case report	Baseball player	Gradual onset of numbness in fingers whilst throwing baseball	Surgical intervention: first rib resection and vein graft due to thrombus	Return to sport unclear
Richardson[42]	Series of three case reports	Aquatic athletes Case 1: diver Case 2: waterpolo player Case 3: swimmer	Case 1: Gradual onset Case 2: Gradual onset Case 3: Gradual onset, classic neurogenic TOS	Case 1: First rib excision Case 2: First rib resection Case 3: Scalenus anticus muscle sectioned	Case 1: return to full diving 3 months post-operatively Case2: Six weeks postoperatively return to collegiate waterpolo Case 3: No change post-surgery. Discontinued competitive swimming career
Nitz[43]	Case study	Collegiate swimmer	Acute presentation of swelling and pain into the upper arm after period of intense training	Initial admission to ICU and thrombolysis Subsequent first rib resection	Returned to modified training and competition post thrombolysis, qualified for nationals but opted for corrective surgery instead. Post-op complication of long thoracic nerve palsy. Retuned to all 'desired activities', but unclear as to how this affected athletic career
Katirji & Hardy[44]	Case study	Competitive swimmer	Gradual onset true neurogenic TOS caused by scalenus anticus compression	Surgery: lower trunk of brachial plexus sectioned and neurolysis	No change to TOS signs and symptoms, athlete advised to abandon athletic career
Twaij et al[1]	Case study and practical review	Football player	Acute episode of arm pain following routine training session	Self-medicated with non-steroidal anti-inflammatory drugs	Return to full training and competition
Safran[56]	Literature review	Not applicable			

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A Night of Clinical Pearls

Auckland Branch of Sports Medicine NZ, 30 November 2015

STEPHEN KARA AND CHRIS HANNA

At the end of 2015, the Auckland Branch held its annual Clinical Pearls evening which was well supported. A summary of the potpourri of presentations, with comments from Dr Chris Hanna, is shared below.

Justin Chong – Podiatrist

Title: Assumptions – Orthotics and Footwear

The assumption that orthotics/footwear work through kinematics by reducing STJ pronation and internal tibial rotation as a systematic model is flawed with evidence dating back to 2000. If this model is used to determine levels of orthotic correction/shoe support caution needs to be placed on the risks of overcorrection and that client responses are highly variable. Kinetics and assessment of forces have shown to be systematic and have stronger support in the decision process. Furthermore, comfort is now a strong predictor for injury and is paramount when prescribing footwear and orthotics.

Take Home Pearls:

1 Managing feet solely with a kinematic model is not systematic and has high subject variability i.e. we cannot predict how clients will respond

2 Clients who find shoes and orthotics uncomfortable are at greater risk for injury. Comfort needs to be maintained to create a preferred movement pathway. Shoes and orthotics need to be viewed as "comfort filters".

3 Look at how forces are interacting with the body to determine how to manage clients with orthotics and shoes. In doing this small changes can have large effects and stop the risk of overcorrection and poor comfort which is regularly seen in clinical practice.

Comments

The current researched based evidence on the selection of footwear and type of orthotics prescribed for lower limb injuries and alignment issues was the fey focus for this presentation. Key messages from his talk are that all feet are different, and even feet that look the same may need different interventions. There is clear evidence that one of the most important predictors of improvement when selecting orthotics or recommending footwear, is foot comfort.

Chris Hanna – Sports Physician

Title: Don't Give Up On Cartilage

Cartilage, be it meniscal or articular, has limited capacity for healing. Typically there is no blood supply, and nourishment comes from exchange with the synovial fluid in the joint, which is constantly being refreshed. Continuous passive motion was proposed to help with joint surface injuries by Salter[1] back in 1970. Since that time it has been shown that cyclical loading of articular cartilage enhances resorption of proteins from synovial fluid,[2] the longevity of articular cartilage cells in culture,[3] and the production of growth promoting hormones.[4] The simplest form of continuous passive motion for most patients is the stationary cycle. I tell patients that they should take a book not a towel, at least in the early stages. An outline of bike setup and load progression is available on the Axis Sports Medicine web-page – www.axissportsmedicine.co.nz.

Ravi Suppiah - Rheumatologist

Title: Inflammatory Back Pain

Back pain is a common complaint seen in the sporting population. In most instances this is due to an acute injury or from an overuse/stress injury. Spondyloarthritis (SpA) i.e. inflammatory arthritis of the spine, occurs in this group of athletes – most frequently in young males, and can be difficult to discriminate from injury. Ankylosing spondylitis (the most common form of SpA) can cause progressive bony fusion of the spine if left untreated. Effective therapies are now available for most forms of SpA, so differentiating SpA from injury is critical for appropriate therapy. The classical description of inflammatory back pain is pain and stiffness in the morning that lasts at least 30 minutes and slowly gets better with activity. However, symptoms of inflammatory back pain can also occur with injury, so other associated features can be helpful. In a patient where the back pain is not improving as expected, clues to look for are: a family history of ankylosing spondylitis, a personal or family history of skin psoriasis, insertional tendinopathy (enthesitis), history of iritis/uveitis, dactylitis (sausage finger or toe), or inflammatory bowel disease. If any of these other features are present, consider SpA in the differential. Blood tests may be normal and plain radiographs are often normal for several years. Referral to a rheumatologist and MRI imaging of the sacroiliac joints are usually required to make the diagnosis in the early stages

Comments

Two cases of low back pain that were almost identical in presenting symptoms, clinical findings, laboratory tests and imaging were presented. One improved with rest, the other did not. One was a sacro-iliac stress fracture, and the other was a sacro-iliitis. Dr Suppiah reminded us to keep the inflammatory diseases in mind when dealing with patients presenting the musculoskeletal injuries, and also to remember musculoskeletal injuries can masquerade as inflammatory enthesopathies.

Clinton Pinto – Radiologist

Title: Could This Be …. Gout?

Comments

Dr Clinton Pinto discussed the fact that gout, a metabolic disorder that is one of the seronegative spondyloarthropathies, has a predilection for connective tissues and can present as a tendonitis, enthesitis or swollen joint. It should be in the back of your mind if your patient is overweight, not improving as expected, or has a family history. Modern imaging can be very good at confirming the diagnosis. Importantly, gout is an indicator of other lifestyle diseases, and should be a reminder to promote weight control, regular exercise and good diet.

Geoff Potts - Physiotherapist

Title: Lower Limb Neuromuscular Changes from Injury

Comments

Geoff Potts, a physiotherapist with a special interest in the knee, presented some preliminary findings showing that isokinetic dynamometry of the muscles around an injured knee – in these cases, post-ACL reconstruction – has long been known to show reduced peak torque. What has only recently been shown is that these same apparently weak muscles have significant fatigue resistance, and that they can be pushed to quite high repetitions before fatiguing. Geoff made the point that it is important in these patients to push their repetitions into the fatigue zone – even if it means performing 30 or more repetitions per set, in order to create a training response. He reported that current research has shown that as strength increases, the fatigue resistance normalizes. Geoff has installed an isokinetic dynamometer in his clinic, and is planning on pursuing a PhD in this topic.

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Tackling Doping in Sport

BRUCE HAMILTON AND JENI PEARCE

- *Is sport corrupt?*
- *Does sport have good governance?*
- *Can we prevent cheating / doping in sport?*
- *Can we protect the "clean" athlete?*
- *How do we fund the anti-doping cause?*

These questions represent some of the themes that pervaded the 2016 Tackling Doping in Sport conference, held over March 9 and 10, 2016 in Twickenham London. While ostensibly designed by lawyers and sport administrators for lawyers and sports administrators, the conference was definitely worthy of attendance from doctors, nutritionists and sport scientists.

As recent as twenty years ago, I suspect that there would not have been enough interest, or money involved in the anti-doping movement to be able to bring together even a small group of lawyers and administrators to debate this topic, and the field was therefore dominated by medicine and sport science expertise. As such, I suspect that the majority of the anti-doping literature at the time was found in sports medicine and science texts. Times have changed and "Tackling Doping in Sport" (a great title for a conference held at the home of England rugby) attracted a large number of international attendees, predominantly sports administrators, sports lawyers, anti-doping agencies from various countries (Spain, Denmark, Qatar, Switzerland, UK, Australia, New Zealand and China) and representatives from national Olympic committees and the IOC. Vast amounts of anti-doping literature can now be found in the legal, sociological and administrative literature, and anti-doping case law is rapidly expanding. If nothing else, this conference has reaffirmed my belief that medicine and science are now only bit-players in a field increasingly dominated by lawyers and legal arguments. While the science remains critical to the operational aspects of anti-doping, if this conference is anything to go by, science and medicine are now subservient to the requirements of the legal teams, rather than leading the space. It is apparent from this meeting that this reflects a required evolution of the anti-doping world.

This realisation brings with it an observation. It is clear that the anti-doping cause, led by the World Anti-Doping Agency (WADA), is remarkably underfunded. This is particularly salient when one compares the WADA budget with the vast amount of money generated by elite and professional sport worldwide, and the fiscal returns recorded by those large companies and organisations that support the sporting entity. However, while only being spoken of in hushed and embarrassed tones, it was clear that those individuals driving the legalisation of anti-doping were the same ones that were making it so expensive. I've often been called naïve, but I'm not naïve enough to believe that lawyers would be working in this space if there wasn't the remuneration associated with it. From where I sit, this appears diametrically opposed to the position of most medical and scientific teams who work diligently in sport despite the (most frequently) relatively low remuneration.

Notwithstanding this observation of the legal framework enveloping anti-doping, a theme repeated constantly during the conference was that of expanding sources of funding. While increased government funding was considered desirable, it was also recognised that governments have multiple competing imperatives, and further funding from governmental sources is unlikely. Of note, the IOC matches dollar for dollar every cent, penny or dime that the governments put into WADA, and so governments remain the primary target for WADA. However, increasingly there are calls for large multi-national companies who both sponsor athletes and benefit from having clean sport, to support the anti-doping cause. Novel suggestions such as those funds that would previously have gone to an athlete who has been "dropped" from sponsorship due to a drug related sanction, be diverted to the anti-doping cause were touted, but there appears to be little momentum in making this funding source a reality. Perhaps leverage exists in the reality check that if doping persists, then public support for elite sport may wane, and as a result the financial returns involved in sport may dry up.

A further, (admittedly defensive) emotion that I left this conference with, was that of the ongoing perception (among the "anti-doping community") of doctors (and nutritionists, sport scientists) as being part of the problem of doping, rather than as part of the solution of anti-doping. This probably just reflects the fact that the only time this group is mentioned is part of a tragic and systematic doping process, rather than a genuine perception. The 99% of practitioners who on a daily basis engage in educational practices as part of their routine consultations, and who vehemently support the anti-doping cause, are not represented in these types of discussions. However, this imbalance is perhaps one of the reasons that medicine appears to have less impact in the higher echelons of anti-doping.

Particularly relevant given the recent revelations regarding Russian track and field athletes and the alleged complicity from individuals in the IAAF (for details watch this documentary: https://www.youtube.com/watch?v=iu9B-ty9JCY), limitations in sports governance (at all levels of sport) were highlighted as one of the major risk factors for endemic and incidental doping practices. Dr

David Hughes, Chief Medical Officer of the Australian Institute of Sport and Australian Olympic Team, provided a great example of how this is not something confined to the northern hemisphere, when he outlined the governance failings surrounding the Essendon Football Club drug scandal. On this note, it was highlighted that sporting bodies typically desire to be autonomous in determining their own structure and path, and resist external regulatory control. However, Jonathon Taylor (Sports Lawyer) summed it up when he suggested that autonomy without good governance is a disaster waiting to happen.

Aligned with discussion regarding sport governance and autonomy, was a fascinating debate on the independence of arbitration of alleged doping cases. Currently, as I understand it, international athletes with an anti-doping rule violation will typically answer the charges before their international federation (at a national level, this will be the National Sporting Organisation (NSO) – in some countries this is outsourced to the National Anti-doping Organisation by the NSO), but athletes or WADA may subsequently appeal to the Court of Arbitration in Sport (CAS - based in Switzerland, using Swiss law). There was a desire from some presenters (albeit with a very lawyer-centric hat on) to centralise all initial hearings into CAS, thereby avoiding the perceived and sometimes real conflict of interest incumbent in federations hearing their own cases, and to increase the legal involvement (at the expense of other professionals such as doctors) in the arbitration process. This concept appears controversial, even amongst the lawyers present!

The conference reinforced the messages from 2015 with the focus shifting to protecting the clean athlete and highlighted the shift towards collaboration with drug enforcement agencies, intelligence gathering and catching the higher level drug traffickers and manufacturers (who could be working out of the basement next door), in order to stop supplies reaching athletes. An excellent presentation was delivered on the Psychology of Doping by Dr Backhouse from Leeds University who reviewed the role of the environment and behaviour in doping activity.[1] She identified the intention to dope is linked to three areas: a positive attitude toward doping, social norms and exposure to those who dope. By contrast, morality and self-efficacy to refrain from doping had the strongest negative association with doping intentions and behaviours. Of interest, she reported that athletes were more likely to dope if they believe that everyone else is doing it and getting away with it or if they have an injury, a drop or 'dip' in performance and contracts or funding are under threat.

Finally, this conference provided the opportunity to review the 2015 WADA Code and the 2016 Prohibited List. Undoubtedly both of these documents have come a long way. The first code was published in 2003 (four years after the founding of WADA) and the latest iteration is far more expansive and comprehensive. From the perspective of a practitioner, it is worth noting that the code now (quite rightly) has the ability to sanction those individuals supporting doping practices, as well as the athlete. There is also increased interest in "forensically" identifying athletes who may be cheating through numerous means including international sharing of data and collaboration with government bodies. It is difficult to determine exactly when the first anti-doping list (originally from the IOC) appeared, since different resources quote different dates, but it was likely in the mid 1960s This was initially a simple and relatively arbitrary list of medications, and this format was essentially the same when I started sports medicine in the 1990s. With the advent of WADA, the prohibited list has changed immensely. Even though I am familiar with the prohibited list, dedicating some time to reviewing it (or at least trying to) made me aware of the growing complexity in both its structure and expansive content. The list is constantly evolving, and one lesson from the ongoing Sharapova publicity is that as practitioners we should be wary of complacency when it comes to understanding the prohibited list.

In addition to Jeni and myself representing the nutrition and medical components of High Performance Sport (HPSNZ) at the "Tackling Doping in Sport" conference, NZ was also represented by Graeme Steele (Chief Executive , Drug Free Sport NZ) and Jude Ellis (Programme Director, Testing and Investigation, DFSNZ). We would like to recognise and thank HPSNZ for its support and in particular the Prime Minister's Scholarship fund, which facilitated our attendance at this conference.

Bruce Hamilton

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Performance Nutrition Lead, HPSNZ

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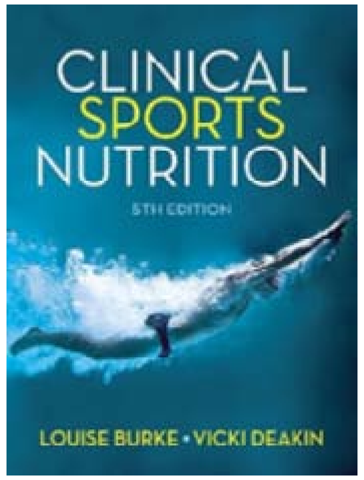

Clinical Sports Nutrition

5th Edition

Editors: Louise Burke and Vicky Deakin

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Also available as an ebook.

ISBN-13: 978-1743073681
ISBN-10: 1743073682

TANYA HAMILTON AND BRUCE HAMILTON

The latest edition of Clinical Sports Nutrition is yet another quality production of this must have reference book. Sports dietitians and nutritionists will already recognise its value from previous editions, but the latest edition either in paperback or as an e-book is a worthy addition to any library. The contributors, all leaders in the sports nutrition industry, have comprehensively reviewed the literature in their respective chapters, expanding significantly since the first edition was published in 1994. Contributions by the next generation of international sports nutrition experts has made this reference book a truly updated and international resource for professionals working in the area of sports nutrition.

The 5th edition expands on the understanding of the interplay between physiology, nutrition, health and disease, sport and exercise, incorporating relevant information for athletes ranging from the adolescent through to masters and Paralympic athletes. As such, this reference book has value for any professional working closely with athletes where it is necessary to understand the comprehensive value of good nutritional advice.

A notable evolution in the latest edition is the more individualised approach to nutrition recommendations, reflecting the increasing academic interest in the merits of this individualised health care. Specific areas such as protein dosing and timing, periodisation of nutritional approaches, training with low carbohydrate availability, and the use of FODMAP diets are increasingly individual prescribed.

Novel topics of increasing interest include the role of vitamin D in bone and muscle health, following recognition of the high prevalence of suboptimal vitamin D status among athletes. Similarly, it was reassuring to note that while metabolic pathways for fat oxidation have not changed, an in depth review of low carbohydrate / high fat literature in relation to adaptive metabolic changes, exercise performance outcomes and potential applications for athletes is incorporated. As we all get older, and with the 2017 World Master Games in New Zealand it was pleasing to see a change in terminology from consideration of the aging athlete to the master athlete!

A must read chapter is that considering immunity, infective illness and for the first time … injury. No prizes for guessing that our role as clinicians will grow in the area of injury prevention and management as we learn more about the role of nutrition in this multi-factorial area.

Finally, the practise tips and commentary's at the end of each chapter turn this text book into a clinical companion that provides valuable assistance in the assessment, intervention and management of clinical sports nutrition challenges.

Tanya Hamilton

HPSNZ Performance Nutritionist

Our understanding of the benefits of good nutrition on athletic performance has taken great strides over the last 20 years and the 5th Edition of Clinical Sports Nutrition by renowned authors Burke and Deakin provides a striking synthesis of that progress. Incorporating comprehensive fully referenced chapters on an impressive range of health related topics and written by genuine international experts, Clinical Sports Nutrition has made a significant contribution to both the academic and clinical literature but most importantly is a valuable tool to have at your side in the clinic.

Not being an expert in nutrition does not appear to be a limitation to reading and understanding this textbook, since it is written in a user friendly manner with chapters walking readers through topics clearly. From the perspective of a Doctor working in Sports Medicine, Clinical Sports Nutrition provides an outstanding resource for clinically relevant areas such as iron deficiency, gastrointestinal issues and vitamin D deficiency to name but a few. With every chapter comprehensively referenced this textbook provides either all the information you need on a given topic, or the means to rapidly source key original articles.

Gold star to Burke and Deakin for their production.

Bruce Hamilton

HPSNZ Medical Director