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SPONSORED EVENTS

09.15 8th July  Welcome
07.30 9th July  Vicon Breakfast
              Holywell Park Conference Centre
WELCOME

It is a great honour and privilege to welcome, on behalf of the WCSMC 2019 organisers, all participants to the 6th World Congress of Science and Medicine in Cricket. This is the second time the congress has been hosted in the United Kingdom, and with over 100 delegates from 20 different countries around the world, it has substantially grown since the inaugural Congress hosted in the United Kingdom during the 1999 Cricket World Cup.

This is the first time that the Congress has been hosted at Loughborough University. The institution dates back to 1909 and has a long and established tradition of world leading sports science teaching, research and innovation. The University’s School of Sport, Exercise and Health Sciences has for the last three years been rated as the best university in the world for sports-related subjects in the global QS higher education league table. While the campus also offers state-of-the-art homes and facilities for national sporting bodies including British Swimming and the England & Wales Cricket Board among others.

The programme aims to deliver on bringing together the most eminent researchers in cricket with coaches, players and administrators of national and international teams. I am delighted that joining us at this year’s Congress are applied practitioners from the English domestic counties and the International Cricket Council’s Associate Nations, as well as the International teams. We hope this allows the Congress to provide a unique setting for both researchers and practitioners to partake in knowledge exchange, innovation and networking opportunities.

I would personally like to thank the Organising Committee for their dedication and hard work, in particular, the local organising committee: Paul Felton, Pete Alway, Laura Keylock, Mike Harwood, Kris Clements, Manisha Patel and Nick Pierce, without whom it would not have been possible to organise this Congress. I would also like to thank our Platinum sponsors: Vicon iMeasureU, and our Gold sponsors: Simi, for their continued support of the Congress.

Finally, I would like to encourage you to make new friends, develop research collaborations, and discuss finding solutions to the current practical problems in cricket. I hope you enjoy the Congress and the camaraderie of the other delegates, and remember we are all part of the cricket family, especially during the “friendly” Loughborough vs Rest of the World Cricket Match!

Mark King

Chair of the 6th World Congress of Science and Medicine in Cricket
LOCAL ORGANISING COMMITTEE

Dr Mark King
Loughborough University

Dr Paul Felton
Loughborough University

Pete Alway
Loughborough University

Dr Nick Pierce
England & Wales Cricket Board

Dr Mike Harwood
Loughborough University

Laura Keylock
Loughborough University

Dr Kristin Clements
Loughborough University
WCSMC SCIENTIFIC COMMITTEE

The Scientific committee consists of the local organising committee and the following:

Vanessa Hobkirk
International Cricket Council

Dr John Orchard
The University of Sydney

Prof Candice Christie
Rhodes University

Dr Craig Ranson
English Institute of Sport

Prof Benita Olivier
University of Witswatersrand

Dr Akshai Mansingh
The University of the West Indies

Dr Alex Kountouris
Cricket Australia

Dr Peter Harcourt
The University of Melbourne

Dr Edouard Ferdinands
The University of Sydney

Dr Mandeep Dhillon
PGIMER Chandigarh

Dr Will Vickery
La Trobe University

Myles Murphy
The University of Notre Dame
PROGRAMME

Sunday 7th July 2019

19.00 - Welcome Reception – The Link Hotel

Note: All events are at Holywell Park Conference Centre unless stated.

Monday 8th July 2019

08.30 REGISTRATION
09.15 WELCOME

INJURY Chair: Peter Brukner

09.30 L. Goggins: Injury epidemiology in men’s elite English and Welsh domestic cricket: A nine season review from 2010 to 2018
09.45 J. Valadao: Neuromuscular electrical stimulation and the hamstring conundrum
10.00 A. Saw: Vertebral artery dissection: Mechanism of injury and implications for risk-reduction in cricket
10.15 COFFEE BREAK

SHOULDS Chair: Jacqueline Alderson

10.45 M. Dutton: The cricketers shoulder: Not a classic throwing shoulder
11.00 B. Olivier: The cricketer’s shoulder and injury: asymmetries in internal rotation range of movement, throwing arc and pectoralis minor muscle length – a longitudinal cohort study
11.15 M. Dutton: Do cricketers display similar overhead throwing biomechanics to baseball players?
11.30 L. Newton: The effect of a cricket fielding session on glenohumeral range of motion and active joint position sense.
11.45 S. McCaig: The musculoskeletal profile of first-class cricketers with throwing arm pain

KEYNOTE LECTURE Chair: Paul Felton

12.00 P. Brukner: Does it matter what a cricketer eats?
13.00 LUNCH & POSTERS (ODD NUMBERS)

INVITED PRESENTATION Chair: Pete Alway

14.30 R. Saw: Imaging and progression of lumbar stress fractures in fast bowlers
ADAPTATIONS & INJURIES IN BOWLING Chair: Anna Saw

14.45 R. Ferdinands: *Investigating the relationships between kinematic factors and lumbar injury in young fast bowlers*

15.00 P. Alway: *Regional lumbar bone mineral density differs in cricket fast bowlers with lumbar bone stress injury*

15.15 L. Keylock: *The effect of age and bowling delivery speed on lumbar bone mineral in adolescent fast bowlers*

15.30 J. Bray: *Investigating the relationship between fast bowling workloads, muscle damage/stress following spells of simulated fast bowling*

15.45 **COFFEE BREAK**

WORKLOAD Chair: Will Vickery

16.15 C. Munro: *Workload monitoring of an elite South African women’s cricket team during the 2018/2019 season*

16.30 S. Feros: *Optimising rhythm, ball release speed, and workload in amateur pace bowlers: is there an ideal prescribed delivery intensity?*

16.45 C. Christie: *Workloads and injury risk in elite South African cricket fast bowlers: A snapshot of one season*

17.00 F. Garcia-Byrne: *GPS-detected lateral sway during a submaximal running test correlates with endurance exercise performance in elite Australian cricketers*

19.00 **BANQUET**

Tuesday 9th July 2019

07.30 **VICON BREAKFAST**

FAST BOWLING STRENGTH & CONDITIONING Chair: Benita Olivier

09.00 C. Peterson: *Effect of a 6-week Indian clubbell strength programme on fast bowlers’ shoulders*

09.15 M. Forrest: *Exercises to modify risk factors for injury in community-level adolescent pace bowlers*

09.30 S. Ranjit: *Functional movement screening in elite Indian fast bowlers*

09.45 W. Vickery: *The development of a fast bowling Twenty20 match simulation*

10.00 S. Feros: *Bowling with modified-implements in the warm-up: do they alter pace bowling skill, rhythm, and sensation with a regular ball?*

10.15 **COFFEE BREAK**
PREPARATION & STRESS Chair: Candice Christie

10.45  P. Gamage: *Understanding heat stress and exposure during test-cricket play: an exploratory study*

11.00  H. Anderson: *Enhancing concentration in an elite international male cricketer: A longitudinal mixed methods study*

11.15  K. McEwan: *Sleep quantification of elite South African cricket players during a home and away series, for both One-day international (ODI) and Twenty20 games*

11.30  B. Campbell: *Pilot study investigating the time of day effects on perceptual, physical and performance indicators of adolescent fast bowlers.*

11.45  T. Turner: *GPS and time motion analysis on the physical demands of fielding in professional cricket*

KEYNOTE LECTURE Chair: Mark King

12.00  K. Shine & P. Felton: *Getting the best from our quicks*

13.00  LUNCH & POSTERS (EVEN NUMBERS)

INVITED PRESENTATION Chair: Pete Alway

14.30  P. Inge: *Comparison of men’s & women’s cricket injuries at the elite level in Australia*

ADAPTATIONS & INJURIES IN BOWLING Chair: Pip Inge

14.45  B. Jones: *Association of leading leg knee cartilage volume with bowling kinetics in current elite fast bowlers*

15.00  A. Alva: *Fast Bowler’s Knee – Management of articular impingement in International players*

15.15  A. Kini: *Foot and ankle overuse injuries in fast bowlers: comparison between front on & side on action bowlers*

15.30  A. Saw: *Observable characteristics of head impacts associated with concussion diagnosis in cricket*

15.45  COFFEE BREAK

SYMPOSIUM Chair: Nick Peirce

16.15  S. Filbay, G. Bullock, N Perera & N. Arden: *The Cricket Health and Wellbeing Study*

17.30  CAMPUS TOUR

OR

16.00  FAST BOWLING WORKSHOP National Cricket Performance Centre

19.00  DELEGATE CRICKET MATCH & BBQ Brockington Cricket Pitch
Wednesday 10th July 2019

**BATTING** Chair: Rene Ferdinands

09.00 B. Jones: Optimising Challenge: *Key in the Development of England’s Greatest Batsmen?*

09.15 H. Noorbhai: *The batting backlift technique in cricket: What is the consensus at all skill levels?*

09.30 S. Taliep: *Visual perceptual ability in adolescent cricket batsmen*

09.45 N. Isaacs: *The kinetics and kinematics of the rotary batting technique*

10.00 S. McErlain-Naylor: *Kinematic determinants of power hitting performance: a technique comparison of male and female cricketers*

10.15 **COFFEE BREAK**

**TALENT ID & DEVELOPMENT** Chair: Stuart McErlain-Naylor


11.00 M.A. Dove: *The value of a socio-ecological approach to talent development in cricket*

11.15 A. Nichol: *How do culture and norm circles (as shaped by coaches and others) play a role in influencing the actions of cricketers?*

11.30 M. Harwood: *Scaling the pitch for under-11s beyond*

11.45 A. Lascu: *Perceptions of talent development in Women’s Cricket from national-level players and coaches.*

**SPIN BOWLING** Chair: Marc Portus


12.15 K.A. Thiagarajan: *Accuracy of Umpiring decisions for detecting illegal bowling action in Cricket from different positions in comparison with 3D Biomechanics analysis*

12.30 P. Felton: *Relationships between spin bowling technique and spin*

**INVITED PRESENTATION** Chair: Pete Alway

12.45 A. Nicholls: *Hand Injuries in Elite Australian Cricketers*

13.00 **LUNCH**

**INVITED PRESENTATION** Chair: Pete Alway

14.30 J. Orchard: *Cricket Australia cardiac screening program*
TECHNOLOGY IN CRICKET Chair: Mark King

14.45 N. Soomra: *Use of smart watches to detect bowling speeds and counts for fast bowlers*

15.00 P. Dias: *Machine Learning of Batting Movement Data Patterns for Injury Prevention*

15.15 C. Petersen: *Cricket Gr8 App: Inspiring net sessions*

15.30 H. Jowitt: *Auto detecting deliveries in elite cricket fast bowlers using microsensors and machine learning*

15.45 CLOSING CEREMONY

WORKSHOPS

16.15 R. Ahmun: *Strength & Conditioning*

17.15 N. Peirce: *Emergency Care*

19.00 CLOSING SOCIAL *Orange Tree, Loughborough*
LIST OF POSTERS

1. N. Isaacs: *The kinetics and kinematics of the rotary backlift*
2. N. Isaacs: *The kinetics and kinematics of the rotary downswing in batting*
3. N. Isaacs: *Increasing the momentum of the cricket bat with a rotary batting technique*
4. N. Isaacs: *Comparative and Functional anatomy of Gluteus Maximus (GM) regarding a change of direction related to performance and injuries*
5. H. S. Bansal: *Is bowling workload a risk factor for injury in English cricket first-class fast bowlers?*
6. R. Sholto-Douglas: *Quantifying movement demands of elite cricket players participating in the 2017/2018 Big Bash League*
7. L. Pote: *The impact of a fast bowling spell on physiological, perceptual and performance responses in non-elite cricketers.*
8. L. Pote: *Workloads placed on adolescent cricket players*
9. W. Vickery: *A coach’s perspective of cricket design: a case report*
10. H. Anderson: *A systematised review of the literature on the biomechanics of fast bowling in cricket: a technique focus*
11. D. Barnard: *Workload does not impact performance responses in the Indian Premier League cricket*
12. C. Munro: *Time motion analyses comparing the 2012, 2016 and 2018 ICC Women’s World T20 Tournaments*
13. D. Kodikara: *Head, neck and facial injuries in cricket: A straight-drive through knowledge gaps*
14. S. Taliep: *A four-week resistance training programme increases cricket bowling velocity*
15. K. Sai Aditya: *Effect of Select Kinematic & Kinetic Variables on the Ball Speed in Cricket Fast Bowling - A 3D Biomechanical Investigation*
16. S. Feros: *Eccentric rate of force development and its relationship with front knee kinematics and peak ball release speed in amateur pace bowlers*
17. S. Badhyal: *Lower limb muscle force estimation for fast bowlers in cricket*
18. P. Gamage: *Epidemiology of junior cricket injuries: a narrative review*
20. N. Soomro: *Design and Development of a Novel Cricket Injury Prevention Program (CIPP)*
21. N. Soomro: *Cricket Injury Epidemiology in the 21st century: What is the burden?*
22. J. Bray: *Monitoring fast bowlers training load: a practitioners perspective*
R. Crowther: *Spinning characteristics of two cricket pitches with contrasting soil properties*

K.A. Thiagarajan: *Comparing Elbow extension between over and around the wicket deliveries using 3D Biomechanical analysis in Indian off-spin bowlers*

L. Keylock: *Reproducibility Assessment of a Musculoskeletal Screening Protocol in Junior Cricket Fast Bowlers, Conducted by a Non-clinician*
GUIDE FOR PRESENTERS

Oral – Presentations are 15 minutes (12 minutes + 3 minutes for questions). All presentations should be produced on PowerPoint and compatible with Windows. We request that you upload your presentation to the presentation laptop in advance of your session.

Poster - Posters should be A0 with a Portrait Orientation. All Posters will be up for the entire event and can be hung during registration on Day 1. We invite those with an odd number to stand by their posters during lunch on day 1, and those with an even number to stand by their posters during lunch on day 2.

Any queries regarding presenting please email: P.J.Felton@lboro.ac.uk or speak to one of the members of the organising committee.

SOCIAL EVENTS

Welcome Reception – Sunday 7th July – 19:00 - The Link Hotel

A casual opening to the congress with drinks being served in the lobby of the The Link Hotel.

Banquet – Monday 8th July – 19:00 – Holywell Park Conference Centre

All delegates are cordially invited to the banquet. Dress up, visit old colleagues, meet new friends and celebrate cricket and good company, while enjoying good food, drinks and the sounds of Britain’s Got Talent Semi-Finalist: Kieran Sutcliffe.

VICON Breakfast – Tuesday 9th July – 07:30-09:00 – Holywell Park Conference Centre

VICON have been a leading developer of motion capture and have been involved in cricket research for almost two decades. VICON have an array of unique hardware and software which can be used to optimise sports performance and prevent injury, which can be used in many different environments. Recently, IMeasureU have created a wearable sensor and software which can measure, manage and maximize human movement. IMeasureU provides a sensor which can quantify body movements and workload metrics in the field rather than in the lab, and can be used to optimise performance, reduce injury risk and enhance return to play protocols. During this breakfast you will hear about how IMeasureU enables a personalised, precise lower limb monitoring system for some of the world’s leading athletes and sports teams.

Please sign up to the breakfast using the following link https://www.eventbrite.co.uk/e/imeasureu-the-wcsmc-2019-breakfast-meeting-tickets-61151900982.

Loughborough v Rest of the World Delegate Cricket Match + BBQ – Tuesday 9th July – 19:00 - Brockington

Weather permitting (fingers crossed) a social cricket match will take place between delegates from Loughborough and those from the Rest of the World. To register your interest in playing in the game please email our chief selector Laura (L.M.Keylock@lboro.ac.uk). All cricket equipment is provided so no need to bring your cricket gear, just trainers and sports attire (and competitive spirit!).

Closing Social – Wednesday 10th July – 19:00 - The Orange Tree

Please join us as we close out the social with some casual drinks and food in one of Loughborough’s atmospheric and relaxing bars.
KEYNOTE LECTURES

MONDAY 8th JULY
DOES IT MATTER WHAT A CRICKETER EATS?
PETER BRUKNER

Peter Brukner OAM is a specialist sports and exercise physician whose most recent position has been Australian cricket team doctor from 2012-17. Peter is the founding partner of Olympic Park Sports Medicine Centre in Melbourne and Professor of Sports Medicine at LaTrobe University. A founding Executive Member of the Australasian College of Sports Physicians, he served two terms as President and played a key role in establishing sports medicine as a medical specialty in Australia. Peter is the co-author of the widely used text book Clinical Sports Medicine and has been team physician for professional football clubs as well as national athletics, swimming, soccer and men’s hockey teams including Olympic and Commonwealth Games. Peter was the Socceroos Team Doctor at the 2010 World Cup in South Africa and subsequently became Head of Sports Medicine and Sports Science at Liverpool Football Club. He is the co-founder of the public health campaign SugarByHalf and is committed to the challenge of improving the nation’s health with improved diet and increased physical activity. His most recent book A Fat Lot of Good was published in May 2018.

TUESDAY 9th JULY
GETTING THE BEST FROM OUR QUICKS
KEVIN SHINE & PAUL FELTON

Kevin Shine is the Lead National Fast Bowling Coach for the England and Wales Cricket Board (ECB). Prior to his coaching career, he played first class cricket representing Hampshire, Middlesex and Somerset. After retiring, Kevin completed the ECB Level 4 coaching course and in 2001 was appointed as Somerset's Head Coach, winning the One-Day trophy in his first season. In 2006, he was appointed to his current role as National Fast Bowling Coach based at Loughborough’s National Cricket Performance Centre. In this role, Kevin oversees every aspect of the elite fast bowling pathway including technical coaching, scouting, player development, coach education and talent identification. He has also built a strong partnership with Loughborough University supporting research into both performance and injury aspects of fast bowling.

Paul Felton is a Research Associate in Sports Biomechanics at Loughborough University. His main research interest is to use computer simulation models to aid coaching by highlighting the limiting factors on individual performance. Paul is also an integral part of the England and Wales Cricket Board’s Elite Fast Bowling Programme as a consultant Biomechanist, and an accredited member of the International Cricket Council’s Suspect Bowling Action testing team. His doctoral research, in collaboration with the England and Wales Cricket Board, investigating the individual factors which limit fast bowling performance is world leading and has been internationally recognised, winning the International Society of Biomechanics in Sports’ New Investigator Award in 2017. More recently, Paul has been the lead tutor for Biomechanics on the ECB’s coach education programme and embarked on a collaboration with the English Institute of Sport, investigating the factors which limit performance in Paralympic athletes using sprinting or jumping prostheses.
INVITED PRESENTATIONS

MONDAY 8th JULY

RICHARD SAW – Imaging and progression of lumbar stress fractures in fast bowlers
Dr Richard Saw is currently the Australian Men’s Cricket team doctor, having previously worked within Australian Rules Football and Gymnastics.

TUESDAY 9th JULY

PIP INGE – Comparison of men’s & women’s cricket injuries at the elite level in Australia
Dr Pip Inge is currently the Australian Women’s Cricket team doctor having previously worked within Rowing.

WEDNESDAY 10th JULY

ALEX NICHOLLS – Hand Injuries in Elite Australian Cricketers
Dr Alex Nicholls is a hand and upper limb surgeon who has previously worked with Cricket Australia.

JOHN ORCHARD – Cricket Australia cardiac screening program
Dr John Orchard is the Chief Medical Officer of Cricket Australia, having previously worked with Cricket NSW, and within Rugby and Australian Rules Football. Dr Orchard wrote the Orchard Sports Injury Classification System (OSICS), and has published over 200 research articles, many of which have been with a cricket focus.

WORKSHOPS

TUESDAY 9th JULY

FAST BOWLING - National Cricket Performance Centre – 16.00-19.00
Dr Edouard Ferdinands (University of Sydney, Australia) will lead a workshop aimed at enhancing fast bowlers’ biomechanics. The workshop will include a 1-hour presentation on fast bowling biomechanics followed by a 2-hour net session where Dr. Ferdinands will apply the biomechanical principles covered in the proceeding lecture.

WEDNESDAY 10th JULY

STRENGTH & CONDITIONING IN ELITE CRICKETERS – Holywell Park Conference Centre – 16.15-17.15
Rob Ahmun is the England and Wales Cricket Board National Lead for Strength and Conditioning having previously obtained over a decade of experience as a Strength and Conditioning Coach within Cricket and Netball. Rob has extensive experience working with both elite and developing fast bowlers to optimise their performance and prevent injuries. Rob will also talk about the unique challenges faced by a strength and conditioning coach in cricket.

EMERGENCY CARE IN CRICKET – Holywell Park Conference Centre – 17:15-18:15
Medical staff of the England and Wales Cricket Board will speak about their experiences dealing with impact injuries, cardiac screening, and concussion testing, how to improve screening and other on-field emergencies.
SYMPOSIUM

TUESDAY 9th JULY - THE CRICKET HEALTH AND WELLBEING STUDY

The Cricket Health & Wellbeing Study explores the relationship between playing cricket and musculoskeletal health, general health, physical activity and quality of life across the lifespan. We recruited 2294 current and former cricketers to capture the diverse array of individuals that play cricket in England and Wales, both men and women, of all standards, from a variety of cultural backgrounds. It is evident that both recreational cricketers and women were largely under-represented in cricket research, so we wanted to include these individuals in this study.

We used a combination of validated tools that will enable comparison to the general population and other sporting groups, as well as player-centred questions, driven by our qualitative work with cricketers and collaboration with the England & Wales Cricket Board. The questionnaire was developed to provide a platform for further studies, targeting specific questions with the aim of enhancing player health and wellbeing across the lifespan. This symposium will present results from the five key focus areas of the Cricket Health & Wellbeing Study.

PROGRAMME

1. An introduction to the Cricket Health & Wellbeing Study
   To provide an overview of the Cricket Health & Wellbeing Study design, methods and participant characteristics to provide background for presentations 2-5 and facilitate collaborations.
   S. Filbay

2. Injury and concussion prevalence and the relationship with playing position, playing standard and helmet-use in recreational and elite cricketers
   To describe the prevalence of hip/groin, knee, ankle, shoulder, hand, back injuries and concussion in current and former cricketers; and evaluate the relationship between playing-position, playing-standard, helmet-use and the odds of injury/concussion.
   S. Filbay

3. Pain and osteoarthritis in current and former cricketers
   To describe the prevalence of hip/groin, knee, ankle, shoulder, hand and back pain and osteoarthritis in current and former cricketers; and determine whether main playing position, playing standard, and length of play are associated with joint-specific pain and osteoarthritis
   G. Bullock

4. Quality of life, flourishing and resilience in current and former cricketers
   To describe quality of life, flourishing and resilience in current and former cricketers and compare these with non-cricketing populations; and identify factors related to better quality of life, flourishing and resilience in current and former cricketers
   G. Bullock

5. Physical activity in current and former cricketers
   To determine how physically active current and former cricketers are and how this compares with the general population; and identify cricket-related factors associated with physical inactivity and sedentary behaviour in former cricketers
   N. Perera

6. General health in current and former cricketers
   To describe the prevalence of health conditions in current and former cricketers and compare this with the general population
   N. Perera

7. The bigger picture – what can we learn from the Cricket Health & Wellbeing Study
   N. Arden
SPEAKERS

Dr Stephanie Filbay is a Postdoctoral Research Fellow at the University of Oxford within the Arthritis Research UK, Centre for Sport, Exercise and Osteoarthritis. Her research focus is on understanding and optimising quality of life following sport-related injury and in individuals with musculoskeletal pain, using both quantitative and qualitative research methodologies. Dr Filbay has won multiple scholarships, prizes and awards for her research, and has held visiting research fellowships at University of Oxford, University of Southern Denmark and Linköping University. She is the lead researcher for the Cricket Health & Wellbeing Study, a diverse cohort of 2294 current and former recreational and elite cricketers in England and Wales.

Prof Nigel Arden is the Lead of Musculoskeletal Epidemiology at University of Oxford and the Deputy Director of Arthritis Research U.K Sports, Exercise and Osteoarthritis Centre of Excellence. Professor Arden has over 800 publications (33500 citations), has supervised 20 PhD students and obtained 85 research grants, to support his research in the field of osteoarthritis, musculoskeletal health and sports medicine.

Dr Nirmala Perera is a post-doctoral researcher within the University of Oxford within the Arthritis Research UK, Centre for Sport, Exercise and Osteoarthritis and a member of the Linköping University’s Sport Without Injury Programme. Her research focuses on injury epidemiology of female cricketers, injury prevention in youth sports and exploring the relationship between sports and osteoarthritis. Dr Perera was a recipient of several grants and awards including the prestigious Australia Awards - Endeavour Fellowship to work as a Research Fellow at the Linköping University. Dr Perera also serves as the Social Media Coordinator for the IOC World Conference on Prevention of Injury and Illness in Sport, Sports Medicine Australia Executive Board Member and the Sri Lanka Sports and Exercise Medicine Conference Scientific Committee Chair.

Dr Garrett Bullock is a DPhil candidate at University of Oxford. His research focus is on developing prediction models to identify injury risk factors for overhead athletes, and the role of physical activity and sport on musculoskeletal health and quality of life. He is currently investigating the relationship between persistent joint pain, physical activity, and health related quality of life in cricketers, and the long-term health effects of playing baseball. Garrett graduated from Wake Forest University with a bachelor’s degree in history, where he was a captain and a four-year letter winner in baseball. Garrett went on to play five years of professional baseball in the Houston Astros Organisation where he was a member of the 2010 New York Penn League Champions. Following retirement, Garrett graduated from Duke University with a Physical Therapy degree.
ABSTRACTS

(in order that they appear during the congress)
Injury epidemiology in men’s elite English and Welsh domestic cricket: A nine season review from 2010 to 2018

Luke Goggins¹, Keith Stokes¹, Carly McKay¹, Nicholas Peirce², David Newman², Ben Langley², Steve Griffin², Craig Ranson³, Steve McCaig³, Mark Young⁴ and Sean Williams¹

¹University of Bath, Bath, United Kingdom
²England and Wales Cricket Board, Loughborough, United Kingdom
³English Institute of Sport, Manchester, United Kingdom
⁴Geelong Cats, Geelong VIC, Australia

Background: More senior professional men’s domestic cricket is played in England and Wales than anywhere else in the world¹, but the epidemiology of injuries in this setting has not been formally described to date. Establishing the extent of the injury problem is the first stage in developing injury preventative measures as part of the ‘sequence of prevention model’².

Aims: To explore differences in injury incidence and prevalence rates between the three main domestic competition formats in England and Wales (First-Class County, One-Day and T20) and describe basic injury epidemiology.

Methods: All eighteen First-Class County Cricket (FCCC) clubs (across Divisions 1 and 2) in England and Wales have been involved in the England and Wales Cricket Board (ECB) injury surveillance programme (mean n = 507 registered players each season) and this prospective cohort study for nine years, encompassing the domestic competition season from April to September each year, from 2010 to 2018 inclusive. Injury incidence and prevalence rates were calculated using the international units for elite senior male England and Wales cricketers proposed in the updated international consensus statement on injury surveillance in cricket³. Statistical process control (SPC) charts were used to detect trends in the data.

Results: The average match time-loss injury incidence rate was 102 injuries/1,000 days of play, with the highest incidence rates for One-Day 50 over cricket (254 injuries/1,000 days of play), followed by T20 cricket (136 injuries/1,000 days of play) and First-Class Cricket (68 injuries/1,000 days of play). The average general seasonal injury prevalence rate was 4.2%, with the highest seasonal prevalence rates for injuries sustained in First-Class cricket (2.1%), followed by One-Day 50 over (1.2%) and T20 cricket (0.9%). Across all competition formats, most match time-loss injuries were sustained during bowling (41.6 injuries/1,000 days of play), followed by fielding (26.8 injuries/1,000 days of play) and batting (22.3 injuries/1,000 days of play). The SPC charts showed highly consistent injury rates for all competitions, reproduced across all nine seasons.

Discussion and Conclusions: These findings were consistent with previous research¹,⁴ and provide a robust empirical base for the extent of the injury problem in domestic cricket played in England and Wales. The findings can guide future research to establish the aetiology and mechanisms of cricket injuries and inform injury prevention strategies in this setting.

References:
2. van Mechelen, W., Hlobil, H. & Kemper, H.C. SM, 14, 82-99.
Neuromuscular electrical stimulation and the hamstring conundrum

Jaime Valadao¹, Barry Andrews¹, Susan Bassett¹, and Maaike Eken²

University of the Western Cape, Cape Town, South Africa
University of Stellenbosch, Cape Town, South Africa

Background: Hamstring injuries remain the most common injury to cricket players.¹ Despite large volumes of research aimed at reducing these injuries they continue to rise.² These factors and the burden of these injuries demonstrate the need for continued research within this area.

Aims: The aim of this study was to understand the changes in lengthened state eccentric strength of the hamstrings following four separate protocols.

Methods: This study was a randomized control trial, using a convenience sample of 35 non-sedentary male participants (mean age, 23.23±4.22). Participants were randomly assigned to either a; Control (C), resistance training alone (RT), neuromuscular electrical stimulation alone (NMES), or NMES superimposed with RT (NMES&RT) group. Participant’s eccentric hamstring strength was tested in a lengthened state, using an isokinetic dynamometer for the pre- and post-tests. The intervention spanned over four weeks. SPSS version 25 was used for data analysis.

Results: All groups demonstrated a mean increase in relative peak torque. However, a repeated-measures analysis of variance (ANOVA) showed no interaction effect (p = 0.411) between the four groups. The NMES&RT group was the only group that had all participants demonstrate an increase in relative peak torque. Magnitude-based inferences (MBI) demonstrated a small positive effect for both the NMES and NMES&RT group when compared to the C and RT groups.

Discussion and Conclusions: Although there are no statistically significant differences between the four groups employed in this study (C, RT, NMES, NMES&RT), NMES and NMES&RT did show small positive effects compared to C and RT with a very low likelihood of negative effects. Thus, using NMES either alone or superimposed with resistance training will be beneficial for trained athletes but it is not a necessity and the use of specific resistance training may be just as effective. However, this study warrants further investigation of using NMES on the hamstrings at an elite level as small percentages at this level of sport could be of great importance.

References:
2. Brukner, P. BJSM, 49(19), 1241-1244.
Vertebral artery dissection: Mechanism of injury and implications for risk-reduction in cricket

Anna Saw1, Alex Kountouris1, Andrew McIntosh2,3

1 Cricket Australia, Melbourne, Australia
2 Australian Centre for Research into Injury in Sport and its Prevention (ACRISP) and School of Engineering, Edith Cowan University, Joondalup, Australia
3 McIntosh Consultancy and Research, Sydney, Australia

Background: Vertebral artery dissection (VAD) is an uncommon yet potentially catastrophic injury which may occur as a result of sports participation1. Improved understanding of this injury specific to the sporting context may inform prevention strategies for sports organisations and industry.

Aims: To understand the mechanism of injury and to identify opportunities for risk reduction strategies in cricket.

Methods: This research was approached in two ways. First, a systematic review of the literature was conducted to synthesise all published cases on VAD attributed to sports participation. Second, semi-structured interviews were conducted with 14 experts from the fields of neurology, forensic pathology, biomechanics, radiology, sports and exercise medicine, and physiotherapy.

Results: The systematic review identified 79 records which described 118 individual cases of VAD attributed to sport. Bat and ball sports, including cricket, accounted for 27 cases. Of these 27 cases, 10 (1 fatal) were attributed to rapid movement, 2 (2 fatal) were attributed to an impact to the mastoid region (area below and behind ear), and 15 (2 fatal) did not report an inciting event. Across all cases and sports, all 10 cases which involved a blunt force to the mastoid region (ball, puck, opponent) were fatal.

Experts described multiple mechanisms of VAD in sport related to an interplay of predisposition, susceptibility, and an inciting event. Inciting events most commonly cited included impact to the mastoid region, impact to the head or neck causing extreme movement, impact to the neck causing cervical fracture, and extreme movement without impact. Suggestions for risk reduction strategies pertained to rules, personal protective equipment, and education.

Discussion and Conclusions: VAD is a risk for sports such as cricket which may expose an individual to impact from a focused blunt object (e.g., ball, bat). Impact to the mastoid region is particularly concerning as the artery is not protected by bone and a dissection may occur or extend intracranially resulting in fatal basal subarachnoid haemorrhage2.

Cricket officials may consider strategies to reduce the risk of impact to the head and neck in the playing and training environment. Protection of the mastoid region requires a collaborative effort between cricket organisations and equipment manufacturers to ensure an effective and acceptable solution is developed and implemented.

References:
The cricketer's shoulder: Not a classic throwing shoulder

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Background: It is speculated that the dominant shoulder in cricketers could exhibit a similar shift in the arc of glenohumeral rotation range of motion, known as the “thrower's paradox” in baseball pitching literature1. This parallel may be drawn as the overhead baseball pitching motion has been likened to the overhead throwing motion in fielding in cricket2. However, limited data exists to support this3. Thus, it is questionable whether these athletes develop a true “thrower’s paradox”, and the associated musculoskeletal adaptations responsible for the alteration in the arc of GH rotational ROM. In addition, the potential influence of these musculoskeletal adaptations on the development upper limb cricket injuries, has yet to be investigated.

Aims: To describe the musculoskeletal adaptations inherent to the cricketers’ shoulder and determine potential predictors of shoulder injury in elite South African cricketers.

Methods: 106 elite South African cricket players completed a pre-season shoulder screening battery consisting of a shoulder function questionnaire, two ultrasonographic shoulder measurements and 14 musculoskeletal tests including pain provocation, range of motion, strength and flexibility. Non-contact dominant shoulder injuries were documented throughout the 2016/2017 season.

Results: A total of 105 cricketers (27 ± 4.2 years) including 50 fast bowlers, 26 spin bowlers and 29 batsmen (including 13 wicketkeepers) were eligible for participation in this study. These cricketers presented with low shoulder function, glenohumeral range of motion <180°; scapula downward rotation; weak serratus anterior and glenohumeral internal and external rotators, posterior shoulder capsule stiffness and pectoralis minor inflexibility. 17% (95%CI: 9-24%) of cricketers sustained an injury during the 2016/2017 season. Two of the 17 screening tests predicted seasonal dominant shoulder injury (p<0.05): a dominant supraspinatus tendon thickness ≥5.85mm (95%CI: 5.61-8.14) and non-dominant pectoralis minor length ≤12.85cm (95%CI: 5.84-8.23).

Discussion and Conclusions: The musculoskeletal adaptations inherent to cricketing shoulders are distinctly different to the classic thrower’s shoulder described in baseball. A thickened dominant supraspinatus tendon and a shortened non-dominant pectoralis minor muscle are risk factors for developing shoulder injury in this group. Additional research is required to understand the musculoskeletal adaptations occurring exclusively in this population of overhead throwing athletes, in an attempt to reduce the potential risk for injury.

References:
The cricketer’s shoulder and injury: asymmetries in internal rotation range of movement, throwing arc and pectoralis minor muscle length – a longitudinal cohort study

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Background: The prevalence of seasonal shoulder injury in professional cricketers is 23%.\(^1\) This includes player-reported injuries (i.e. pain experienced during cricket matches, training and activities of daily living).\(^1\) Glenohumeral joint injuries in overhead athletes occur mostly during the late cocking\(^2\) and the follow-through phase of throwing.\(^3\)

Aims: The aim of this study was to determine whether there are associations between shoulder internal and external rotation range of movement (ROM), throwing arc (TA) ROM, glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG), pectoralis minor muscle length and the incidence of shoulder injury during the first three months of a cricket season amongst provincial and club cricket players.

Methods: This prospective longitudinal cohort study was conducted at a provincial cricket stadium and at a local cricket club house. Thirty-six male, actively participating, provincial and club cricket players. Baseline testing occurred at the beginning of the cricket season. The independent variables included baseline shoulder pain, which did not limit participation in cricket training and matches; shoulder external and internal rotation (ROM, TA ROM, GIRD, ERG) and pectoralis minor muscle length. The main outcome measure was time-loss dominant shoulder injury as recorded during the season for a period of three months. Independent t-tests and paired t-tests were used to analyse the parametric data with Cohen's d to indicate the magnitude of effect. The Mann-Whitney U tests, chi-squared tests and Wilcoxon Signed Ranked tests were used to analyse the non-parametric data. The effect sizes were calculated for the non-parametric data using the Rank-Biserial Correlation Coefficient for the Mann-Whitney U and the Wilcoxon Signed Ranked tests.

Results: Nine of the 32 participants sustained time-loss shoulder injuries on the dominant side. Initial non-time-loss shoulder pain during baseline testing was associated with time-loss in-season shoulder injury [Chi square \(\chi^2\) (n=32) =7.31 (p=0.007)]. Statistically significant side-to-side differences were found for the majority of independent variables (internal rotation ROM (p=0.0001), TA ROM (p=0.005), pectoralis minor muscle length distance (p=0.0002), with the exception of external rotation ROM (p=0.473), amongst the uninjured players.

Discussion and Conclusion: Shoulder pain, which does not limit a cricketer from participating in cricket-related activities, may be a precursor to time-loss shoulder injuries in cricket players. The presence of pain should be investigated during the pre-season screening phase for preventative programmes for shoulder injuries to be put in place early on. With the exception of ER ROM, side-to-side differences in terms of all of the independent variables (IR ROM, TA ROM, pectoralis minor muscle length distance), were found among the uninjured players. Since these asymmetries may have an injury-protective role, further research is needed to confirm these preliminary findings.

References:
Do cricketers display similar overhead throwing biomechanics to baseball players?

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**Background:** Quantifiable differences in throwing velocity¹, accuracy¹ and biomechanics² between the overhead baseball pitch and throw employed by cricketers exist. More specifically, cricketers have been described as having a ‘preparatory arc’ of the upper limb, rather than a baseball pitcher’s wind-up³. Unfortunately, little else is known about the basic mechanisms employed when throwing in cricket. Previous research has described overhead throwing kinematics in cricket from wind-up to ball release in a variety of fielding scenarios⁴. However, the forces acting about the shoulder joint were not determined⁴. Further, the biomechanical variables between the point of ball release and arm deceleration have yet to be described.

**Aims:** To describe and compare the biomechanics of stationary overhead throwing between elite and amateur cricketers, with emphasis on maximum glenohumeral external rotation, the point of ball release and maximum glenohumeral internal rotation.

**Methods:** Stationary overhead throwing was assessed in 21 South African cricketers. Kinematics and ground reaction forces were collected during these throwing trials. Inverse dynamics was used to calculate joint kinetics. Inter-subject variability was calculated using the coefficient of variance. One-dimensional statistical parametric mapping ANOVA was conducted to assess differences between the coefficient of variance over the throwing cycle; and differences between the kinematic waveforms for elite and amateur cricketers (p<0.05).

**Results:** 15 cricketers (elite: n=8; amateur: n=7) were eligible for participation in this study, 22.0 ± 3.4 years. The basic parameters of a cricketer’s throwing action are described. Moderate to high inter-subject variability was noted for most variables. Cricketers presented with 74.9 ± 27.3° glenohumeral external rotation and 94.8 ± 23.7° elbow flexion, at maximum external rotation (MER). Amateur cricketers had significantly decreased elbow flexion range of motion between 2 and 14% of the throwing cycle (F=9.365; p=0.01); greater shoulder (121.0 vs 85.9N; F=0.36, p=0.021) and elbow compression (105.6 vs 72.8N; F=0.007, p=0.043), and greater superior shoulder force (203.1 vs 115.5N; F=2.43, p=0.022) at MER, compared to elite cricketers.

**Discussion and Conclusions:** Cricketers display a similar trend to baseball pitchers when throwing overhead from a stationary position. The “preparatory arc” utilised is different to the wind-up noted for baseball. The forces exerted on the shoulder and elbow, in amateur cricketers specifically, are significantly greater and may indicate the potential risk for injury at maximum external rotation.

**References:**
The effect of a cricket fielding session on glenohumeral range of motion and active joint position sense

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Background: Shoulder and throwing related injuries contribute a significant proportion of cricket injuries with up to 23% of first class cricketers reporting a shoulder injury. Cricketers with a greater throwing workload and reduced number of rest days have been identified of having an increased injury risk, while specific acute and cumulative workloads have also been identified to increase injury risk. It however, remains unclear what effect a single cricket throwing session may have on shoulder function.

Aims: The aim of this study was to assess the effects of a cricket fielding session, at an identified injury risk workload, on shoulder joint position sense (JPS) and active range of motion (ROM).

Methods: Nineteen, asymptomatic University first team cricketers participated in the study during pre-season indoor training. Active ROM was assessed supine at 90° abduction and from this 10% off end range internal (IR) and external rotation (ER) was used as the position matching angle to assess JPS. JPS error scores as well as active ROM were assessed pre and post a cricket fielding session consisting of 40 throws.

Results: Following the cricket fielding session, no alteration in JPS in ER \( (p = 0.91) \) or IR \( (p = 0.27) \) was observed. There was however a significant decrease in IR \(-3.9°\) active ROM following the fielding drill \( (p = 0.007) \) while no change in ER or total motion was observed.

Discussion and Conclusions: Active IR ROM is significantly decreased immediately following a cricket fielding drill, while no alterations in JPS were observed. These results support those of Reinold et al. who reported a 9.5° reduction in IR after a baseball pitching protocol which persisted up to 48hours post. High levels of eccentric stress have been reported in the external rotators after throwing that may contribute to the acute musculotendinous adaptations observed. Changes in IR, with an increased throwing workload, may be a contributing factor to workload-acquired shoulder throwing injuries.

References:
The musculoskeletal profile of first-class cricketers with throwing arm pain

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Background: Throwing arm pain (TAP) both at the shoulder and elbow, is commonly reported in overhead throwing sports1, however in cricket the shoulder has received most attention2,3,4. Musculoskeletal changes such as scapula dyskinesis, internal rotation deficit, total rotation range of motion deficit, increased shoulder internal rotation/external rotation strength ratio are commonly reported in athletes with TAP. However, few studies in cricket have investigated the musculoskeletal profile of cricketers with TAP, and none of these included cricketers with elbow TAP3,4.

Aims: To describe the musculoskeletal profile of first-class cricketers with and without a history of TAP, both shoulder and elbow; and determine if any differences exist between these groups

Methods: Ninety first-class cricketers were profiled at the beginning of winter training programmes between 2014-15 and 2017-18. Participants completed questionnaires regarding TAP and a battery of musculoskeletal tests which assessed resting scapulo-thoracic posture, shoulder, elbow and hip range of motion, shoulder strength and grip strength. Based on their response to the questionnaire they were assigned to one of three groups: history of shoulder TAP, history of elbow TAP or no history of TAP. A one-way ANOVA or Kruskal-Wallis test was performed to determine if any differences were present between the groups on any of these measures for continuous data and a Pearson’s Chi-square or Fisher’s exact test was used for categorical data.

Results: Thirty-one participants (34.4%) reported a history of shoulder TAP and seventeen (18.9%) elbow TAP in the previous season, ten of these participants stated they currently had TAP (nine shoulder). There were significant differences between groups on the KJOC (no history of TAP 93.1± 7.8, shoulder TAP 77.7± 15.8; elbow TAP 86.6± 10.6). Dominant shoulder external rotation strength normalised to body mass was significantly weaker in those with shoulder TAP compared to those without a history of TAP and those with elbow TAP (shoulder TAP 20.1% ±3.5; no history of TAP 22.6% ±3.4; elbow TAP 22.7% ±3.3); and shoulder external rotation strength asymmetry index was different between those without a history of TAP (5.3% ±11.2) and those with shoulder TAP (-6.1% ±18.4). There were no other differences between the groups on any musculoskeletal measure.

Discussion and Conclusions: TAP is a common condition in cricket, with just over half of all participants experiencing it in the previous season. Very few differences were present between groups, this suggests that there are no consistent musculoskeletal changes associated with TAP in cricketers. These findings may also be due to the study being conducted in the off-season, with few participants stated they were experiencing arm trouble at the time of testing. This could have resulted in any musculoskeletal changes associated with TAP having resolved by the time of testing due to either a specific rehabilitation plan or with resolution of the condition. Despite this those with a history of TAP scored reported poorer function on a throwing specific outcome measure. Based on the findings it is recommended that practitioners focus on identifying the specific impairments associated with that players pain presentation.

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2. Ranson C.A. & Gregory, P.L PTIS 9(1) 34-39
Investigating the relationships between kinematic factors and lumbar injury in young fast bowlers

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Background: Fast bowlers place a high physical demand on the lumbar spine that can increase the risk of injuries, such as stress fractures of the pars interarticularis¹. Kinematics such as shoulder counter-rotation and pelvis-shoulder separation have shown weak-moderate links to lumbar injury. However, fast bowlers must simultaneously flex, laterally bend and rotate the lumbar spine to release the ball at maximum speed. Since a crunch factor analysis can quantify the simultaneous 3-dimensional motion of the lumbar spine, it may reveal a variable that has a stronger link with lumbar injury risk than other kinematic factors.

Aims: To investigate the relationships between kinematic factors and lumbar injury risk in a sample of young fast bowlers.

Methods: Sixteen elite young fast bowlers each bowled six maximum-speed balls in an indoor biomechanics laboratory. A 14-camera Cortex Motion Analysis System (Motion Analysis Corporation Ltd.) (200 Hz) was used to capture data on six trials for each bowler. Kinematic analysis was performed using Visual3D (Version 5, C-Motion, Germantown, MD). Shoulder-pelvis angles were calculated about the flexion-extension (FE), axial rotation (AR), and lateral bending (LB) axes. Crunch factors were calculated by adding shoulder-pelvis angles from each combination of two adjacent axes.

To assess lumbar spine condition, each bowler underwent an end-of-season MRI scanning of the lumbar spine using a Phillips Achieva 3T phase array spine coil: T1, T2 and STIR sequences sagittal; T12 to S2, and T1 and T2 fat suppressed axial L3 to S1.

Results: All bowlers displayed signs of lumbar injury, varying in severity: stress fractures (4 bowlers), bone oedema (6 bowlers), disc abnormalities (6 bowlers). Mean shoulder counter-rotation was 53.8° ±18.1°, which increased to 70.2° ±4.4° for bowlers with stress fractures. The crunch factors for the delivery (del) phase (back foot contact to front foot contact), and arm-acceleration (acc) phase (front foot contact to ball release) were crunch FE-AR (del 33.9° ±13.1°; acc 73.2° ±15.4°); crunch FE-LB (del 60.3° ±9.1°; acc 79.6° ±17.9°); crunch LB-AR (del 54.9° ±13.1°; acc 95.5° ±21.7°). None of the crunch factor threshold values could not differentiate between any of the injury types.

Discussion and Conclusions: This study showed that a high percentage of the young fast bowlers sustain lumbar injury. Previous research has shown some found weak-moderate kinematic links with lumbar injury in fast bowlers. In this study, we found that the bowlers with post-season stress fractures all exceeded a shoulder counter-rotation threshold of 60°. Surprisingly, the crunch factors were not higher for the bowlers with stress fractures. The calculation of crunch factor may need to be revised for future studies. In addition, it may be necessary to analyse the mechanics of highly mixed actions to reveal the mechanisms that are more causative of lumbar injury.

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1. Elliott, B.C et al., Clinical Biomechanics, 8(5), 227-234.
Regional lumbar bone mineral density differs in cricket fast bowlers with lumbar bone stress injury

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Background: Lumbar bone stress injuries (LBS) have the greatest prevalence of any injury in cricket, with time loss in excess of 200 days¹. They most often occur in the non-dominant side of the L4 and L5 vertebra at the pars interarticularis and pedicle in response to the unique lumbar loading characteristics of fast bowling². LBS are caused by the accumulation and propagation of microdamage across the neural arch of the lumbar vertebra, at a rate greater than the repair processes of bone³. It is not known whether lumbar spine bone mineral density differs according to current or previous LBS.

Aims: To determine differences in lumbar bone mineral density (BMD) between current LBS, previous LBS and never LBS fast bowling groups.

Methods: 58 fast bowlers (mean ± SD: age: 21.23 ± 4.21 years; height: 1.88 ± 0.06 m; body mass: 84.13 ± 9.14 kg) declared as fit to bowl received a lumbar MRI scan (3.0T Discovery MR750w, GE Healthcare, Milwaukee, WI), an AP lumbar DXA scan (Lunar iDXA, GE Healthcare, USA), and had their medical history and MRI scans reviewed for historical incidence of LBS. MRI scans were analysed to determine current LBS. DXA scans were analysed to measure specific bone accrual of dominant (ipsilateral to bowling arm) and non-dominant sides of the lumbar spine. Rectangular custom regions of interest (Lunar enCORE v 17.0) were added to the lateral 33% of each lumbar vertebral body, to exclude the spinous process, and BMD of these regions were calculated. One-way ANOVA determined if groups differed in age, height, body mass, total asymmetry and whole vertebra BMD. Two-way mixed repeated measures ANOVA determined within and between group differences between sides.

Results: MRI and medical history demonstrated 19 current, 23 never and 16 previous LBS fast bowlers. Age was significantly greater (p < 0.05) in previous LBS (23.71 ± 4.80) compared with current (19.52 ± 2.22) and never LBS (20.90 ± 4.36). No significant differences were found between groups for height, body mass or whole vertebra BMD (p > 0.05). BMD was higher at the non-dominant than dominant side of the vertebrae (1.63 vs. 1.50 g/cm², p < 0.001) and this differed between vertebra (3.0 – 30.8%, p < 0.001) and groups (p = 0.03). BMD on the dominant side was higher in current (+4.4%) and previous (+3.7%) than never LBS. BMD on the non-dominant side was lower in current (-2.3%) and previous (-0.8%) than never LBS. Asymmetry was significantly greater in never LBS than current LBS.

Discussion and Conclusions: Bone mineral accrual differs between current, never and previous LBS groups. Never LBS group may have a more positive osteogenic response to cricket fast bowling through optimisation of intrinsic (maturation, hormonal status, previous injury, bone geometry) and extrinsic factors (technique, muscle capability, workload, nutrition, footwear, pharmaceutical use⁴,) compared with current and previous LBS groups may identify those at risk of LBS.

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The effect of age and bowling delivery speed on lumbar spine bone mineral in adolescent fast bowlers

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Background: Cricket fast bowlers (FB) have high lumbar spine bone mineral density (BMD), particularly on the contralateral side to their bowling arm. It is thought that bone possesses its greatest ability to adapt to loading during adolescence, but is unknown at what age asymmetry develops, and whether it is dependent on loading intensity, which may be greatest in those who bowl at greatest speed.

Aims: This study aims to explore the association of age and ball speed with lumbar spine bone mineral content, density and asymmetry in adolescent FB.

Methods: With NHS and institutional ethics approval, 41 adolescent male FB (mean ± SD: 15.6 ± 1.1 years; 179.5 ± 6.8 cm; 68.7 ± 10.5 kg) received an anterior-posterior lumbar spine DXA (GE Lunar iDXA, GE Healthcare, USA) scan during pre-season. BMD and bone mineral content (BMC) were derived for each vertebra (Lunar enCore v17, GE Healthcare, USA). Asymmetry was calculated as the bone mineral in the lateral third of the non-dominant side minus that of the dominant side (respective to bowling arm). Ball speed was calculated during the 10 frames after ball release (MATLAB® 2018a, The MathWorks Inc., USA) from 3D motion analysis data (Vicon Nexus 2.8.2, Vicon Motion Systems Ltd, UK). The average of 12 deliveries and the fastest ball was found. ANOVAs were used to compare bone mineral and asymmetry between age groups. Partial correlations were sought between fastest delivery speed and bone mineral at each vertebra with age as the covariate.

Results: BMD Z scores were 0.7 ± 1.2, 0.8 ± 1.3, 1 ± 1.2 and 0.7 ± 1.3 at L1, L2, L3 and L4 respectively. BMC and BMD differed according to age at L1-L4 combined (P≤0.014) but not in individual vertebrae (P≥0.088). Bone mineral asymmetry was significantly different between vertebrae (P≤0.003) with BMC asymmetry of 1.8 ± 3.0%, 6.7 ± 3.1%, 9.5 ± 4.1% and 10.1 ± 3.5% at L1, L2, L3 and L4 respectively. BMD asymmetry was also greatest at L4 of 4.7 ± 3.0%. Bone mineral asymmetry did not differ according to age (P≥0.198). With age controlled for, fastest delivery speed was positively correlated with BMD at all levels (r between 0.480 – 0.494, P=0.002), and explained 23-24% variance in BMD. Ball speed was not significantly correlated with BMC, BMD asymmetry or BMC asymmetry at L1, L3 and L4 (r between -0.26 to -0.086, P≥0.114), but was with BMC asymmetry at L2 (r= -0.364, P=0.025). Eliminating age as the covariate slightly decreased the correlation in most cases.

Discussion and Conclusions: Adolescent FB had higher than average BMD, which showed the expected increase with age. Asymmetry was present at age 14 but this did not increase with age in this sample, although the asymmetry in BMD and BMC were only 35% and 53% respectively of that reported in seniors. Ball speed was highly correlated with BMD however variation in bone size may confound relationships of bowling intensity and BMC. Moreover, skeletal maturation, workload and technique may have additional effects on bone mineral. Future research should examine longitudinal changes in bone mineral and their relationship to skeletal maturation and injury, to aid athlete management and injury prevention.

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Investigating the relationship between fast bowling workloads, muscle damage/stress following spells of simulated fast bowling

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**Background:** Cricketers are now increasingly required to compete across all forms of cricket (i.e. one-day [50-over]; Twenty20 [T20]) and multi-day), for extended periods. Wearable technology (i.e. micromechanical-electrical system devices) continues to contribute to an increased understanding of match-specific variations in fast-bowling workloads, specifically quantifying the bowling action. These high-intensity actions are synonymous with microdamage to skeletal muscle and catabolic stress. Ultimately, combining this information may enable practitioners to implement training and recovery strategies relative to changes in fast-bowling workloads.

**Aims:** To examine the “dose-response” relationship of fast-bowling workloads and post simulation plasma creatine kinase (CK) and salivary cortisol (sCort) for up to 24-hours.

**Methods:** Eleven senior club male fast bowlers completed four modified bouts of the Cricket Australia-Australian Institute of Sport (CA-AIS) fast-bowling skills test. Each session comprised of four different fast-bowling spells. Bowling workloads were quantified in Sprint (Catapult Innovations, Australia) using tri-axial accelerometry sampling at 100 Hz (PlayerLoad™ [PL]). Plasma CK and sCort were collected before (pre; -0.5 h), immediately after (post; +0.5 h) and 24-hours post-trial (post; +24 h), respectively. Pearson product-moment correlations ($r$) with 95% confidence intervals (95% CI) were calculated to assess relationships between bowling workloads and the $\Delta$ from baseline in CK and sCort.

**Results:** A small relationship was found between the number of overs bowled ($r = 0.30$ [95% CI 0.00 to 0.56]; $P \leq 0.05$) and CK immediately following (+0.5 h) simulated fast-bowling. Longer-term (+24 h), moderate relationships were found between the number of overs ($r = 0.48$ [95% CI 0.20 to 0.69]; $P \leq 0.01$) and deliveries ($r = 0.48$ [95% CI 0.20 to 0.69]; $P \leq 0.01$) bowled, respectively. A moderate relationship was found between changes in CK and bowling duration 24-hours following simulated fast-bowling ($r = 0.44$ [95% CI 0.15 to 0.66]; $P \leq 0.01$). PlayerLoad™ was shown to moderately correlate with CK ($r = 0.41$ [95% CI 0.11 to 0.64]; $P \leq 0.01$), 24-hours post simulation.

**Discussion and Conclusions:** Primarily our findings are suggestive of a “dose-response” relationship between descriptive measures of fast-bowling workload and muscle damage (CK). Furthermore, PL was shown to correlate with CK following simulated fast-bowling (+24 h). To our knowledge, this is the first study to explore “dose-response” relationships between external training load characteristics and markers of muscle damage (CK) and stress (sCort), in cricket. McNamara et al. found that following competition fast bowlers tended to achieve higher sCort concentrations compared to non-fast bowlers. Despite this, we failed to find any significance between sCort and selected workload variables spanning 24-hours. Generalising this data is likely recognised by practitioners, however specific workload analysis to mimic competition type (i.e. one-day [10-over spell]) is imperative for individualised, evidence based training and recovery strategies. Further research is needed to address longitudinal seasonal variations in competition format – advancing the understanding of match-play workloads relative to muscle damage and stress.

**References:**
Background: Initially, when women’s cricket began, it took the form of test matches played over three days, but this was increased to four days in 1985. The game now includes one-day international cricket (50-over games), and more recently, the Twenty/20 (T20) format, which includes the Women’s Big Bash League (WBBL) and the Kia Super League. This has resulted in a greater number of international and local matches being played all over the world as well as a greater exposure of women’s cricket. As both elite and semi-professional players are now being exposed to an increase in the number of matches played both locally and internationally, the need for accurate workload monitoring is vital for optimal performance and injury prevention. To the authors knowledge there is no published research on workload monitoring of elite women cricketers.

Aim: The aim of the study is to determine and compare the workloads of elite women cricketers in both the T20 and ODI match formats.

Methods: The study was a retrospective cohort study of ten elite female cricket players in the national side in South Africa during the period between April 2018 and April 2019. To determine workloads the following calculations were used: Bowling workload was calculated by multiplying RPE (1 = very, very light to 10 = very, very hard) by number of deliveries (balls). Batting workload was calculated by multiplying by duration (min) spent batting. Fielding was calculated by multiplying RPE by duration (min) spent fielding. Exploratory data analysis was conducted to check for normality, with descriptive data presented as mean± standard deviation (SD). As data did not follow a normal distribution, Kruskal Wallis tests were performed to compare the workloads between the different player disciplines (bowling, batting and fielding) and Match formats (ODI and T20). Cliff’s Delta (δ) and 90% confidence intervals were used as a non-parametric measure of effect size. Cliff’s Delta scores were defined as 0.15 = small, 0.33 = moderate, and 0.47 = large.

Results: Overall, there was a greater ODI match workload compared to T20 matches (χ² (1) = 39.08; p < 0.0001; δ= 0.54[0.40; 0.65]). There was a greater fielding workload during ODI matches compared to T20 matches (χ² (1) = 61.34; p < 0.0001; δ= 0.82 [0.70; 0.89]). There was no difference between ODI batting workload and T20 batting workload (χ² (1) = 3.02; p =0.08; δ= 0.26 [0.01; 0.49]). Bowling workload has not been analysed yet but will be presented at the conference.

Discussion and Conclusions: The preliminary results of this investigation suggest that fielding workload in the ODI format is greater than the T20 format, which is to be expected due to the amount of time spent in the field with ODIs. There was no difference in batting workload between the two formats mostly because sRPE was higher in the T20 format which negated the shorter duration. Thus, the interplay between intensity and duration in the different formats was key in driving workload. Bowling workload will be discussed at the conference.

References:
Optimising rhythm, ball release speed, and workload in amateur pace bowlers: is there an ideal prescribed delivery intensity?

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Background: Cricket coaches and bowlers regard ‘rhythm’ to be an important element to pace bowling performance1. Although rhythm is usually considered a subjective quality, Ferdinands et al.1 demonstrated that rhythm can be quantified through segmental sequencing. Ferdinands et al.1 found sequential timing of particular segments to explain 55% of the variability in ball release speed (BRS). Coaches prescribe various delivery intensities to pace bowlers in attempt to manage workload2. However, we do not know how prescribed delivery intensity affects rhythm, and if there is a particular prescribed intensity that optimises rhythm, BRS and workload. Knowledge of this may influence future planning of bowling sessions.

Aims: To investigate the differences between delivery rhythm, BRS, and workload with various prescribed delivery intensities, in amateur pace bowlers.

Methods: Thirteen amateur male pace bowlers attended an indoor stadium on one occasion. The session comprised a general aerobic and dynamic warm-up, followed by 15 sub-maximal warm-up deliveries (3 x 60%, 70%, 80%, 90%, and 95% perceived effort), and six maximal-effort warm-up deliveries (i.e., 100%). Ball release speed was captured by radar gun. After each delivery, bowlers rated their delivery rating of perceived exertion (% of 100), and rhythm (5 point Likert scale, 1 = very poor, 5 = very good). Peak resultant acceleration was calculated each delivery (square root of $x^2 + y^2 + z^2$) from a global positioning system unit positioned between the scapulae2; operating at 100 Hz. In SPSS, linear mixed models examined the differences between prescribed delivery intensities on each dependent variable, while controlling the within-subject error from repeated trials (using compound symmetry). Pairwise comparisons were conducted with the least squares difference procedure. Statistical significance was set at $p < 0.05$.

Results: The maximal-effort and 80% prescribed intensities resulted in the highest rhythm ratings (mean ± SE: 3.4 ± 0.1 and 3.4 ± 0.1 respectively), with both significantly different to the 60% and 70% prescribed intensities ($p < 0.05$). There was no significant difference in rhythm rating between the maximal-effort and 80% prescribed intensities ($p = 0.970$). However, there was a significant difference in BRS (mean ± 95 CI: 3.7 ± 1.6 km·h⁻¹, $p < 0.001$), delivery rating of perceived exertion (mean ± 95 CI: 14.9 ± 2.5%, $p < 0.001$), and delivery peak resultant acceleration (mean ± 95 CI: 0.57 ± 0.42 g, $p = 0.008$) between the maximal-effort and 80% prescribed intensities.

Discussion and Conclusions: Although there was a statistically significant difference in BRS between the maximal-effort and 80% prescribed intensities, the mean difference of 3.7 km·h⁻¹ is not likely to be noticeable to a batter3. This small change in BRS is probably not worth the 14.9% average increase in delivery rating of perceived exertion and 0.57 g average increase in delivery peak resultant acceleration when bowling at maximal-effort. Therefore, the ideal prescribed intensity for amateur pace bowlers appears to be 80% perceived effort, upon consideration of rhythm, BRS, and workload.

References:
Workloads and injury risk in elite South African cricket fast bowlers:  
A snapshot of one season

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Background: Several studies have investigated the relationship between workloads and injury risk in fast bowlers of varying levels¹,²,³,⁴ however, no study has looked at the workloads placed on South African elite players, or linked this to injury risk in this level of player. Furthermore, very few studies have considered individual responses to workload and risk of injury.⁴

Aims: The aims of this study were to prospectively monitor workloads placed on fast bowlers playing for the South African national side and to link these to injury risk while considering individual differences.

Method: The study was a prospective cohort study where bowling workloads (total match and practice deliveries) and injury data were collected for sixteen male fast bowlers (age range 20 to 35 years) who played for the South African men's national side between April 2017 to April 2018. Workload variables were calculated (acute:chronic workload ratios) and the likelihood of injury and individual effects were explored using a binary logistic regression model.

Results: There were 26 medical attention injuries which included 12 time-loss injuries and 14 non time-loss injuries. Lumbar spine injuries predominated followed by the hip and groin. There was no significant differences between acute, chronic and acute:chronic workload ratio as predictors of injury occurrence. However, when workloads were categorized, it was found that low chronic workload and moderate-low acute:chronic workload ratios had a small, yet significant increased injury risk compared to the other workload thresholds. Even though non-significant; low, high and very high acute, chronic and acute:chronic ratios also demonstrated an increased risk in injury.

Discussion and conclusion: Acute, chronic and acute:chronic ratios are limited in their ability of injury occurrence (AUC = 0.69). This finding is similar to other modelling studies in other team based sports. More data is needed to ensure more stability and accurate results. Nonetheless, this not does not rule out training load monitoring and management as a valid practice as there is strong evidence that spikes in acute:chronic workload ratios are associated with increases in team injury rates.¹,²,³,⁴ Therefore, measuring absolute and relative training loads in team sports to monitor load progression and allow for informed modification of training schedules is still considered best practice.

References:
GPS-detected lateral sway during a submaximal running test correlates with endurance exercise performance in elite Australian cricketers.

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Background: Global Positioning Satellite (GPS) embedded accelerometers can detect changes in movement that are related to neuromuscular fatigue1. Recently it was shown that changes in the vertical and lateral components of the GPS-derived PlayerLoad metric (a measure of total movement) were associated with changes in vertical jump performance, a marker of neuromuscular fatigue2. Whether PlayerLoad metrics can detect changes in movement patterns associated with changes in endurance exercise performance has not been evaluated.

Aims: The aim was to identify whether changes in components of PlayerLoad assessed during a standardized submaximal running test (SSRT) were associated with changes in aerobic exercise performance.

Methods: Twenty-three professional male cricketers and thirteen semi-professional male cricketers participated in the study (25±3 years, 82±6 kg, 183±6cm). All testing was performed during routine pre-season training. SSRT was performed as part of the warm up at the start of training, prior to the completion of a monthly 2km running time trial (2kmTT). The SSRT consisted of running between two markers positioned twenty metres apart for two minutes, with foot strikes occurring in time to a metronome set at 154 beats/min (shown to elicit a running speed of 8 kmh). GPS devices with embedded triaxial accelerometers (model 5S, Catapult Sports, Catapult Innovations, Melbourne Australia) sampling at 100Hz were worn in specialized vests, positioned on the upper back between the scapulae. PlayerLoad 1D Side % (PL1Dside%) (medio-lateral vector), PlayerLoad 1D Up % (PL1Dup%) (Vertical vector) and PlayerLoad 1D forward % (PL1Dfwd%) (anterior-posterior vector) were assessed. Mixed effects models were used to assess relationships between the PlayerLoad vectors and 2kmTT performance (Stata 15.0, Stata Corp, Texas, USA). Statistical significance was set at p<0.05.

Results: PlayerLoad vectors during the first minute of SSRT were 2kmTT performance (p>0.23). During the second minute of SSRT there was a significant relationship between 2kmTT running performance and PL1Dside% (B 2.12, p<0.03), but not PL1Dup% (p=0.76) or PL1Dfwd% (p=0.41).

Discussion and Conclusion: Changes in movement pattern (PL1Dside%) during the second minute of SSRT were positively related to changes in aerobic exercise performance (2kmTT), such that an increase in PL1Dside% was associated with an increase in time taken to run the 2kmTT. This indicates that when an athlete performed poorly in the 2kmTT they exhibited increased lateral sway when running at 8 kmh, and less lateral sway when they performed better. This relationship may not have been evident during the first minute of SSRT because of greater variations in movement pattern as athletes moved from a stationary start to running at a steady speed. This simple field test could be used to provide insight into how athletes are responding to changes in training loads for any sport which requires aerobic exercise performance as a component.

References:
Effect of a 6-week Indian clubbell strength programme on fast bowlers' shoulders

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**Background:** Shoulder injuries are highly prevalent in overhead throwing sports including cricket. Consequences of shoulder injuries include reduced sport performance, loss of enjoyment and restricted participation, not to mention the associated medical treatment costs. Deficits in shoulder range of motion (ROM) and muscle strength have been implicated as contributing factors of injury. Exploring the effectiveness of training methods to reduce shoulder injuries is therefore of great interest to both the sporting and medical communities.

**Aims:** To investigate the effectiveness for cricket fast bowlers of a 6-week Indian clubbell programme on shoulder range of motion and muscle strength.

**Methods:** Using a randomized controlled trial, 21 club cricket male fast bowlers were pair-matched on initial shoulder-rotator isometric muscle strength (IMS) and assigned to either an Indian clubbell shoulder strengthening group (Clubbell: n=11, age 24 ± 6 y, mass 83 ± 8 kg, height 1.84 ± 0.05 m) or a cricket training only group (Control: n=10, age 24 ± 5 y, mass 81 ± 8 kg, height 1.83 ± 0.11 m). Shoulder rotator IMS and rotational ROM measures were taken at baseline, week 2, 4 and 6 using a goniometer and muscle testing dynamometer (MicroFET3, Hoggan Scientific, USA). Three trials were averaged for each parameter. The clubbell (Purpleheart Armoury, USA) programme (20 min/day, 3 days/week, 6 weeks) was designed to target and strengthen the shoulder-rotator and scapular stabiliser muscles with 5 exercises per session (20 exercises in total). Two tailed paired T-Tests were used to compare within group changes over the training period. Two tailed independent samples T-Tests of pre-to-post change scores compared between group changes, at P<0.05 level of significance.

**Results:** Over six weeks, within the Clubbell group, internal rotation (IR) IMS, IR ROM, external rotation (ER) ROM and posterior capsule tightness all displayed significant beneficial changes (P<0.05). Specifically, there was a 15% increase in IR IMS (39 ± 7 to 45 ± 6 Nm) but no change in ER IMS (42 ± 5 to 42 ± 6 Nm) (p=0.69). Only IR ROM improved (P<0.05) in the Control group. While the clubbell group had a greater improvement in their bowling arm IR muscle strength than the control (p<0.05), no other between-group changes reached statistical significance.

**Discussion and Conclusions:** Our findings suggest the Indian clubbell programme is beneficial as it improved 4 of 5 strength and flexibility measures. Stability of the shoulder is dependent on the rotator cuff muscle strength. Suffice to say, strengthening the rotator cuff has previously been shown to reduce shoulder injuries in overhead throwing athletes. Further refinement of the Indian clubbell exercises employed could target the shoulder ER more specifically. Increased IR ROM decreases posterior capsule tightness which agrees with our current findings. While, currently unknown whether this programme will reduce shoulder injuries we believe implementation of an Indian clubbell exercise programme into players’ conditioning combined with injury surveillance is warranted.

**References:**
Exercises to modify risk factors for injury in community-level adolescent pace bowlers

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Background: Non-contact injuries to pace bowlers are common in cricket and typically affect the shoulder, low back, hamstring and groin1. Potentially modifiable risk factors for these injuries include reduced muscular strength, decreased muscular endurance and poor dynamic neuromuscular control2. Exercise-based injury prevention programs can reduce non-contact injury rates in adolescent athletes3, however, the impact of these programs on community-level cricketers is not yet known.

Aims: To investigate if an exercise-based injury prevention program can modify neuromuscular risk factors for injury in community-level adolescent cricket pace bowlers.

Methods: Sixty-five adolescent pace bowlers were cluster-randomised into either an intervention (n=32) or control group (n=33). At baseline and follow-up, the following measures were recorded: eccentric isokinetic strength of the external shoulder rotators (90°/sec and 180°/sec), eccentric isokinetic strength of the hamstring muscles (60°/sec and 180°/sec), isometric hip adductor strength, hold time on the Biering-Sorensen test, and maximal reach distance on the star excursion balance test (normalised to leg length). Between testing sessions, and in addition to normal training, the intervention group completed an eight-week exercise program4. This included shoulder, hamstring and groin strengthening exercises, trunk extensor endurance exercises, and dynamic neuromuscular control drills. The control group continued their normal cricket activity over this time. Data on mean number of balls bowled, sessional rate of perceived exertion (sRPE), and training attendance were also collected from both groups during the intervention period. Differences between the groups at follow-up were estimated with linear mixed models. Baseline outcome score was included as a covariate and cricket club as a random effect. Estimated marginal means with 95% confidence intervals (CI) were calculated for each outcome, as were Cohen’s D effect sizes (d).

Results: There were no significant differences between the groups at follow-up for shoulder and hamstring strength (all testing speeds). Significant between-group differences were observed favouring the intervention group for hip adductor strength (0.38 95%CI 0.25-0.51 N.m/kg, d=0.7), Biering-Sorensen test hold time (20.45 95%CI 5.20-35.70 seconds, d=0.3), and star excursion balance test (3.99 95%CI 1.34-6.64 % reach distance, d=0.5). There were no differences between the groups when examining mean number of balls bowled, sRPE or training session attendance (p>0.05). Players in the intervention group attended 86% of all exercise sessions.

Discussion and Conclusions: Some neuromuscular risk factors for injury in community-level adolescent pace bowlers are modifiable with an exercise intervention, and these findings accord with those seen in other adolescent sporting populations5. Cohen’s D effect sizes for hip adductor strength and star excursion balance test indicate a moderate treatment effect, whereas the treatment effect for the Biering-Sorensen test was small. The non-significant differences between the groups for shoulder and hamstring strength may be related to exercise specificity, as the training speeds were likely slower than those used during testing. Future large-scale cluster-randomised studies, which control for confounding variables, such as bowling load and bowling biomechanics, are needed to confirm if the current exercise program can reduce injury rates in adolescent pace bowlers.

References
Functional movement screening in elite Indian fast bowlers

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Background: Functional movement screening (FMS) is an established pre-participation screening tool in the prediction of injury among athletes across various sports 1. Athletes with poor functional movement patterns, strength and flexibility are more likely to be injured 2. The total FMS score and the individual sub-scores can provide an indication on the potential areas of injury risk. In Cricket, the art of fast bowling requires precise and efficient movement patterns for better performance and to prevent injuries. Despite the popularity of the sport in India, there is a lack of literature on the functional movement screening scores in Indian fast bowlers.

Aims: To derive functional movement screening scores of elite Indian fast bowlers and describe the potential areas of injury risk.

Methods: 22 elite male fast bowlers underwent Functional Movement Screening at the High Performance Centre of a University sports medicine facility. Seven components including deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise (SLR), trunk stability push-up and rotary stability were assessed. Three clearance tests for pain during the movements were also noted. Each test was assessed for a score of three and a total score out of 21 was recorded. A sub-score of less than 2 out of 3 and total score less than 17 was considered significant for injury risk 3. Descriptive statistical analysis of the data was done.

Results: All bowlers had a total score <17 with mean total FMS score of 14.3 ± 1.5. Bowlers had Mean scores of less than 2 in Deep Squat (1.86 ± 0.62), Hurdle step (1.82 ± 0.39), In-Line Lunge (1.86 ± 0.34) and Rotary Stability (1.95 ± 0.21). Mean scores were more than 2 in Shoulder mobility (2.36 ± 0.71), Active SLR (2.27 ± 0.45) and Trunk Stability Push-up (2.18 ± 0.57).

Discussion and Conclusions: These findings suggest that Indian fast bowlers are at risk of injury based on the total FMS score and specifically in areas including deep squat, hurdle step, in-line lunge and rotary stability. This implies that the players have limited motor control within the movement patterns. This in-turn can cause movement deficiency which could possibly lead to injury during performance. Corrective exercises to target these areas will improve the quality of movement and movement patterns thus reducing the risk of injury.

References:
The development of a fast bowling Twenty20 match simulation

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Background: The use of match simulations has previously been adapted and used within cricket. However, within the sport of cricket there are a number of specialty positions and up to this date, this remains the only match simulation protocol which exists. Given the difficulty in examining the demands of fast bowling whilst in a match environment without becoming intrusive and potentially interfering in the match, the development of reliable and valid match simulation may be of use to both coaches and researchers.

Aims: The aim of this study was (1) determine the reliability and validity of the Twenty20 fast bowling simulation (FBS-T20) and, (2) examine the demands of fast bowlers as they completed the simulation.

Methods: Six amateur fast bowlers (age= 23.6 ± 1.4 yr, body mass= 82.3 ± 8.8 kg, height= 185.4 ± 5.3 cm) completed three sessions of the FBS-T20 during which physical (distance covered, bowling approach speed, 10 m sprint time), psycho-physiological (heart rate, RPE) and technical (bowling accuracy) demands were collected. Each FBS-T20 consisted of four bowling overs and sixteen fielding and was based on previous time-motion analysis data. To complete the first part of the study, the data collected from the FBS-T20 was compared to this previously reported data to determine the validity of the simulation (independent samples t-tests), whilst reliability was determined by comparing the intra- (session 1 v session 2) and inter-session (session 2 v session 3) demands over the three sessions (MANOVA, typical error (CV%), intra-class correlation coefficients (ICC), and limits of agreement (LoA represented as ±2SD)). With regards to the second aim, one-way ANOVA with Bonferroni post hoc (p<0.05) was used to determine differences between measures during the bowling and fielding overs across all sessions.

Results: With regards to the first aim, no significant (p>0.05) differences existed for validity or inter-session reliability for any of the physical measures. Specifically, an adequate level of inter-session reliability existed for most measures of distance covered during the FBS-T20 (CV=3.8-13.4%; ICC=0.81-0.96; LoA:-72.67-42.00 m). Approach speed (CV=10.0-13.5%; ICC=-1.19-0.51; LoA: -0.44--0.09 m∙s⁻¹) and 10 m sprint speed (CV=1.3-5.1%; ICC=0.11-0.87; LoA: -0.83-0.28 m∙s⁻¹) displayed varied levels of inter-session variability. There were significant differences for mean heart rate between all three testing sessions compared to previously reported data. Regarding the second part of this study, fast bowlers completed 7917 ± 934 m during each session. No significant differences (p>0.05) were evident when comparing any of the physical or technical measures across the three sessions. Differences existed (p<0.05) when comparing the bowling and fielding overs completed for the psycho-physiological measures.

Discussion and Conclusions: The FBS-T20 developed for this study appears to be both a valid and reliable method for simulating a Twenty20 match environment for fast bowlers. This may provide coaches and researcher with a novel method of both training their athletes in a match-specific environment as well as allowing for a more detailed understanding of the demands of fast bowlers.

References:
Bowling with modified-implements in the warm-up: do they alter pace bowling skill, rhythm, and sensation with a regular ball?

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**Background:** Pitching with a 10% lighter ball in a warm-up can enhance subsequent velocity with a regular ball by ~3.2–4.9 km·h⁻¹, with no significant differences in pitching accuracy¹. Conversely, bowling accuracy can temporarily worsen, with no significant change in ball release speed (BRS) after warming-up with balls 92% and 60% heavier than regular ². Feros et al.² speculated intermuscular coordination (i.e., rhythm) was adversely affected after bowling with the heavier cricket balls. However, warming-up with balls that are ±10% of regular mass may yield acute enhancements in BRS without negatively affecting bowling accuracy.

**Aims:** To investigate the acute effects of modified-implement bowling on subsequent pace bowling skill, rhythm, and sensation with a regular ball.

**Methods:** Thirteen amateur male pace bowlers attended an indoor stadium on three separate days. Each session comprised a general aerobic and dynamic warm-up, followed by 15 sub-maximal warm-up deliveries, six maximal-effort warm-up deliveries, and a four-over bowling test³. The 21 warm-up deliveries were performed either with a regular (156 g), lighter (140.4 g), or heavier ball (171.6 g). Ball release speed was captured by radar gun. Ball accuracy was calculated via a grid-based scoring system superimposed onto a vertical target sheet. After each delivery, bowlers rated their delivery rating of perceived exertion (% of 100), rhythm (5 point Likert scale, 1 = very poor, 5 = very good), and “sensation” (5 point Likert scale, 1 = very light, 5 = very heavy). Delivery sensation represented the feeling of the ball in the hands when completing the bowling motion. In SPSS, linear mixed models examined the differences between warm-up protocols on each dependent variable, while controlling for delivery rating of perceived exertion, and the within-subject error from repeated trials (using compound symmetry). Pairwise comparisons were conducted with the least squares difference procedure. Statistical significance was set at \( p < 0.05 \).

**Results:** Compared to a regular-ball warm-up, the heavier- and lighter-ball warm-ups resulted in no significant difference in mean BRS (\( F_{2,908} = 1.72, p = 0.178 \)), bowling accuracy (\( F_{2,780} = 0.61, p = 0.547 \)), and delivery rhythm (\( F_{2,919} = 2.19, p = 0.112 \)). A significant difference was detected for delivery sensation (\( F_{2,919} = 24.24, p < 0.001 \)); more specifically, between the regular- and heavier-ball warm-ups (mean ± SE: -0.202 ± 0.35, \( p < 0.001 \)).

**Discussion and Conclusions:** Warming-up with a ball that is 10% heavier or lighter does not significantly alter BRS, accuracy, or rhythm with a regular ball in a four-over test among amateur pace bowlers. The regular ball appears to feel “lighter” to use following the heavier ball; supporting previous observations¹. However, this kinaesthetic change does not appear to influence bowling skill or rhythm. This may be explained through dynamic systems theory, where the amateur pace bowlers may have been able to “self-organise” quickly in response to change in task constraint (i.e., implement mass). Nevertheless, the acute enhancement in velocity reported in baseball pitching by Morimoto et al.¹ could not be replicated in cricket pace bowling; at least not in amateur pace bowlers.

**References:**
2. Feros S.A., Young, W.B., & O'Brien, B.J. JASC, 21(S2), 41-44.
Understanding heat stress and exposure during test-cricket play: an exploratory study

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Background: Monitoring environmental and activity parameters (as markers of external and internal thermogenesis respectively) for risk of heat stress can help to identify circumstances that put cricketers at risk of exertional heat illnesses (EHI).¹

Aims: This study aimed to explore individual variability in heat stress and exposure among Australian national cricketers during the test-cricket matches played in Colombo and Kandy, Sri Lanka in July-August 2016.

Methods: Three heat illness risk parameters were identified and analysed on a per player basis. Climate data were obtained from the department of meteorology, Sri Lanka and reported as hourly ambient temperature and relative humidity data. Individual player data (n = 11) were obtained from an online cricket database: http://www.espncricinfo.com. As a proxy for workload, the duration of exposure (based on number of overs played) and intensity of activity (based on different cricket-specific roles), are reported.

Results: Ambient temperature during the playing period (10am - 5pm) ranged from 29.4 - 30.5°C in Colombo (mean = 30.2 ± 0.4) and 25.5 - 28.2°C in Kandy (mean = 27.2 ± 0.9), and relative humidity ranged from 70.2 - 75.8% in Colombo (mean = 72.2 ± 2.0) and 68.8 - 80.0% in Kandy (mean = 73.5 ± 4.0). The period from 11am to 2pm (second half of session-1 and the first half of session-2) recorded the highest mean temperature. Per player, the total on-field play ranged from 244 overs (59% of total match overs; fielding = 209, fast-bowling = 32, batting = 3) to 346 overs (84% of total match overs; fielding = 241, batting = 105); (mean = 272 ± 34). The workload of players in different playing tasks ranged from 154 - 241 overs (mean = 217 ± 30) in fielding, 2 - 45 overs (mean = 23 ± 19) in fast-bowling, 2 - 87 overs (mean = 37 ± 42) in spin-bowling, 3 - 105 overs (mean = 31 ± 34) in batting, and 66 - 168 overs (mean = 140 ± 34) resting in the pavilion.

Discussion and Conclusions: There is considerable variability in heat stress risk parameters (climate, duration, and intensity of play) among players within the same team during a test-cricket match. Variations in climatic parameters were observed between different playing venues, between the five days of the test-cricket match for a single venue, and also between the three sessions for each day. For playing duration and intensity, considerable individual variability among players was observed on a daily basis as well as over the five days of the test-cricket match. Overall, these results suggest the importance of an individualised approach towards monitoring cricketers during test-cricket play as they differ in terms of heat exposure and heat stress. This study objectively assessed the environment and workload related parameters that allowed a better understanding of heat exposure during test-cricket play, and provided insight for developments in heat exposure monitoring among cricketers in the future. Further, EHI-related policies and guidelines in cricket need to be adaptive and flexible to the different conditions and playing context.

References
Enhancing concentration in an elite international male cricketer: A longitudinal mixed methods study

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Background: The ability to concentrate during a game of cricket is an essential element of successful performance. Therefore, a successful approach to enhance a player's ability to concentrate is essential to the work of coaches and sport psychologists.

Aims: This mixed methods study charts the development, implementation and evaluation of an evidence-based approach to improve concentration in elite male cricketers.

Methods: Part 1 of the study investigated a group of twelve elite cricketers' perceptions of 'concentration'. Semi-structured interviews were carried out and a thematic analysis using a Grounded Theory approach followed.

Part 2 took an auto-ethnographic account of how the author used this evidence base (study one), the academic literature and his own experiences as a player and as an elite coach to implement strategies with elite young cricketers to enhance concentration and reduce the likelihood of 'reinvestment' which has the potential to lead towards such negative psycho-motor issues as the 'yips'.

Part 3 used a thematic analysis of a semi-structured interviews with an elite (International) male cricketer, who had received coaching using the evidence-based intervention discussed in study two and had gone on to use it over several years including during performances in International cricket matches.

Results: Part 1: Findings were consistent across the two groups. Both sets of cricketers had distinct strategies to maintain their concentration. Although they used different methodologies, all players appeared to use a similar approach, which was also similar to that described by Galwey, amongst others.

Part 2: The author used the findings of study for the development of an evidence-based, personalised pre- and concurrent-performance routine used with fast bowlers, as advancement to current coaching practice and generalised guidelines.

Part 3: The findings of this were that the athlete tended to use two approaches, depending on (1) performance and (2) perceptions of concentration. When the athlete felt performance was going well, he reported similar experiences to those reported in a 'flow state' and so would "let it happen". However, when he felt that he was not concentrating so well (usually linked to his performance outcome) then he would consciously and systematically use the approach previously described (study two).

Discussion and Conclusions: The findings of this study suggest that the evidence-based intervention (study two) was successfully implemented and used in International cricket.

The implications are that cricket players can use interventions, delivered by coaches or sport psychologists to enhance concentration. Coaches and sport psychologist should create approaches for athletes both in flow states and to enable good repeatable performances. And finally, that these must be individualised and may also be context specific.

References:
Sleep behaviours of elite South African cricket players during a home and away tour, for both One-day International and Twenty20 series’

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Background: The notion that sleep is a pre-requisite for optimal recovery and performance ability in elite athletes is well established1. Despite this, sleep is often deprioritised by athletes, with evidence of sleep impairment at elite level2,3. Modern elite cricket players have unique physical and cognitive demands, severe competition programs, and must accommodate for arduous travel schedules and night matches (all of which put them at high risk of experiencing disruptive sleep)2,4. While there is evidence of poor sleep behaviour in elite athletes during competition3, there is still a need to investigate these findings in elite cricket.

Aims: To profile the sleep of elite South African cricket players during competition for both One-day International (ODI) and Twenty20 series’.

Methods: The study was a longitudinal field-based investigation, whereby elite South African cricket players’ sleep was monitored during home and away competitive tours (September-November 2018). Players completed the Athlete Sleep Behaviour Questionnaire (ASBQ) once and an altered version of the Core Consensus Sleep Diary every morning post-travel, pre-match and post-match. Linear mixed models and ordinal regression was used to compare differences between sleep variables, using Tukey’s post hoc method for significant pairwise comparisons. Spearman’s (r_s) correlation was used to assess the relationship between stimulant use (alcohol and caffeine), age and experience level with selected sleep metrics. Hedges’ (g) was used as a measure of effect size.

Results: Significantly earlier post-match bedtimes (p= 0.01; g=0.80), greater time in bed (p < 0.0001; g=1.26) and total sleep times (p= 0.004; g=0.85) were found away compared to home. Players had moderately greater wake-after-sleep onset durations (p = 0.25; g = 0.77) and less total sleep (p= 0.12; g= 0.61) before Twenty20 compared to ODI matches. Older players were associated with longer wake after sleep onset durations during the away tour (r_s(52) = 0.52, p =0.0003). No significant correlations between experience level and sleep were found at home; however, more experienced players obtained greater sleep quantities during the away tour (r_s(52) = 0.26, p =0.02). Later timing of last alcoholic drink consumed was strongly associated with lesser total sleep duration during the home tour (r_s(52) = -0.69, p < 0.0001). No significant indication of a dose-response was found between units of caffeine and poor sleep, regardless of venue. Inter-individual differences in sleep-onset latency, total sleep time and subjective sleep quality were observed.

Discussion and Conclusions: From a quantity perspective, there were no concerns in preparation for a match, irrespective of venue. However, the poor post-match sleeping behaviour observed could have adverse consequences on recovery. Further research is needed to explain the higher wake-after sleep onset and lesser total sleep durations before Twenty20 matches. The Spearman correlation and ASBQ results suggest that practical strategies to reduce bedtime light-emitting technology use, late evening alcohol and caffeine consumption and to alleviate muscle pain should be implemented. Further, the moderate correlations in age and experience with sleep, as well as inter-individual differences found, emphasise the importance of personalised sleep monitoring in team-sports.

References:
A pilot study to investigate the time of day effects on perceptual, physical and performance indicators of adolescent fast bowlers.

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**Background:** Previous research has found evidence of time of day fluctuations and diurnal variation, underpinned by circadian rhythm, in cognitive, physical and perceptual responses¹. This is relevant to cricketers as they are expected to play at different times of the day because of the different formats of the game. Fast bowlers (particularly adolescents) have been found to be placed under the greatest workload².

**Aims:** No studies have investigated the time of day effects on perceptual, physical and performance indicators of non-elite, school level fast bowlers, making this the purpose of the current study.

**Methods:** First team adolescent male fast bowlers (n = 5) were required to complete a fast bowling simulation protocol whereby perceptual, physical and bowling-specific performance measures were collected at three different times of day (10:30, 14:30, 18:30). The bowling protocol involved a four over bowling spell completed by two bowlers at a time, bowling in tandem to imitate changeover periods between overs. Session RPE was taken to obtain how they perceived the load of the overall testing session. The overhead medicine ball throw and standing broad jump were used to measure upper and lower body power, both pre and post the bowling spell. Ball release speed and accuracy of delivery were the measures used to obtain performance responses to the bowling spell. Within-group one-way ANOVAs were calculated to investigate the difference in the dependent variables at each time period.

**Results:** Significant differences were found in the bowling speed performance parameter. These differences were seen between 10:30 and 14:30, and between overs one and four of the protocol; with an increase seen at 14:30 and in over four. No significant differences were found in bowling accuracy, upper and lower body power, and ratings of perceived exertion.

**Discussion and Conclusions:** In conclusion, this investigation found time of day had no significant effect on physical and perceptual responses of fast bowlers as well as on accuracy of delivery. However, bowling speed was slowest in the afternoon. These results have implications for both bowlers and coaches. It is important for coaches to promote more consistent bowling performance by emphasising to fast bowlers the need to achieve and maintain accuracy of delivery, not just speed, throughout their bowling performance. Additionally, coaches can use the knowledge that bowling performance can change at different times of the day. Bowlers can be made to train at several different times to adapt to performing across the day, including times when bowling performance isn’t usually good, thus under constraints. Specific conditioning and recovery work can be organised for bowlers based on how bowling is affecting the bowlers at different times of the day. Essentially these implications will result in bowlers being prepared to perform at many different times.

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GPS AND TIME MOTION ANALYSIS ON THE PHYSICAL DEMANDS OF FIELDING IN PROFESSIONAL CRICKET

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Background: Previous research has used time motion analysis to investigate the demands of professional cricket in both batting¹ and as playing roles when fielding². However, players are classified by their role in the team with their fielding position ignored. This may lead to inaccurate representations of the physical demands in the field.

Aims: To identify the demands of fielding within the game (catcher, ring fielder and boundary fielder), across all three formats played (Multi-day, One-day and T20).

Methods: Fourteen members of a professional team were randomly assigned to wear GPS units during 14 matches of the 2017 season. Movement categories were established as: Walking (0 - 7 km/h), Jogging (7 - 15 km/h), Striding (15 - 20 km/h), High speed running (20 - 25 km/h), Sprinting (> 25 km/h). “Low intensity running” consisted of the walking and jogging categories, while “high intensity running” (HIR) contained the striding, high speed running and sprinting categories. To allow for a comparison of intensity across formats, data relating to HIR was compared as meters per hour (m/h). Mean peak velocities were also compared to identify whether the requirements of each fielding position changed between formats.

Results: The HIR running was significantly different for each fielding position within each game format: Multi-day: 370 ± 291 vs. 227 ± 345 vs. 889 ± 435 m (catcher vs. ring vs. boundary); One-day: 385 ± 342 vs. 594 ± 286 vs. 930 ± 1085 m (catcher vs. ring vs. boundary); T20: 170 ± 165 vs. 628 ± 438 m (ring vs. boundary – no data collected for catcher). Significant differences in HIR were seen between formats in the boundary position with more HIR occurring in the shorter formats: 502 ± 350 vs. 266 ± 291 vs. 148 ± 72 m/h (T20 vs. One-day vs. Multi-day). Mean peak velocity was also seen to be different between formats with higher velocities seen in ring fielders: 8.0 ± 0.9 vs 6.2 ± 1.3 m/s (Multi-day vs. T20) and catchers: 7.6 ± 1.5 vs 4.7 ± 0.6 m/s (Multi-day vs. One-day).

Discussion and Conclusions: This study identifies the HIR demands of three differing fielding positions with the boundary position having the highest HIR demand across all three formats. The amount of HIR reduces as the format becomes shorter, however higher peak velocities were seen in ring fielders (Multi-day vs. T20) and catchers (Multi-day vs. One-day) suggesting that the field setting, and match objective can change the physical demands of the fielding position. This information is able to better inform physical preparation specialists, skills coaches and tacticians in the sport.

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Association of leading leg knee cartilage volume with bowling kinetics in current elite fast bowlers

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Background: Certain kinetics of the knee during gait can influence cartilage volume¹,², and can influence the initiation and progression of osteoarthritis of the knee³,⁴. It is unknown whether the moments experienced by the leading leg of fast bowlers during the delivery stride are associated with knee cartilage volume.

Aims: To test the association of normalised knee cartilage measurements with bowling kinetic parameters in current elite English bowlers.

Methods: Kinetic and kinematic data during bowling and unloaded knee MR images were obtained from 10 male and 3 female healthy elite bowlers. Compartmental cartilage volume was measured using manual segmentation (intra-observer intra-class correlation coefficient=0.91). Linear regression models were used to evaluate the association of the leading leg knee flexion-extension (FE), abduction-adduction (AA), and internal-external (IE) rotation moments at leading leg strike of the delivery stride with the normalised lateral and medial tibial cartilage measurements from the leading leg. Regression models were unadjusted and adjusted for age.

Results: Eight of the 13 bowlers had complete data for the lateral cartilage measurements (5 male, 3 female bowlers). As the FE moment and AA moment at leading leg strike increased, they were significantly associated with an increase in the normalised lateral tibial cartilage measurement in the unadjusted model (p=0.020 and p=0.042, respectively). Only the FE moment was significant when these models were adjusted for age (p=0.035). No significant associations were found between the medial cartilage measurements and any of the kinetic parameters tested.

Discussion and Conclusions: This study suggests that a significant association exists between increased cartilage in the lateral tibial compartment and increased FE and AA knee moments at leading leg strike. These results support the hypothesis that knee cartilage demonstrates some level of sensitivity to mechanical loads, which can influence risk of long-term joint health and osteoarthritis.

References:
Fast Bowler's Knee – Management of articular impingement in International players

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Background: The front leg is used as a lever for faster bowling and also absorbs the tremendous decelerating force on front foot impact\(^1\). This can lead to knee injuries due to articular impingement.

Aims: We describe a series of impingement lesions found on the anterior aspect of the medial femoral condyle in international cricketers. We discuss their management and results.

Methods: Seven international level fast bowlers presented to our clinic with knee pain in the lead leg between 2005 and 2013. The mean age of the patients was 26.7 years (20-29 years). In all patients a careful history and examination was undertaken followed by appropriate investigations. Conservative and arthroscopic surgery was performed on these cases. We aimed for a primary outcome of pain free quiet knee with resolved oedema on MRI and secondary outcome of return to sport.

Results: MRI images showed oedema in the medial femoral condyle in all patients and 4 patients also had associated cartilage loss. These 4 patients underwent arthroscopic surgery whereas the other 3 were less symptomatic and were managed conservatively. All patients returned to international cricket at an average of 6 months in the non-operative group and 8 months in the operative group.

Discussion and Conclusions: Anterior impingement of the anteromedial femoral condyle can be a potentially serious lesion in the fast bowler. A strong index of suspicion regarding this lesion has to be exercised when a fast bowler attends with knee pain and effusion. In our experience, bowlers with such knee conditions can successfully return to sport following treatment.

References

Foot and ankle overuse injuries in fast bowlers: comparison between front on & side on action bowlers.

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Background: Cricket bowling action involves complex movement of the body to deliver the ball at desired speed. Depending on the contact position of the back foot on the popping crease, the bowling action is broadly categorized in front on, side on and mixed types. The contact position of the back foot is an important point of pivot for the entire body to generate pace of delivery.

Aim: With this study, we aim to compare the various foot and ankle overuse injuries in these two types of bowling actions namely the front on type & the side on type.

Method: In a retrospective review of fast bowlers above the age of 15 years having trained & playing competitive cricket at club level and above for a minimum duration of one year were considered in this study. A questionnaire containing age, type of action, injured foot (back or front foot), bowling load (balls per week), body weight, body mass index (BMI), approach velocity (speed of run up) to the crease and expert's (bowling coach) comment on the action were noted for bowlers with foot and ankle injuries during the period between January 2017 to December 2018. We did not consider acute injuries like acute lateral ligament injuries, acute tendon ruptures or fractures of foot and ankle.

Results: We noted eighty-seven bowlers with foot and ankle injuries with 40 having front on action and 47 with side on action. 21 bowlers were between 15-19 years, 30 bowlers between 20-23 years and 36 bowlers were above 23 years age. The various injuries noted were posterior and anterior impingement of ankle, stress fracture of calcaneum, stress fracture of 5th metatarsal, heel fat pad edema, tendinopathy of Achilles tendon, flexor hallucis longus tendon, tibialis posterior tendon, peroneal tendon injuries and sesmoid stress injuries. There was significant higher incidence (p<0.05) of posterior impingement in side on bowling action bowlers and higher incidence of Achilles and Tibialis posterior tendinopathy in front on bowlers. Rest of the injuries did not show any significant difference between the two types of actions. 78 out of 87 (89.6%) bowlers were noted to have extra play (excessive outward deviation) of their front foot during bowling by their coach, pointing abnormal biomechanical loading during the delivery phase of bowling leading to overuse injuries.

Discussion & Conclusion: Deviations from bowling action play a significant role in overuse injuries of foot and ankle with excessive play being noted in 89.6% of bowlers. Front on bowlers have higher incidence of Achilles & Tibialis posterior tendinopathy and Side on bowlers have higher incidence posterior impingement. This emphasizes the need to stick to correct technical aspects of their respective bowling actions to avoid excessive play of front foot to reduce the incidence of foot and ankle overuse injuries.

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Observable characteristics of head impacts associated with concussion diagnosis in cricket

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Background: Participation in cricket carries an inherent risk of head impacts. Statistics for elite-level Australian players report a match incidence of 7.2 head impacts (2.3 concussions, 32%) per 1000 player days for male players, and 3.7 head impacts (2.0 concussions, 53%) per 1000 player days for female players¹. Seventy-five percent of head impacts occur to on-strike batters¹, which presents a challenge to medical staff to quickly assess a player and determine whether the player needs to be removed from play for further assessment, and thus disrupt the game. An additional challenge is that a large proportion of concussions in cricket are delayed concussions, with 70% of concussions diagnosed later in the day or the next day¹. Therefore, there is a need to assist medical staff to differentiate between a concussive and a non-concussive head impact.

Video review has become an important tool to aid sideline identification and management of potentially concussed athletes in other professional sports². However, video signs typically identified in these contact sports (e.g., loss of consciousness, motor incoordination, blank and vacant gaze) are not often seen in cricket-related concussion and are difficult to detect in a player wearing a helmet and without multiple camera angles. Therefore, there is a need to identify cricket-specific video signs which are associated with concussion diagnosis.

Aims: To identify observable characteristics of head impacts associated with concussion diagnosis in elite male and female cricket players.

Methods: A retrospective review of 199 head impacts with corresponding match video and medical records between November 2014 and February 2019. Thirty-five head impacts were diagnosed as concussion (28 male, 7 female).

Results: Head impacts most commonly occurred to on-strike batters hit by a ball (n=173, 87%), of which 28 (16%) were diagnosed as concussion. Characteristics of head impacts most commonly associated with concussion diagnosis were: ball bowled by a pace bowler (17% of head impacts with characteristic diagnosed as concussion), ball which stopped or rebounded towards the source (21%), impact to an unprotected head (33%), and impact to the back of the helmet (36%).

Discussion and Conclusions: Medical staff may integrate these findings into their clinical assessment of players who sustain a head impact, and therefore be more confident in their decision on whether or not to remove the player from the field for further assessment. The availability of video footage on the sideline, with the ability to replay incidents, would further support the identification and assessment of head impacts by medical staff.

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51
Optimising Challenge: Key in the Development of England’s Greatest Batsmen?

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Background: There is a dearth of research which has examined the nature and microstructure of cricket (and wider sport) practice within the expertise development field. That is, the influence of the nature and structure of skills-based practice, on the existing relationship between practice quantity and cricket expertise, is unknown¹. Consequently, if future research is to achieve a better understanding of desirable cricket development environments, discipline-specific examinations of the nature and microstructure of the practice activity of super-elite sportsmen, alongside developmental experiences, are warranted, in identifying: the skills that were practiced; how this practice was structured and delivered; how frequently this was practiced; and how this practice changed over the course of development².

Aims: To determine the variables from the practice biographies and developmental histories of batsmen, that discriminate between England’s greatest (super-elite) batsmen of the modern era and (elite) county batsmen.

Methods: The total sample comprised 20 past and present batsmen, 10 of whom were super-elite (M_age = 36; SD = 6.3) and 10 were elite (M_age = 34; SD = 3.6). A clear distinction exists in the performance levels reached by the elite and super-elite; the super-elite represent a subsample of just 2% of English batsmen who played First Class County Cricket within the same era (2004-2016). This clear distinction in participant’s level of expertise allowed a robust examination of the precursors of super-elite expertise. A structured interview schedule was developed comprising four sections. Section 1 (Demographic information), 2 (Developmental sporting activity) and 3 (Cricket developmental milestones & performance indicators) of the interview schedule were informed by previous research exploring precursors of expertise³,⁴. Section 4 was developed specifically for the present study by the researchers, to explore the influence of the nature, and microstructure, of skills-based batting practice on the development of expertise. Following a multi-staged piloting process, the interview schedule was finalised. The interviews lasted approximately 3 hours, each collecting 658 variables, which were subsequently analysed quantitatively using pattern recognition (machine learning) techniques.

Results: Results revealed that a subset of 18 variables, from 658 measured, discriminated between the super-elite and elite batsmen with excellent classification accuracy (96%). Evidence for the external validity of this new model was offered by its ability to utilise the data of six unseen batsmen to correctly predict their expertise group (i.e., super-elite or elite) with 100% accuracy.

Discussion and Conclusions: The study findings demonstrate that the super-elite batsmen undertook a larger volume of skills-based practice (hours) that was both more random, and more varied in nature, at age 16. They subsequently adapted to, and transitioned across, the different levels of senior competition quicker. The findings suggest that experiencing challenging skill-based, and psychological-based practice, relatively early in the development journey, is a catalyst for progression to super-elite expertise. Application of this holistically-driven, non-linear, methodological approach to other cricket disciplines, and wider domains of expertise in sport, would likely prove productive.

References:
The batting backlift technique in cricket: What is the consensus at all skill levels?

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Background: The batting technique in cricket consists of various elements such as the grip, stance, backlift, downswing, impact with the ball and follow through1. Whilst there has been an extensive amount of research into these batting elements, there is little research specifically on the backlift technique. We aimed to investigate and provide a scientific understanding of the batting backlift technique (BBT) in cricket at the various skill levels.

Aims: We aimed to investigate the BBT of the most successful batsmen (n = 65) in the last 120 years; players in the Indian Premier League (IPL) (n = 30); semi-professional, professional and international cricketers (n = 155) from South Africa and the United Kingdom; and coached and uncoached cricketers (UC) (n = 80).

Methods: Biomechanical and video analyses were performed on all participant groups. Classifiers were utilised to identify the batting backlift technique type (BBTT) employed by all batsmen. All statistics and wagon wheels (scoring areas of the batsmen on a cricket field) were sourced online. A Pearson's Chi-squared test, Student T-test and T-test were performed in this study. All analyses were performed using R (R Core Team, 2014) at a significance level of α = 0.05.

Results: It was found that successful batsmen over the last 120 years did not conform to the current cricket coaching method that advocates a straight batting backlift technique (SBBT)2. Instead, 77% of successful batsmen and 90% of IPL batsmen employed a lateral batting backlift technique (LBBT) in which they lifted their bats in the direction of second slip or beyond with the bat face towards the off-side. Using this technique, both the toe of the bat and face of the bat points directly towards the off-side (usually between slips and point). The number of players using the LBBT was significantly greater than those using the SBBT ($\chi^2 = 19.2$, df = 1, $p < 0.001$). Given these findings, we were curious to determine whether this finding was similar at other levels of cricket. It was found that a LBBT is more prevalent at the highest levels of the professional game and a likely contributor factor for successful batting at the highest level (p<0.05)3. We then proceeded to investigate the BBT amongst the lower levels of cricket (junior and adolescent cricketers). It was found that more than 70% of UC adopted a LBBT, whereas more than 70% of coached cricketers adopted the SBBT.

Discussion and Conclusions: The LBBT is a likely contributing factor to successful batsmanship at all levels of cricket ability (junior cricketers, adolescent cricketers, semi professional cricketers, professional cricketers, international cricketers and former elite/successful cricketers). Early coaching emphasising the SBBT (one of the basic fundamentals of batting coaching) could be less favourable to the long-term success of young cricketers. Coaching a LBBT to young batsman may be challenging and, therefore, a coaching cricket bat has been developed and has shown to be a promising training aid for coaching the LBBT to young cricketers4.

References:
Visual perception ability in adolescent cricket batsmen

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Background: Skilled adult cricket batsmen use visual anticipation to overcome the temporal and spatial constraints when facing fast bowling by utilising advanced cues from the bowler’s action.¹ However, this perceptual decision making is not well developed in adolescent cricket batsmen. The point at which skilled adolescent batsmen start distinguishing the delivery is not known. This information is important to understand the perceptual development of players.

Aims: The aim of the study was to investigate the visual anticipation of skilled adolescent cricket batsmen during a temporal occlusion task.

Methods: Thirty-five, adolescent skilled cricket batsmen (Mean age = 14.4, SD = .7) were recruited for the study. A temporal occlusion paradigm was employed to allow participants to predict the swing and length of the delivery of a bowler. A projected video was occluded at seven points during the delivery, with each subsequent point providing progressively more visual information. The seven occlusion points were back-foot landing, front-foot landing, ball release, 100 ms after ball release, 200 ms after ball release, 300 ms after ball release, and at ball bounce.

Results: Skilled adolescent batsmen were not able to correctly anticipate the delivery without ball flight information. They required approximately 200 ms of ball flight information to anticipate the swing better than the 50% level of chance. For the anticipation of length, the skilled batsmen required slightly less time (i.e. 100 ms) of ball flight information before their percentage anticipation were above the chance level. Their anticipation gradually improved until ball bounce.

Discussion and Conclusions: Evidence in the trial suggests that skilled adolescent batsmen required approximately 100-200 ms of ball flight information to start to correctly anticipate the swing and length of the delivery. Advanced perceptual decision making is therefore unlikely to occur in the skilled adolescent population. Future research should investigate the reasons for this and to what extent this anticipatory skill can be trained in adolescent batsmen.

References:
The kinetics and kinematics of the rotary batting technique

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Background: Traditional batting coaching changed little until questioned this century. Findings such as Bradman’s lateral backlift was highlighted, challenging coaching with a traditional backlift that may impede performance and development but was also unexpectedly found in skilled batsmen with impact further away from the front foot in the off drive with less rotation of the hips suggesting a lesser role in kinetics than the larger documented rotation of the shoulders as well as the majority of the best batsmen of the last century with a more lateral backlift is largely unexplained. Bat velocity is increased in the x-factor stretch in the early downswing.

Aims: An analysis of the different stages of a cricket shot to improve performance and prevention of related injuries.

Methods: Kinetics and kinematics of other sports were explored that may be utilized in batting. Slow motion videos of footage of Don Bradman and replays of top international batsman were reviewed by tapping slow-motion videos in turn with the slow-motion function of an Apple iPhone.

Results: A lateral backlift aids movement by directing mass in the direction of the stride. An “O” grip with a rotary technique in rotating the shoulders enables a straight bat shot further to the off in the line of the delivery and has the ability to change the line of the pendulum swing into the line of the delivery on the leg side which allows a larger stride forwards and backwards. Rotation of the shoulders decreases the strain on the wrist adductors to achieve a vertical bat at impact. Rotations in the transverse plane, especially the hips, increase the bat momentum explained by functional and comparative anatomy that can be compared to a change in direction. The front arm is used in a double pendulum with the bat. The bottom hand closer to the mass of the blade with an “O” grip increases the moment of inertia around the long axis of the back upper arm to transfer momentum from the rotations of the trunk.

Discussion and Conclusions: The moment of inertia around the upper arm is increased by the thumb and distal thicker radius and may be further increased by moving more mass in the bat to the outside half in order to transfer momentum from the trunk into the bat. The thoracolumbar fascia and its connections from the humerus to the tibia play a large role in loading transverse plane rotations to improve performance and may play a role in preventing back injuries as Gluteus maximus similarly does in the lower limb providing pelvic rotation torque as a biarticular muscle. Rotating the bat from a lateral backlift and adjusting its path according to the individual delivery, once the line and length is assessed, may aid movement, decrease risk, increase momentum of the bat, decrease downswing time and increase decision making time. The rotary stance, backswing, downswing, impact and follow through will be illustrated with a slow motion replay of Don Bradman.

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Kinematic determinants of power hitting performance: a technique comparison of male and female cricketers

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Background: Recent research has investigated the relationships between technique and bat speed during a cricket range hitting task in 20 male batsmen ranging from club to international standard¹. The separation between the pelvis and thorax segments in the transverse plane at the commencement of the downswing, and both lead elbow extension and wrist uncocking during the downswing explained 78% of the observed variation in maximum bat speed. However, no research to date has compared such kinematic parameters between male and female batters during power hitting.

Aims: To compare power hitting kinematics between experienced male and female batters.

Methods: Fifteen male and fifteen female batters, ranging from MCCU to international standard, each performed a series of 20 shots against a bowling machine, aiming to hit the ball for maximum carry distance back over the bowling machine in a match-representative manner. An 18 camera Vicon Motion Analysis System operating at 400 Hz was used to collect three-dimensional kinematic data. Fifty-one 14 mm retro-reflective markers were attached to each participant plus bat, with an additional five 15 x 15 mm patches of 3M Scotch-Lite reflective tape placed on the ball. The logarithmic curve fitting methodology of Peploe et al.² was used to calculate instantaneous post-impact ball speed and carry distance for each trial. For each participant’s best trial (furthest carry distance), the 28 kinematic parameters previously measured in male batsmen¹ were calculated in Visual 3D software. Bayesian t-tests with non-informative priors compared each kinematic parameter between male and female groups. Evidence for the alternative hypothesis was set as Bayes factor (BF₁₀) > 3.

Results: Extreme differences between groups (males > females) were reported for maximum bat speed, ball launch speed, and carry distance. Of the technique parameters, males displayed greater separation between the pelvis and thorax segments in the frontal plane at the commencement of the downswing (moderate), lead elbow extension during the downswing (extreme), rear elbow extension during the downswing (very strong), and rear elbow angle at impact (strong) than females. Females had longer downswing durations (strong). No other differences were reported. On average, females flexed their lead elbow during the downswing (-3 ± 24°) whilst males extended theirs (30 ± 12°). Seven females (range: -9 to -34°), but no males, flexed their lead elbow during the downswing.

Discussion and Conclusions:
Experienced male and female batters differ in a number of kinematic parameters during power hitting performance. Males displayed greater lead and rear elbow extension during the downswing and greater separation between the pelvis and thorax segments in the frontal plane at the commencement of the downswing compared to females. These differences are highlighted by a tendency for some females to flex the lead elbow, perhaps demonstrating more of a traditional checked drive than a specific power hitting technique similar to that seen in sports such as golf. It is not clear whether the female participants could be coached to extend the lead elbow during the downswing, or whether their use of such a technique may be limited by strength characteristics.

References:
The Relative Age Effect in World’s Best Cricketers: A Case for the Survival and Evolution of the Fittest

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Background: The relative age effect (RAE) describes an overrepresentation of players born early (Q1) in the selection year, and is highly prevalent within youth cricket pathways. Despite this, the long-term developmental impact of the RAE is less understood. This is likely due to (at least) two reasons. Firstly, the prevalence of RAEs in senior cricket is largely unknown. Secondly, this limited body of research in senior cricket has failed to explore discipline-differences in RAE prevalence, owing to the unique physical, technical and cognitive requirements of the cricket disciplines.

Aims: The aims of the current research were two-fold. Firstly, to test whether RAEs highlighted thus far extend beyond youth sport, into the world’s best cricketers. Secondly, to assess RAE prevalence across the different cricket disciplines for intra-sport differences. That is, consideration of the unique physical, technical and cognitive demands attached to the different disciplines may assist in identifying the long-term impact of RAEs on cricket development.

Methods: The initial sample (n = 262) consisted of past and present male cricketers, representing 9 different International Test teams between 1994 and 2014. Cricketers were included in the research on the basis that the players had been recorded in the top 30 in the World in Test format within the 20-year period specified. The cricketers were categorised as batsmen, spin bowlers, pace bowlers, bowlers combined, and all disciplines combined. Subsets of these participants were identified using 11 criteria of increasing stringency, in recognition of the inconsistent criteria previously used to define level of expertise. This resulted in the sample ranging from 262 (least stringent) to 110 (most stringent).

Results: Results revealed the RAE (Q1) when all disciplines were combined. Upon closer examination, this effect was also observed for the batting and spin bowling disciplines, whereas no RAE was found for the pace bowling.

Discussion and Conclusions: The current findings suggest that the less weighting that is placed on physical characteristics, the more likely the Q1 RAE is to persist. This is illustrated by the Q1 RAE observed for cricket batsmen and spin bowlers, and the absence of the RAE for pace bowlers, indicative of the survival of the fittest; prolonged opportunity and exposure to pathway expertise may facilitate the development of robust technique, required cope with technical demands at international level. The opposite may also be true; the greater the emphasis placed on physical capability in a given sport, the less likely that the Q1 RAE will extend from junior to senior level, due to the ongoing potential of Q4’s. This is supported by the lack of RAE found for pace bowlers within the current study, and emerging research in world’s best rugby union player, revealing a Q4 finding. These findings are instead indicative of the evolution of the fittest, where overcoming significant challenges, associated with the disparity in physical size early on, likely assists in developing resilience and/or the technique to achieve at the highest level. Suggested directions for future RAE research are presented.

References:
The value of a socio-ecological approach to talent development in cricket

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Background: The factors affecting the development of sporting talent continue to be researched as individuals, teams and countries seek to optimise sporting performance and excellence. Whilst much of this research previously focused on the individual athlete’s personal characteristics, in more recent years there has been a move to understand the environment and context in which the athlete develops.¹ However, these environmental influences may vary between socio-economic and cultural contexts, as well as across different sports leading to exclusion and drop out of participants. Talent development in cricket has received limited attention. South Africa’s history of colonialism and apartheid, which institutionalised segregation between the ethnic groups resulted in significant socio-economic inequalities between the different groups. This unique context, provides an opportunity to understand how environmental factors could influence talent development in cricket in a diverse society.

Aims: To determine the role that socio-ecological factors may play in the development of cricket talent.

Methods: A qualitative methodology was used to explore the experiences and perceptions of South Africa’s cricketers as they progressed through the talent pathway from initial exposure to the game to the elite level. Fifty-seven semi-structured interviews were conducted with a purposeful sample of elite male players (n=43) from all ethnic groups, as well as knowledgeable and experienced key informants (coaches and administrators) (n=15), who provided objectivity and credibility to the data. An adapted thematic analysis of the data resulted in the identification of themes and sub-themes.

Results: All players progressed to the elite level, however their access points to, and routes through the pathway varied. This progress was found to be influenced by the inter-relationship of distal (South African society, diverse communities and organisational) and proximal (family, schools and clubs, coaches and team environments) factors that they experienced during their cricketing careers. These influences can be summarised into five talent development components that acted either as barriers or enablers to progress. These are: (1) access to opportunities and competition, (2) holistic player development, (3) effective support networks, (4) inclusive team environments, and (5) adaptive mind-sets.

Discussion and Conclusions: The findings of this research support the idiosyncratic, multifactorial, dynamic and complex manner in which cricket expertise is achieved.², ³ Furthermore, it provides a framework for understanding the inter-relationship within and between distal and proximal socio-ecological factors. These relationships determine how talent development may be enabled or hindered. A socio-ecological approach provides stakeholders involved in the talent development process with evidence to inform policy and practice, as well as design effective interventions to manage the barriers and enablers experienced by cricketers.

References:

How do culture and norm circles (as shaped by coaches and others) play a role in
influencing the actions of cricketers?

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Background: Previous literature has widely represented the influence of coaching practice (e.g., coach behaviour) on athletes’ actions or ‘outcomes’ as linear, simplistic and homogeneous (i.e., the same coach behaviour is likely to have the same influence on athletes if repeated). However, these rationalistic accounts ignore and misrepresent the inherent social complexity of coaching and imply that specific coach behaviours (e.g. praise) can directly affect athletes and their actions, in isolation. Further, this ignores the ability of coach behaviour to exert a heterogeneous influence on different athletes, or the same athlete at different time points. Specifically, few studies have sociologically explored how athletes’ actions are influenced by both structural (i.e., culture, norms) and agential factors (i.e., conscious deliberation), and the role played by the coach in shaping these entities.

Aims: To critically explore how both the (inter)actions of coaches and athletes shape the culture and norms of a squad, and how this plays a role in shaping subsequent (inter)actions of athletes.

Method: A qualitative longitudinal ethnography was conducted with one representative-level minor county junior cricket squad in the North East of England. The squad was comprised of 26 cricketers, a head coach, a team manager, an assistant coach, and a strength and conditioning intern. A bricolage of methods including participant observation, semi-structured interviews and stimulated recall interviews were adopted to understand both the formation and influence of cultural norms in the specific context studied. Critical realist modes of data analysis were employed: retroduction – identifying the parts of an entity and their causal power; and retrodiction – understanding how causal powers and mechanisms interact to produce events or actions. The analysis draws upon Elder-Vass¹ ² theories of emergentism, norm circles and the causal power of social structures as heuristic devices to critically explore how, when, why, to what extent, and under which circumstances coach and athlete (inter)action both shaped, and was shaped by the norms of the context.

Results: Through emergent (inter)actions of coaches and athletes, the established norms and culture of the specific squad included a focus on: intensity, high performance, accountability and responsibility. The actions of athletes were found to be shaped by both these norms and conscious reflexivity (their capacity to think before acting). Specific examples are provided whereby coach or athlete (inter)actions (e.g., praise) served to shape and endorse or enforce the norms of the squad, and thus played a role in influencing the subsequent (inter)actions (e.g., performance) of athletes.

Discussion and Conclusions: These findings have important implications to help coaches, athletes and other stakeholders (e.g., sport scientists, sports medicine practitioners, physiologists, administrators) of cricket coaching contexts to better understand how their actions may influence the norms or culture of an organisation, and how this can subsequently influence the (inter)actions of others. Critically challenging the assumption that behaviour or action, alone, can have a direct, unmediated, and stable impact on others may help stakeholders to understand both the potential intended and unintended consequences of their actions. These findings, then, provide a fruitful opportunity to support the effective development of others within a cricket environment.

References:
Scaling the pitch for under-11s and beyond

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Background: Prior to 2019 the England and Wales Cricket Board (ECB) pitch length recommendations for junior cricket were disproportionately long; in the simplest terms, the 20 yard (18.29 m) long under-11 pitch was 12.8 times the average stature of 11-year-olds, equivalent to requiring adults to play on 24.9 yard (22.78 m) pitches, 13% longer than the standard 22 yards (20.12 m). Research showed that playing on a shorter pitch improved numerous game measures and technical outcomes. However, the ideal pitch length for junior age groups remained to be determined.

Aims: To present a method for determining pitch lengths which enable bowlers to bowl good length deliveries while releasing the ball more like top adult bowlers, to apply this to the under-11 age group and to explore the influence on bowling and batting demands.

Methods: The pitch length was divided into three horizontal components: Release distance, from the bowler's end stumps to the ball position at release; Flight distance, from release to the bounce point; and the post-bounce distance to the batter's stumps. Typical under-11 ball release position and speed were obtained from a study of top age-group bowlers, while a projection angle of 6.2° below horizontal was based on elite pace bowlers' stock deliveries, adjusted to average adult stature. These were combined to calculate flight distance. The centre of the good length region estimated for this age group was used as the post-bounce distance to the batter's stumps. The time taken for a full toss delivery to reach a batter was used to estimate the change in temporal demands for batters. The sensitivity of the calculated pitch length to realistic variability in the inputs was explored, as was the margin of error afforded by the old and new pitch lengths to release speed and angle variability.

Results: The pitch length calculated for under-11s was 14.83 m (16.22 yards). This was sensitive to the typical variability in the projection angle displayed by young players, but insensitive to typical variability in release speed and release height. The shorter pitch reduced the time available to batters by 22.5%, though it was still 500 ms or more. On the shorter pitch there was an 88% greater tolerance to speed variability and 40% greater tolerance to angle variability. Flight distance was less sensitive to release angle when the intended release angle was steeper.

Discussion and Conclusions: The calculated pitch length is 19% shorter than the pre-2019 recommendation, and over 9% shorter than scaling down from 22 yards based on stature alone, emphasising the influence of incorporating performance information in the scaling method. Increased tolerance to the inevitable ball release variability is beneficial to young bowlers and while the shorter pitch reduces the time available for batters, it is a more representative task demand. Ball speed is essentially unchanged and so therefore is that component of the task. Scaling pitches in this way for all age groups should enable more consistent ball release by bowlers and temporal demands for batters as they develop.

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4. Worthington, P.J. Retrieved from https://dspace.lboro.ac.uk/2134/6839
Perceptions of talent development in Women’s Cricket from national-level players and coaches

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Background: Experiential knowledge is a valuable method of understanding high performance cricket for both batting¹ and bowling² expertise. Talent development has been extensively researched highlighting the need for a holistic approach, including the sociodevelopmental aspects of learning alongside skill development and talent³. Further research in Women’s cricket on talent development (including sociodevelopmental factors) is required to inform policy development, organisational processes and the preparation of junior and senior players.

Aims: To identify critical developmental experiences of elite female cricketers and coaches through the talent development pathway and conceptualise a contemporary framework for holistic talent development in Women’s cricket.

Methods: Analysis of semi-structured interviews was conducted on 10 national-level women cricket players. Questions targeted the following topics: initial interactions with cricket to establish exposure to early unstructured play and sampling sport; age of entrance into and navigating the pathway; skill development methods that coaches use at the elite level and throughout the pathway; goals and guidelines of the pathway; the role of adaptability in elite performance and; adaptability and decision-making characterising talent in Women’s Cricket. A threshold of 80% of participants was required to identify any specific theme as significant.

Results: Sociodevelopmental experiences such as early unstructured play, sampling sport and early exposure to adult competition were all present as significant themes, consistent with previous research in other sports and men’s cricket¹. Major drop out factors were identified as lack of dedication or drive, large skill gaps between levels of competition and/or pursuing a career or other life goal. Initial interactions with the pathway all occurred before the age of 15 y, and 90% of national-level players continued through every stage of the pathway uninterrupted. Different aims for the junior and senior levels of the pathway were identified, and skill development methods changed with progression through the pathway. Player adaptability and decision making was recognised as integral to expert performance by all (100%) of the survey participants.

Discussion and Conclusions: Several contradicting factors were identified in the talent development pathway. The benefits of early unstructured play, sampling sport and adult competition is well described¹, but the existing pathway prioritises early specialization by inducting players into the pathway at a very early age (<15 y). Skill development was often practiced in deconstructed and unrepresentative training environments, removing important sources of information from training and limiting the transfer of learning to the game environment. Training practices improve at senior levels of the pathway with better access to resources whereas transitioning back into the pathway is challenging after players are left out of the system. Player adaptability and decision-making were identified as integral to elite performance, but there was little evidence of both elements in the design of training. It is evident that despite the extensive knowledge of talent development in cricket, there appears to be numerous contradictory factors in the current talent development pathway that can be improved. Further investigation into training practices in the pathway is also warranted.

The Identification of ‘Game Changers’ in England Cricket’s Developmental Pathway for Elite Spin Bowling: A Machine Learning Approach

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Background: At present, the developmental trajectories of English spin bowlers are not empirically known, owing to the scarcity of expertise development research in cricket. The development of sporting expertise is dynamic, and therefore requires a holistic approach to fully explore its multifaceted nature¹. Despite this, precursors of expertise have largely been identified through adopting linear analysis methods, such as assessing statistical differences between isolated variables, e.g., deliberate practice hours². Consequently, drawing linear comparisons, to examine the dynamic nature of expertise development, is likely overly simplistic.

Aims: To utilise machine learning techniques to address the question of ‘what makes the difference?’ in the developmental trajectories of England international (elite) cricket spin bowlers, setting them apart from county (sub-elite) spin bowlers.

Methods: The sample comprised 15 international and 13 county past and present spin bowlers. International spin bowlers (M_age = 43; SD = 14.32) had represented the England international team in Test and/or Limited Over formats (M_caps = 37; SD = 43). The county spin bowlers (M_age = 40.62; SD = 7.30) had maintained prolonged careers in professional county cricket (M_caps = 261; SD = 47), but had not represented England at senior international level. An interview schedule was specially developed by the researchers for this study based on methodologies that had been successfully used in previous research³,⁴. The interview comprised four sections: Demographics; Structured Sporting History; Cricket Developmental Milestones; and Unstructured Cricket Activity. A total of 93 variables were collected from the interviews, each lasting approximately 2 hours. Once all interviews had been completed, this quantitative data was subsequently standardised, and analysed using pattern recognition (machine learning) approaches, with the primary aim of determining which developmental variables discriminate between international and county spin bowlers.

Results: Results revealed that 12 variables, from a possible 93, discriminated between the international and county bowlers, with good to very good accuracy (79 – 93%), producing a holistic development profile of these discriminating variables. Evidence for the external validity of this new model was offered by its ability to utilise the data of five unseen spin bowlers to correctly predict their expertise group (i.e., international or county) with 100% accuracy.

Discussion and Conclusions: The study findings highlight the international spin bowlers’ earlier engagement in cricket, greater quantity of domain-specific practice & competition, and superior adaptability to new levels of senior competition. A working group consisting of ECB officials was subsequently formed, to scrutinise the interpretation of findings, producing a series of recommendations for the wider game. We suggest that profiling youth spin bowlers in England and Wales against the predictive model in the short term will enable the identification of areas for development. Future research exploring precursors of cricket expertise across the different disciplines would benefit most from investigating the micro-structure of practice, to obtain a greater understanding of desirable cricket practice environments.

References:
Comparing Elbow extension between over and around the wicket deliveries using 3D Biomechanical analysis in Indian off-spin bowlers

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Background
Cricket is arguably the second most popular sport in the world. Off-spin is the most popular method of spin bowling in cricket in which the ball turns from the off-side to the leg side when bowled at a right-handed batsman. The Off-spin is generated by the first and second fingers of the right hand. The more revolutions on the ball; the better chance of getting more turn when the ball pitches.¹ Research done on the legality of bowling action has focused elbow extension from arm horizontal to ball release.²³⁴ However, there has not been a comparison of the bowling action legality of elbow extension when bowling over the wicket and around the wicket which is a commonly utilised technique in spin bowling.

Aim
The aim of this comparison study is to identify technique related differences in elbow extension when bowling off spine from Over and Around the Wicket using 3D biomechanical analysis.

Method
16 off-spin bowlers (mean age: 24 ± 5 years) underwent biomechanical assessment using the ICC Standardized Protocol for the assessment of Suspected Illegal Bowling Actions (SPASIBA) which utilised a cluster based 26 marker-set. 16 Vicon 3D cameras and two 2D cameras were used to track the markers while they bowled 6 legal deliveries from over and around the wicket. Comparative statistical analysis was done to determine the difference in elbow extension

Results
10 out of the 16 bowlers showed higher elbow extension when bowling around the wicket. 5 bowlers showed higher extension from the over the wicket.¹ 1 bowler had the same elbow extension from both sides of the wicket Average variance in elbow extension was 2 degrees.

Discussion and Conclusions
The results suggest that the Off-Spin bowlers could be more likely to have a higher elbow extension when bowling around the wicket. However, further studies with a larger subject base need to conducted to support the findings.

References
1. BBC Sport - Cricket - How to bowl off-spin (2016, February 02),
2. Aginsky et al., BJSM medicine, 44(6), 420-425.
Relationships between spin bowling technique and spin

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**Background**: Previous research has considered spin to be a major contributor to spin bowling success¹. Relatively few investigations have sought to identify the aspects of technique associated with spin rate. The scarcity of finger spin bowling research has led to coaching and talent identification of spin bowlers to be based on anecdotal evidence², which recommends that the optimal technique is one where the pelvis and shoulders rotate from a side-on position during the delivery stride, to front-on at ball release³.

**Aims**: To identify the key kinematic parameters of an elite finger spin bowler’s technique which can predict spin rate.

**Methods**: 23 elite finger spin bowlers bowled ten maximal spin rate deliveries of a good length in an indoor practice facility. An 18 camera Vicon Motion Analysis system was used to collect three-dimensional kinematic data. Fifty-six 14 mm retro-reflective markers were attached to the subject to calculate joint kinematics. All marker trajectories were filtered using a fourth-order low pass Butterworth filter with a cut-off frequency of 30 Hz. Spin rate was recorded using the Doppler radar system, Trackman. The three trials with maximum spin rate were averaged and 30 kinematic parameters were determined for each trial. The effect of interactions between the spin bowling technique parameters and spin rate were investigated using Pearson product moment correlation analyses and stepwise linear regression.

**Results**: The 23 bowlers produced spin rates in the range 1432 - 2143 rpm (1685 ± 170 rpm) along with ball release speeds 17.7 - 23.4 m/s (20.4 ± 1.3 m/s). Eight of the 30 kinematic parameters were found to be linearly correlated with spin rate: back foot orientation at back foot contact; front foot orientation at front foot contact; pelvis orientation at front foot contact and ball release; minimum pelvis orientation between back foot contact and ball release; shoulder orientation at ball release; minimum shoulder orientation from back foot contact to ball release; pelvis shoulder separation at front foot contact. The highest variation in spin rate was explained using one technique variable: pelvis orientation at ball release, which explained 43.1% of the observed variation in spin rate. However, pelvis orientation at front foot contact could explain a similar level of variation in spin rate explaining 42.9%.

**Discussion and Conclusions**: Coaching literature has previously suggested that the optimal technique for a finger spin bowler is one where the pelvis and shoulders rotate from a side-on position during the delivery stride, to front-on at ball release³. The results of this study suggest that higher spin rates can be achieved by using a finger spin bowling technique where the pelvis orientation is less side-on than previously recommended. This allows a larger pelvis-shoulder separation angle and a shoulder orientation short of side-on at FFC. During the FFC phase, the segments should then rotate sequentially, starting with the pelvis and finishing with the pronation of the forearm. The results of this investigation are likely to be very useful in the coaching of finger spin bowlers, as well as talent identification.

**References**:
Hand Injuries in Elite Australian Cricketers

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Background: Hand injuries make up approximately 11-12% off all injuries in elite cricketers ¹,². Less detail is known about the specific patterns of injury, treatment and outcome.

Aims: Part of a wider review being conducted by Cricket Australia on all Hand Injuries sustained by their elite cricketers, this audit of cases treated in a single unit aims to describe the patterns of hand injuries, their mechanisms and treatments.

Methods: A retrospective review was carried out to identify all elite cricketers referred for treatment at St Luke’s Hand Unit, Sydney. Their medical records were cross referenced with data held by Cricket Australia’s medical team.

Results: Between 2002-2018 45 injuries in 28 players were treated. 23 male, 5 female. 9 players had multiple or recurrent injuries (range 2-7 injuries). The majority of injuries were sustained fielding, followed by batting then bowling and 60% of all injuries affected the digits. Ring and Little finger injuries were most often sustained fielding, as opposed to thumb and index finger which were more likely to be injured batting or keeping wicket. 27 injuries were treated operatively, 18 non-operatively. When grouped into injuries around the Proximal Interphalangeal Joint (PIPJ) or around the Distal Interphalangeal Joint (DIPJ), there was a significantly higher number of PIPJ injuries treated surgically (13/14) than for the DIPJ (4/13).

Discussion and Conclusions: This series adds to our understanding of hand injuries in elite cricketers and should help clinicians to triage and treat such injuries. Some clear patterns of injury have been identified which correlate with data already published ³,⁴.

References:

4. Dhillon MS et al. Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology 4:42
Use of smartwatches to detect bowling speeds and counts for fast bowlers

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**Background:** Up to 50% of fast bowlers in a cricket team can be injured during a season.\textsuperscript{1} There is a direct relationship between injuries in fast bowlers and bowling workloads.\textsuperscript{2} To date, there is no simple solution to automatically detect bowling counts and ball velocities without using sophisticated equipment. Commercially available smart watches have sensors (accelerometers and gyroscopes) which can be used to detect bowling counts and velocities.\textsuperscript{3}

**Aims:** Use commercially available smartwatch to extract accelerometer and gyroscope data for detecting bowling counts and velocities. This study aims to develop a novel algorithm to alert users on developing overuse related bowling injuries on their smart watch.

**Methods** - We used FitBit smartwatch’s inertial motion units (IMUs). Android studio with the integrated development environment (IDE) was used with JAVA to develop a platform for data extraction. The system used Sensor-Event class to create a sensor event object, which provided information about sensor events. A sensor event object included: the raw sensor data, the type of sensor that generated the event, and the timestamp for the event. The data displayed readings from the x, y, and z axis in a graphical format and were plotted against time. All non-360 degree moments were filtered using gyroscope data.

**Results:** The peaks of arm accelerations on the accelerometer data correlated well with the bowling counts. Testing on 5 fast-bowlers each bowling 50 test deliveries showed 96% sensitivity in detecting bowling counts and algorithm for bowling speeds is under development.

**Discussion and Conclusions:** An App that can assist in tracking and understanding workloads by measuring arm movement patterns can assist in better managing fast bowling workloads. Our project will develop a novel algorithm to alert users on developing overuse related bowling injuries on their smart watch. This App can later be synced with any major smart watch brands (i.e. Apple, Samsung) to allow users accessibility to the product. The commercial value of this research also lies in exporting this technology to other throwing sports such as Baseball, Javelin etc.

**References:**
Machine Learning of Batting Movement Data Patterns for Injury Prevention

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Background: The design of Personal Protective Equipment (PPE) for use when batting in cricket is ideally required to provide complete protection to the wearer without inhibiting their performance or causing discomfort. Understandably, the design and development of current, commercially available PPE has been primarily focused on providing adequate protection. Ergonomic factors, whilst important, have been secondary considerations. However, thermal stress, physical discomfort and restrictions on movements have all been shown to affect the wearer’s performance. In seeking a resolution to this challenge, it has been identified that the primary protective function of the PPE is required only for limited periods and an opportunity exists to consider whether it would be possible to develop a system capable of identifying imminent threat such that impact protection could be deployed in a timely fashion whilst offering minimal discomfort or physical impedance at other times. To achieve this, early and accurate prediction of impending ball impact is required.

Aims: To use supervised machine learning to analyse data recorded from a cricket batter to establish an appropriate algorithm capable of reliably identifying ball approach sufficiently in advance of an impact.

Methods: Fifteen body-worn Shimmer3 IMU sensors located at specific anatomical landmarks were used to capture data at 512 Hz from 10 batters during a cricket training session. Each IMU sensor provided nine channels of data; three orthogonal channels of acceleration, angular velocity and magnetic field, respectively. Each batter received three overs of a simulated cricket match including running between the wickets and other typical interruptions as well as facing 18 deliveries.

The threat posed by the ball whilst batting in cricket varies between no-risk, when the ball is not in active play, through to high risk, when the ball is approaching the batter at high speed. Three states of readiness were therefore identified to represent periods when the PPE can exist in i) a dormant state, ii) an alert state in anticipation of iii) an active state.

The annotated IMU data was analysed using a series of conventional machine learning algorithms and their suitability was assessed using five widely used performance measures. Given the specific requirements of the cricket application, a new model filtering criterion, based on identifying the active state with maximum reliability, minimal response time and a minimum probability of failure was developed and assessed.

Results: The newly developed model filtering criterion, based on minimising time of detection, recorded a probability of failing to detect the active state of 1.5x10^{-8}, whilst the models filtered using the standard performance measures; F-Score, Recall, Precision, Informedness and Specificity recorded probabilities of 8.8x10^{-4}, 1.5x10^{-8}, 0.0035, 8.8x10^{-4} and 0.0035 respectively. The failure probability of the newly developed criterion equates to approximately one failure over 120 career spans of a top-class batsman.

Discussion and Conclusions: The results suggest the newly developed model filtering criterion is more suitable for the chosen sports application presented here, suggesting that application specific model assessment methods have potential to outperform conventional methods.

References:
Cricket GR8 App: Inspiring Net Sessions

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Background: Sports stars are role models, as especially younger people attempt to emulate their success and/or behaviour. How much fun did you have in your childhood pretending to be or imitating the actions of a famous player? One just needs to observe the vast number of named sports jerseys walking the streets to understand the appeal of feeling like a sporting hero. With this in mind, the idea emerged to develop an App for training to replicate the performance of a cricket great.

Aims: To discuss a new development in cricket technology – the Cricket GR8 app.

Methods: Every piece of action in cricket starts with the delivery of the bowler. Over a series of deliveries the bowler plans to dismiss batters. ESPNCricinfo.com™ commentary and where possible archived video footage was obtained to understand how successful bowler’s executed their bowling plan in one of their more successful performances. Bowling line and length were plotted and coded on a pitch map with six pitch lengths (Bouncer, Short, Length, ½ Volley, Yorker, Full toss) and four pitch lines (Outside off, Off stump, Middle and Leg, Down Leg). In addition, the type of delivery bowled was recorded which included balls that swung (in/out swing) or seamed as well as slow balls. A multi-platform app was then developed which included spells from 47 bowlers.¹,²

Results: Users can select to emulate a bowler from one of 10 countries, or alternatively select via handedness or bowling type (fast, medium, off/leg spin). Designed for the net situation, a friend/coach/parent holding the device at the end of the bowler’s run-up informs the bowler of what the next delivery entails. After each delivery, the observed line and length is inputted with one click. If the correct delivery type was bowled and whether any runs or wickets resulted (subjectively assessed when bowling to a batter) is also easily inputted. To cater for different skill levels, provision was made for progression by selecting bowler by level. Club level bowlers have larger target zones in comparison to the first-class or international level. Feedback screens allow reviewing a session ball-by-ball, with statistics on the execution (%), runs conceded, and wickets taken in the bowling spell.

Discussion and Conclusions: It is the bowler that dictates to a large extent a batter’s shot selection and probable hitting zone³. With these thoughts in mind, one could argue that what distinguishes great players from lesser players is their ability to consistently pitch the ball where they want. This app allows you to test your ability against 47 bowlers to replicate a 2 to 4-over spell. App users feel a sense of accomplishment as their ability to replicate a spell from a bowler improves. Logically this should be accompanied by an improved skill execution. In summary, the Cricket GR8 app develops mastery of both skill and tactical awareness and encourages healthy competition as players attempt to better their own performance against the template player chosen. With a goal oriented mindset players enjoy trying to bowl like a cricket great.

References:
Auto detecting deliveries in elite cricket fast bowlers using microsensors and machine learning

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Background: Cricket fast bowlers are at a high risk of injury occurrence, and this has previously been shown to be correlated to bowling workloads. McNamara et al.¹ have previously looked to use technology such as global positioning system units (GPS) to automatically detect fast bowling deliveries and aid the monitoring of bowling workloads. However simple linear model algorithms, similar to that used by McNamara et al.¹ have limitations when detecting complex human movements such as fast bowling. A variety of studies have looked at using a selection of machine learning algorithms to effectively predict and classify sporting events by using previous data, and to analyse and model sporting performance.

Aims: To develop and test a machine learning algorithm that can automatically, reliably and accurately detect bowling deliveries.

Methods: Inertial sensor data from a Catapult OptimEye S5 device was collected from twenty nine fast bowlers, of national and international level, in both training and matches, indoors and outdoors, at various intensities. A lowest common denominator was used to transform this data from a time series into a classification problem. Random forest was then used to predict whether the events identified in the lowest common denominator process were real deliveries or not. Outputs were compared with over 20,000 manually recorded events. Validity of the algorithm was tested in three conditions; matches, training and both. Sensitivity and specificity were calculated by determining the proportion of true or false versus positive or negative events. Matthews Correlation Coefficient (MCC) was used to analyse the relationship between actual events and events detected.

Results: A high MCC ($r=0.957$) showed very good agreement between the automatically detected bowling deliveries and manually recorded ones. The algorithm was found to be both sensitive and specific in training (97.5%, 98.4%) and matches (99.8%, 97.6%), respectively. Rare falsely classified events were typically warm up deliveries or throws preceded by a run.

Discussion and Conclusions: Inertial sensors data processed by a machine learning based algorithm provide a valid tool to automatically detect bowling events, both in training and matches, indoors and outdoors. This creates the potential for more complete and accurate workload monitoring. The GPS and inertial sensors data also provides the opportunity to provide metrics on performance such as run up speed, deceleration and trunk rotation. This offers the possibility to better monitor bowling workloads across a range of intensities to mitigate injury risk potential, whilst also providing feedback on performance and in match technique to coaches.

References:
1. McNamara, D.J., Gabbett, T.J., Chapman, Naughton, G., & Farhart, P. JSPP, 10, 71-75.
POSTERS

(in order that they are numbered)
The kinetics and kinematics of the rotary backlift

Neil Isaacs

Private General Practice, Ballito, South Africa

Background: Video analysis has revolutionized coaching with slow motion replays now becoming available to anyone with cell phone capability of 200 frames per second. The era of pre and post video analysis has closely coincided with increased interest in the rotary batting technique with highlighted findings of a more lateral backlift. (Shillinglaw AL, Hale B.¹)

Aims: A review of the backlift by slow motion video analysis of Don Bradman and modern top international ranked players to obtain aspects of the rotary batting technique with regard to functional anatomy related to rotations around the long axis of the limbs, trunk and bat with comparison to traditional coaching.

Methods: This is a descriptive observational study. Slow-motion videos of footage of Don Bradman and replays of top international batsman were reviewed by taping the slow-motion videos of the backlift in turn with the slow-motion function of an Apple iPhone7.

Results: Backlift loop divided into stages:
Stage 1:
The backlift of Don Bradman involved flexion of the elbows from pointing the face of the bat to midwicket in the stance, to lifting the bat horizontally pointing to gully by extending the shoulders and flexing the elbows till the bat was in the same horizontal plane of the elbows.
Stage 2:
The front shoulder internally rotates, using the back hand as a fulcrum, the bat lifts into a vertical position as the back wrist cocks (radial deviation), the back shoulder extends with the back forearm still directed towards cover. The backlift may end in Stage 2 or continue to any point at the end of stage 3.
Stage 3:
Abduction of the back shoulder elevates the hands and forearm to the level of the back shoulder with the bat still vertical, maintaining the forearm and bat face directed to point, the back forearm supinates, keeping the bat vertical.
From the stance to the top of the backlift, the edges of the bat were directed in the plane of the pitch. External rotation of the front hip may initiate rotation and closing of the hips and shoulders.

Discussion and Conclusions: During stage 1, the centre of mass (COM) shifts towards gully. Preparation for the stride starts during Stage 1. Moment of inertia (MOI) of the arms and bat is reduced by extension of the back shoulder and flexion of the elbow. At the end of all stages, the hands are further to the off side compared to traditional coaching, allowing flexibility. Forward strides keep the bat close to the COM, optionally moving the hands forwards upwards and backwards in a semicircle, aiding propulsion in the direction of the stride. Similarly, backward strides rotate the hands backwards and upwards. Sideways movement to the off side is aided by flexing the back shoulder and flexion or extension enables flexibility of the vertical pendulum line of the downswing. Traditional coaching (Woolmer B, Noakes T.²) and studies (Stuelcken MC, et al.³) and (Stretch R, et al.⁴) reveal an increased MOI, the elbow above the back hand and the back shoulder internally rotated to form a figure 6 with the arms at the end of the backlift.

References:
1. Shillinglaw AL, Hale B. Parrs Wood;
2. Woolmer B, Noakes T. Struik Pub;
The kinetics and kinematics of the rotary downswing in batting

Neil Isaacs

Private General Practice, Ballito, South Africa

Background: Research on cricket batting is limited with mainly descriptive studies. Findings of a more lateral backlift in the best players of the last century against traditional coaching of a straighter backlift towards the stumps (Noorbhai MH, Noakes TD.)¹ raises the question as to the reason why.

Aims: A review of the downswing by slow motion video analysis of Don Bradman and modern top international ranked players to obtain aspects of the rotary batting technique around the long axis of the limbs and trunk and related functional anatomy to improve the velocity of the bat (performance) compared to traditional coaching.

Methods: This is a descriptive observational study. Slow motion videos of footage of Don Bradman and replays of top international batsman were reviewed by taping the slow-motion videos of the downswing in turn with the slow-motion function of an Apple iPhone7.

Results: Downswing stages:
Stage 1: The back hip horizontally abducts while flexed up to 90 degrees, after the pelvis closed and the back hip adducted with a varus or neutral back knee in the rotary backlift, opening the pelvis. Shoulders close, back shoulder externally rotates and adducts the elbow to the waist. Back forearm supinates and wrist extends obtaining the bat in the direction of the pendulum swing until the bat is horizontal.
Stage 2: Back hip externally rotates while the shoulders open towards direction of shot, after X-factor stretch, passively externally rotating the back shoulder. The back elbow remains close to the waist, forearm supinated and wrist extended.
Double pendulum formed by front arm and bat is released as late as possible.
Bat face is directed to point in stage 1 and 2 in vertical pendulum shots.
Stage 3: Active internal rotation of back upper arm occurs immediately before impact, after horizontal adduction accelerates the back upper arm, still externally rotated, into the scapula plane. Pronation of the back forearm, flexion and ulnar deviation of wrist occurs through impact. Front foot and back foot are in the direction of the shot in front and back foot vertical pendulum shots respectively.

Discussion and Conclusions: Stretch reflexes of the back hip, trunk and back shoulder add power to the shot. At impact the hips and shoulders are open compared to shoulders rotating vertically in traditional coaching (BCCI, National Cricket Academy²). Back upper arm moves from external rotation to internal rotation compared to being internally rotated from top of backswing to impact in traditional coaching (Woolmer B, Noakes T.³). “O” grip (Woolmer B, Noakes T.³) noted increases moment of inertia around back upper arm and with opening of the shoulders, concern (Woolmer B, Noakes T.³) of deviation off the line of the downswing to the off side in vertical pendulum shots and above the horizontal pendulum in cross bat shots is allayed. Lateral flexion occurs at the lumbar spine to increase the thoracohumeral angle closer to 90 degrees increasing the bat velocity. Impact is away from the front foot in front foot drives (Stuelcken MC, Portus MR, Mason BR.⁴) and back foot in backfoot drives.

References:
3. Woolmer B, Noakes T. Struik Pub;
Increasing the momentum of the cricket bat with a rotary batting technique

Neil Isaacs

Private General Practice, Ballito, South Africa

**Background:** Cricket batting compared to other sports has little research. Traditional coaching has limited evidence that has been questioned only recently regarding the backlift.

**Aims:** Explore the success of Don Bradman and top international cricket batters regarding kinetics and kinematics by video analysis and literature review.

**Methods:**

**Literature search**

Comparative and functional anatomy analysis regarding rotations around the long axes of body segments and bat exploring injuries and performance.

Evaluation of the technique of various sporting disciplines and models of kinematics and kinetics including baseball, tennis, squash, hockey, golf, discus and hammer throw and applications to cricket batting.

**Video analysis**

Slow motion videos of footage of Don Bradman and replays of top international batsman were reviewed by taping the slow-motion videos in turn with the slow-motion function of an iphone7 for aspects to increase bat velocity.

**Results:** Angular momentum is transferred from large joints to smaller joints using a double pendulum (front arm) (Cross R1) and rotations around the long axis of different body segments (back arm). (Marshall RN, Elliot BC2)

**Discussion and Conclusions:** Rotation of the pelvis in the transverse plane is initiated largely by abduction and external rotation at the hip by Gluteus maximus utilizing a pulley mechanism around the greater trochanter to increase the moment arms. This is enhanced by a “position of increased performance” with the back hip internally rotated, flexed and initially adducted and a valgus knee flexed and externally rotated with the inverted foot pointed at right angles to the direction of the shot which increases the moment arms of Gluteus maximus and provides a stretch and active release of the muscle. The position angles the force exerted on the ground further away from the centre of mass with a more horizontal force vector enabling generation of more angular momentum. The momentum is saved and enhanced in the x-factor stretch of the trunk (Hume PA et al.3) with active release rotating the shoulders horizontally and vertically. This is in turn transferred to the back upper arm by stretching and releasing the internal rotators of the back shoulder providing the last link in the rotary kinetic chain (Marshall RN, Elliot BC2). It is enhanced by the thoracolumbar fascia connecting the front leg Gluteus maximus to the inner upper back arm via Latissimus dorsi. The carrying angle of the elbow and holding angle of the hand increase the moment of inertia around the back upper arm, along with the relatively greater mass of the distal radius and thumb allowing transfer of momentum through the hand to the bat via an “O” grip (Woolmer B, Noakes T4). A bat that has more mass on its outside half in and around the sweet spot, will in turn increase the moment of inertia around the long axis of the back upper arm increasing its momentum at impact if performed with a rotary batting technique. Traditional coaching (Woolmer B, Noakes T4) with the back arm internally rotated throughout the swing forming a figure 6 at the end of a backlift and a figure 9 at impact with the front arm will impair this effect.

**References:**

4. Woolmer B, Noakes T. Struik Pub;
Comparative and Functional anatomy of Gluteus Maximus (GM) regarding a change of
direction related to performance and injuries

Neil Isaacs

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Background: A cricket shot in effect is a change of direction (cod) from an open stance in the stride with
initial rotation at the hips followed by the shoulders and upper back arm. The moment arms of GM are
altered by different degrees of flexion and the structures around the hip need to be taken into account. A cod
in the first half of a running stride or landing with the position of internal rotation, adduction and flexion of the
hip, with knee flexion allowing external rotation and abduction (increased valgus) at the knee has been
suggested as a position of risk (Ireland ML.1). Programs to prevent injuries, in particular rupture of the anterior
cruciate ligament, have met mixed results with interest in proximal muscles playing a role in stabilizing joints.
Training in the sagittal plane has not improved change of direction performance.

Aims: Analysis of the role of GM in a cod by rotating the pelvis regarding performance and injuries.

Methods: This is an observational descriptive study. Literature review of the hip joint with reference to the
role of Gluteus maximus and video analysis of international cricket players.

Results: The majority of moment arms of the muscles across the hip increase their tendency towards
internal rotation as flexion of the hip progresses from zero to ninety degrees (Delp SL, et al.2). As expected,
internal rotation torque increases considerably as the hip flexes, but external rotation torque also increases
unexpectedly up to five percent (Johnson S, Hoffman M.3).
GM moment arms are changed in all three planes by the greater trochanter in humans by providing a pulley
effect with flexion of the hip as the greater trochanter slides medially to GM which pushes it laterally. The
Iliotibial tract (ITT) is the prime restraint against internal rotation of the tibia from 30-90 degrees of knee
flexion.

Discussion and Conclusions: GM provides a horizontal abduction force at the hip at 90 degrees of flexion
in the deceleration phase of the first half of the stance in a running stride that aids rotation of the pelvis
braced with a varus knee. The position of risk in a change of direction with a lateral placement from the stride
line increases the torque for abduction and external rotation at the hip due to the change in the moment arms
of GM for propulsion at the beginning of the second half of the stance in the running stride. The position
angles the force exerted on the ground further away from the centre of mass with a more horizontal force
vector from the lower leg enabling generation of more angular momentum while all limbs are closer to the
vertical axis through the centre of mass. The ITT provides functional stability against internal rotation of the
tibia. Opening of the front foot and back foot in the direction of the shot in front and back foot vertical
pendulum shots respectively, allows effective rotation of the pelvis (Wang LH, et al.4). Balance is maintained
with less stress on the joints in the follow through.

References:
IS BOWLING WORKLOAD A RISK FACTOR FOR INJURY IN ENGLISH CRICKET FIRST-CLASS FAST BOWLERS?

Harpal Soni Bansal¹, Steve McCaig², Ben Langley² and Aleksandra Birn-Jeffery¹

¹Queen Mary University of London; UK,
²Science and medicine department, England & Wales Cricket Board, UK

Background: Fast bowlers in cricket have a higher injury prevalence compared to other positions¹ as they require greater physical demand secondary to increasing number of matches per year resulting in higher bowling workloads². Relationships between fast bowling workloads and injury have been reported previously as Hulin et al.’s¹ study shows that sudden sharp increases in acute workload is associated with increased injury risk.

Aims: To examine the relationship between acute, chronic and the notion of acute:chronic bowling workload ratio and injury risk in English first class fast bowlers.

Methods: 45 fast bowlers who played in 194 matches over one English cricket county season were followed in a prospective cohort study to compare the relationship between overs bowled in each match (subdivided into acute (1-week) and chronic (4-weeks)) and injury risk. The likelihood of sustaining an injury was analysed using logistic regression analysis with a significance of <0.05. The dependent variable was injury which had three variations of interest which were injured that week, injured 1-2 weeks post and injured 2-4 weeks post. The predictor variables were acute workloads, chronic workloads and training stress balance ranges.

Results: There was a relationship between chronic workload and injury risk in current week (p=0.047), 1-2 weeks post (p=0.014) and 2-4 weeks post (p=0.011). A negative training-stress balance was associated with an increased risk of injury (p=0.044) in 2-4 weeks post. No relationship was found between acute workload and injury risk.

Discussion and Conclusions: Chronic workload patterns and a negative training-stress balance were associated with increased risk of injury in the 2-4 weeks post a subsequent high workload match. Therefore, workload monitoring and analysis is vital for injury prevention in fast bowlers and should precede the development of individualised training programs. This will lead to better preparation of fast bowlers, improve their on-field performance and enhance their fitness allowing them to enjoy long and illustrious cricketing careers.

References:
Quantifying movement demands of elite cricket players participating in the 2017/2018 T20 Big Bash League

Robert Sholto-Douglas, Ryan Cook, Matthew Wilkie and Candice Christie
Rhodes University, Grahamstown, South Africa

**Background:** Twenty20 (T20) cricket is the shortest and fastest version of the game of cricket. As a result, it is popular and carries financial weight. It is therefore important that franchise owners, management teams and coaches apply successful game tactics and select (and then retain) players which are more capable of executing the appropriate game strategy. Strategies and tactics, of when, and how players position changes due to the stage of the game, have not been looked at in scientific literature. The Big Bash League (BBL) was established in 2011 by Cricket Australia. The final of the 2017/2018 season attracted a crowd of 43,330 people and crowd of 1.52 million people on TV in Australia. Currently there hasn’t been a publicly available report on season prize money since the 2015/16 season which had an overall prize pool of $890,000.

**Aims:** The purpose of this study was to investigate the movement demands placed on elite T20 cricket players playing in the Big Bash League in Australia in the 2017/2018 season.

**Methods:** Player positional movements were determined from the time motion data obtained from a 10 Hz global positioning (GPS) unit during all of the teams BBL games in the 2017/2018 season. Various movements were quantified, including: total distance (km), distance travelled walking (movement speed 0-3.1 m.s\(^{-1}\)), jogging (3.1-3.9 m.s\(^{-1}\)), running (3.9-5.8 m.s\(^{-1}\)), striding (5.8-7.2 m.s\(^{-1}\)) and sprinting (7.2+ m.s\(^{-1}\)). It also recorded number of sprints, the maximum speed (m.s\(^{-1}\)), the total duration (s), the number of times striding and the number of times sprinting. Objective measures obtained from the GPS were then linked to players’ positional movements during a game.

**Results:** On average, fielders covered the largest distance during the competition (5.70km), followed by batsmen (1.75km) and lastly, fast bowlers (0.66m). In all player disciplines, the highest percentage of their total distance was covered walking (fielding = 74.44%; batting = 71.92%; fast bowling = 68.19%) and the least was spent sprinting (fielding = 0.62%; batting = 0.08%; fast bowling = 0.07%). Jogging accounted for 5.33%, 7.72% and 10.87%, and running accounted for 10.07%,17.67% and 13.83%, of the total distance covered for fielding, batting and fast bowling respectively. Fast bowlers strode more of their total distance (12.59%) compared to fielders (4%) and batsmen (2.61%).

**Discussion and Conclusions:** This is the first study that has quantified movement demands of players playing in the Big Bash League in Australia. The study found that fielders have higher loads than originally thought and therefore more attention needs to be devoted to fielding, an often-neglected part of the game, particularly in terms of high intensity efforts or interval training. However, it must be acknowledged that the data only reflects one team of the BBL in only one season. Irrespective, it does provide a solid base for future research. From these findings it is evident that as the game is evolving, the need for better conditioned cricketers is highlighted and both coaches and players need to adapt to physical, and other preparation before the format does.

**References:**
The impact of a fast bowling spell on physiological, perceptual and performance responses in non-elite cricketers

Lee Pote, Kayla McEwan, Shannon Proctor and Candice Christie

Rhodes University, Grahamstown, South Africa

Background: The demands placed on fast bowlers may elicit unique responses that contribute towards increased injury risk and comprised performance capabilities 1. Despite this, very few investigations have attempted to quantify these demands and their impact on performance.

Aims: This investigation attempted to quantify the effects of a fast bowling protocol on the musculoskeletal, physiological and perceptual responses of fast bowlers; as well as ball speed and accuracy.

Methods: Eight young adult bowlers (20 ± 1.85 years) participated in a ten over bowling protocol that had been separated by intermittent fielding drills into three bowling spells (4-,3- and3- overs). Selected responses were collected throughout.

Results: Functional strength measured experienced no change. Heart rate responses increased significantly (p<0.05) in response to the start of the bowling protocol. ‘Local’ ratings of perceived exertion increased significantly (p<0.05) as a function of exercise duration while low to moderate intensities of perceived discomfort were noted in the anterior and posterior shoulder areas, upper portion of the lower limb musculature, as well as the middle and lower back regions. Performance responses experienced no significant change.

Discussion and Conclusions: This study found that performance was consistent across a 10-over bowling spell and that lower limb muscle power remained unchanged. Heart rates reached a steady-state after the first over. In contrast, local ratings of perceived effort and body discomfort increased over time. This could mean that those unchanged measures do not accurately reflect fatigue or, that perceptions are a better indicator of imminent fatigue and potential injury risk as it is well known that fast bowlers are the player most at risk of injury.

References:
Workloads placed on adolescent cricket players: a pilot study

Lee Pote and Candice Christie

Rhodes University, Grahamstown, South Africa

Background: Cricket players nowadays are faced with increased physical demands and as a result it is important to manage their workload, particularly to control and predict risk of injury\(^1\)\(^-\)\(^2\). While this has been investigated at an elite level, few studies have looked at the workloads placed on adolescent cricket players.

Aims: The purpose of this study was therefore to determine the workloads placed on school boy cricketers, specifically within a South African context.

Methods: Twelve male school boy cricketers between the ages of 16 and 19 years participated in the study. Match and practice data was collected over a period of 74 days and included number of shuttles run (batsmen), number of deliveries bowled (bowlers) as well as central ratings of perceived exertion (RPE). Injury data was also collected. These data were then used to determine the acute:chronic (a:c) workload ratio (two week rolling average) as well as session RPE (sRPE).

Results: Fast bowlers delivered more balls during matches compared to practices, whereas batsmen ran more shuttles at practices compared to matches. Session RPE was higher for matches compared to practices. There did not appear to be a relationship between workload and injury risk, however this may have been due to the small sample size.

Discussion and Conclusions: This is the first investigation to examine the workloads placed on adolescent school boy cricket players in South Africa. While the study did not find a correlation between workload and injury risk, future research with a larger sample size would be needed to investigate this relationship further. It is also important to monitor players individually, particularly fast bowlers who differ in terms of injuries and spikes in acute workload. Findings suggest that fast bowlers need to bowl more deliveries during practice sessions to better prepare them for the demands of cricket match play. This should however carefully be monitored for each player. The training performed by batsmen must replicate in-match situations. It would seem as if the intensity of practices also needs to be increased however the accuracy of this measure should be questioned at an adolescent level due to the above mentioned factors. Lastly, it is likely that the study design is was effective and that different aspects of monitoring were found to be feasible, hence the methods of this investigation may be appropriate for a bigger population study.

References:
A coach’s perspective of cricket practice design: a case report

Will Vickery¹, Candice Christie², & Janine Gray³

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Background: Practice is regarded as the variable that has the greatest influence on the development of skill amongst all learners.¹ A significant amount of research is dedicated towards the different types of practice design available to and used by sport coaches. Traditionally, the environment in which cricket players train appears to be quite similar regardless of the age, ability level, gender or country it is taking place in. However, despite cricket being one of the oldest organised sports in the world, the specific nature of the training methods used by cricket coaches and why they are performed in a particular manner is poorly understood.

Aims: The purpose of this study was to not only gain a clearer understanding of how cricket coaches plan, develop and implement training sessions but also to examine why coaches use these plans and how this links to the development and performance of their players.

Methods: One high-performance cricket coach took part in a semi-structured interview lasting 127 min. Upon completion of the interview, this was transcribed verbatim and thematic analysis² was conducted using an inductive and semantic approach to allow the data to drive the analysis process.

Results: The higher order (and lower order) themes identified were: effective practice design/coaching (accountability, progress of the athlete, creating success, use of technology), practice structure (characteristics of practice, type of activity, match-specific activity, leadership), practice objectives (match-specific, behavior, planning, enjoyment), coach/staff involvement (specific roles, accountability, planning) and, factors impacting practice (accessibility, culture, training/playing conditions, time of season).

Discussion and Conclusions: The findings suggest that from a coach’s perspective, designing and implementing practice is a complex process with numerous factors to consider, in order to achieve a variety of objectives. To create an environment which allows for the successful development of a player this coach focuses on multiple facets of a cricket player’s performance (technical, tactical and, physical), mainly through the use of more training form (net-based) activities, although much of this appears to include match specific scenarios (or consequence training). Additionally, this coach looks to improve the behavioural qualities of his playing group (character, commitment, team cohesion) in order to create a more holistic player for both the present time and in the future. The findings of this case report are the first which examine the knowledge and experience of cricket coaches with regards to the manner in which they design their practice sessions. Future research should look to consider the numerous facets of practice design provide for the most effective opportunity to transfer the skills developed during practice into cricket match performance.

References:
A systematised review of the literature on the biomechanics of fast bowling in cricket: a technique focus

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Background: The ‘fast bowler’ is seen as having a key role to the success of a cricket team and tends to bring great interest to the spectating public. Whilst fast bowlers are often seen as match winners in cricket and bring excitement to the spectator, they are also the most likely set of players to be injured, with injuries to the lower back the most prevalent. With prevalence rates being reported between 6% and as high as 67%, and with cricket being such a globally popular game, this really is an area of concern.

Both Bartlett et al. and Glazier & Wheat have reviewed the biomechanical literature, but both conclude that there has been a lack of ‘technique focus’ in these reviews, and no one has attempted to examine an ‘ideal’ fast bowling technique.

Aims: To conduct a systematic review to explore if there is an ‘ideal’ bowling technique described in the literature, and if not, what consensus is there on technique in relation to its ability to produce results (speed) and reduce the risk of injury.

Methods: A literature review was carried out using SPORTDiscus, Scopus, MEDLINE, CINAHL Complete; Web of science, Cochrane Library and PubMed databases. The search terms “fast bowling”, AND “biomechanics” OR “kinematics” OR “technique” OR “model” OR “bowling action” were used. All articles had to be deemed peer-reviewed and had to have been published between 1st January 2005 and 1st December 2017. Articles were manually checked according to the analysis theme, with duplications, unavailable papers and previous literature reviews removed. The remaining articles were reviewed manually to find those articles that in some way provided recommendations or guidance for a fast bowling technique in respect to three categories: (a) Enhanced performance; (b) Injury reduction, and (c) Other.

Results: Twenty-four papers were found that met the criteria for the systematised review. In terms of the categorisation, 11 of 24 articles (46%) were focused on performance, 10 of 24 articles (42%) focussed on injury prevention, leaving 3 of 24 (12%) articles focussing on ‘other’ impact factors. The subjects in the majority of studies were male (22 of 24 studies (92%)) and there was a bias towards using adult elite (state/county level and above) cricketers (18 of 24 studies (75%)). No one paper proposed or measured an ‘ideal’ bowling technique.

Discussion and Conclusions: The review concluded that the bowling technique is composed of 8 phases not 6 as reported by Bartlett et al. The phases are: 1. Run-up; 2. Pre-delivery/gather; 3. Back foot contact (BFC); 4. Front foot contact (FFC); 5. Front foot flat (FFF); 6. Acceleration phase;7. Ball release (BR); 8. Follow-through. Recommendations for each phase are given.

References:
3. Johnstone, J.A. et al. JS&CR, 28(5); 1465-1473
Workload does not impact performance responses in the Indian Premier League cricket

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Background: Elite cricket is an international sport dominated by three main formats, namely test, one day and most recently, T20 matches; each with its own workload requirements (Hulin et al. 2014, Petersen et al. 2010, Petersen et al. 2011, McNamara et al. 2017). The performance aspect of the game is of particular importance in bowlers, who are essential to a team’s success as they restrict the opposition’s runs and attempt to bowl them out (Stuelcken, 2007). As a result, better bowling performance results in improved overall team performance and an increased chance of winning (Saikia, Bhattacharjee, & Lemmer, 2012). Research has shown that bowling requires players to perform multiple quick actions simultaneously, which can increase the physical demands placed on the body (Stuelcken, 2007). Thus, an increase in workload may have an effect on a player’s bowling performance; which is of a particular concern with an increase in the amount of competitions that are currently being played globally. The Indian Premier League started in 2008 and has been ongoing since then, with the prize money for the winning team in 2018 being four million dollars.

Aims: The aim of this investigation was to determine the relationship between bowling performance and player workload in elite Indian Premier League bowlers.

Methods: The sample consisted of eleven male, professional cricket bowlers (mean ±SD, 27 ± 5.61 years; stature: 1.77 ± 0.07 m; mass: 72.09 ± 10.89 kg) currently playing for a team in the Indian Premier League cricket competition. Both bowling disciplines (seam and spin) as well as all-rounders were considered for the investigation. Workload data was obtained using Microzone data capturing software and was reduced into total weekly workload and total cumulative workload. The match data was gathered from ESPN CricInfo for the 2018 season. Match data included; overs bowled, runs conceded, wickets taken, bowling economy, dot balls bowled, 4’s conceded, 6’s conceded and wides bowled. The performance data and match data were used to establish relationships between workloads and performance related data.

Results: No significant relationships were found between total weekly workload and performance. Conversely, cumulative workload did have an impact on some performance measures. Specifically, the total cumulative workload of weeks 1 to 4 had a strong negative association (r = 0.89) with total overs bowled in the fourth match week (p=0.041). In addition, total cumulative workload of weeks 1 to 7 had a strong positive (r = 0.83) relationship with the total number of 6’s conceded in match week 7. No other relationships were observed.

Discussion and conclusion: The most important finding of the investigation was that workload does not predict performance in this Indian Premier League cohort of bowlers. However, associations were observed between total cumulative workload and specific measures. This may be due to the fact that the nature of the game of cricket is exceptionally unpredictable and it is challenging to measure performance related responses.

References:
Time motion analyses comparing the 2012, 2016 and 2018 ICC Women’s World T20 Tournaments

Catherine Munro and Candice Christie

Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa

Background:
Women’s cricket has been played for over 100 years. It is only in the past few decades, however, that the women’s game has expanded and been embraced by a variety of nations all around the world. In terms of competition at an international level, women’s cricket is still a relatively recent game, which can be seen by the fact that the first women’s world T20 tournament was played in 2009 and there have since been six tournaments played. It is, therefore, not surprising that the number of studies focusing solely on women’s cricket is limited.

Time-motion analysis has been utilised for over 30 years. In terms of cricket research, time-motion analysis is the first stage in developing cricket-specific training protocols. In recent years, there have been several motion-analysis studies on male cricket games in the T20 and ODI formats, however according to the authors knowledge there have been no studies on the women’s games.

Aims:
The aim of the study was to compare and analyse the different motion demands of the 2012, 2016- and 2018-women’s world T20 tournaments.

Methods:
Time-motion analyses were conducted on international cricket matches played at the 2012, 2016 and 2018 world T20 cup. The following countries were included in the time-motion analyses: South Africa, Australia, England, New Zealand, Sri Lanka, Ireland and the West Indies as these were the countries playing in the available televised matches. Two innings from the 2012, four innings from the 2016 and eight innings from the 2018 cup were used for the time-motion analyses due to the limited availability of televised matches, this lack of available televised matches restricted the sample size. The game analyses were divided into the bowling and batting innings. Descriptive measures of the motion analyses included means and standard deviations. All motion categories were recorded in time, utilising a stopwatch, as minutes and seconds. A one-way ANOVA was used to compare differences between various measures in the time-motion analyses of the different tournaments.

Results:
Analyses is currently being conducted on the data and will be presented at the conference.

Discussion and Conclusion:
Pending results and will be presented at the conference
Head, neck and facial injuries in cricket: A straight-drive through knowledge gaps

Dulan Kodikara, Dara Twomey and Mandy Plumb

Federation University Australia, Ballarat, Australia

Background: Cricket is generally considered as a minimum contact sport, particularly in comparison with contact sports such as rugby, Australian football and ice hockey. However, there have been several traumatic and fatal head related injuries in cricket in the recent past and the tragic death of Australian cricketer Phillip Hughes in 2014 challenged the perception of whether cricket is a safe sport. It is believed that the increased exposure due to increased number of tournaments, increased intensity of the game with the introduction of twenty-twenty cricket tournaments, high bowling speeds, improved bat design and bat speeds contribute to head, neck, facial injuries in cricket.

Aims: To review head, neck and facial injury studies in cricket and identify gaps for future research.

Study design: Scoping literature review

Methods: PubMed, MEDLINE, CINAHL, EMBASE and Sport Discuss were searched from inception up to 10 December 2018 using key sport and injury terms related to cricket. English-language, peer-reviewed, original research articles reporting cricket injuries in any population were included. Studies were categorised according to their geographic origin, sex (male, female), level of play (elite, community or junior), injury definition used, anatomical region injured and sample size. The level of evidence was evaluated using the National Health and Medical Research Council (NHMRC) evidence hierarchy and Translating Research into Injury Prevention Practice (TRIPP) framework.

Results: The initial search identified 397 potential articles from which 93 cricket injury studies met all inclusion criteria. Duplicates and studies with “cricket” insects were excluded. Nine studies out of those 93 studies reported head related injuries with four of those reporting head and facial injuries in combination. From those nine selected studies, seven studies (78%) identified “struck by ball” as the cause of injury often leading to serious, career-ending injuries. Five studies (56%) included elite level cricketers as their target sample population. However, as per NHMRC guidelines, seven studies (78%) out of these nine are either case series or retrospective studies. Of the two prospective studies, only one reported on a large sample population of 411 school, male cricketers.

Discussion and Conclusions: It is evident from these results that there is a lack of prospective head, neck and facial injury studies particularly in community level cricket where large numbers take part in the game. This review highlights the need of high quality injury surveillance with a special focus on head, neck and facial injuries at all different levels of play, since these injuries can often be serious or sometimes be fatal or career ending. A thorough understanding of the prevalence and incidence of these injuries will be vital to inform stakeholders of the need to implement risk minimization strategies to make cricket a safe sport for all. As headgear use has been highlighted post 2014 as an injury prevention strategy, it would also be valuable to record headgear use and understand the perception of headgear use among participants in future studies.

References:
A four-week resistance training programme increases cricket bowling velocity

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Background: Previous research that investigated the effects of resistance training on pitching (baseball), throwing (baseball and handball) and cricket bowling velocity used protocols that were fairly long in duration (six weeks and longer), required expensive equipment and generally only focused on one type of resistance training. Small significant training effects for these studies were only visible after six weeks. There was a need to develop and test a time- and cost-effective resistance training programme that amateur (club-level) players could utilise to improve their bowling velocity.

Aim: To investigate the effects of a four-week resistance training programme on bowling velocity in amateur club cricket fast bowlers.

Methods: Twenty male participants were recruited and randomly assigned to an experimental (n = 11) and control (n = 9) group. The experimental group was required to perform the training programme for four weeks. This programme consisted of a combination of general, special, and specific resistance training. This included two sets of 6-12 reps of bodyweight squats, split squats, hip raises, chest passes (general resistance), as well as two sets of 6-8 reps of recoiled overhead slams, standing side toss, recoiled rotational throws, hop back and throws, and step behind and throws (special resistance). All special resistance exercises were done with a 3kg medicine ball. Additionally, specific resistance training was incorporated, where participants were required to perform 24-30 deliveries each session with an over-weighted (10-15%), under-weighted (10-15%), and regular cricket ball. All training was performed during their teams’ regular sports specific training sessions, twice a week. The control group did not participate in any strength training during this period and only performed their regular sports specific training. All participants’ performance was measured through a testing protocol which took place at baseline, after two weeks and after four weeks. Significant changes (P < 0.05) in the testing variables (bowling velocity, bowling accuracy, upper body power and lower body power) were determined using a General Linear Model.

Results: The experimental group revealed significant increases in bowling velocity between the baseline test and two weeks of training (4.1km/h, p= 0.003) and between the baseline test and four weeks of training (5.1km/h, p< 0.001). This equates to a final 6% increase across the four weeks. There was no significant change in bowling accuracy, upper body power and lower body power across the four weeks.

Discussion and Conclusions: The use of a four-week resistance training programme, consisting of a combination of core and lower body exercises as well as cricket-specific plyometric exercises and weighted implement training, significantly increased bowling velocity by 6%. This increase in bowling velocity after the four weeks is one of the largest improvements found for any sporting code within such a short time period. The positive results can be attributed to the combination of resistance training utilised.

References:
Effect of Select Kinematic & Kinetic Variables on the Ball Speed in Cricket Fast Bowling - A 3D Biomechanical Investigation

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Background: Cricket researchers have postulated some biomechanical variables as predictors of higher ball speed in fast bowlers, but with varying results\textsuperscript{1,2,3}. Some of these variables also have implication for overuse injuries. During the landing phase of bowling, large vertical ground reaction forces when not dissipated, pose a definitive risk for lower limb and lumbar spine injuries\textsuperscript{2}. There still exists controversy in literature on the association between these key Kinematic and Kinetic factors with ball speed.

Aim: To evaluate the relationship between select kinetic and kinematic variables and ball speed in Cricket Fast Bowlers.

Methods: A cross sectional study was carried out on 42 Indian male State Level fast bowlers aged between 18 and 30 years who were subjected to 3D motion analysis in an accredited biomechanics testing facility of a university sports science centre. After lab and subject calibration, the bowler was allowed a self-directed warm up and the bowling action was captured using a set of 3D cameras (@250 fps) and a set of 2D video cameras (@125fps). Data processing & analysis was done with proprietary software using a standard retro-reflective marker model. Key biomechanical variables including Knee Flexion at Front Foot Contact, Maximum Knee Flexion, Lateral Trunk Flexion at Ball Release, Stride Length and Ball Release Height were measured. Peak Vertical Ground Reaction Forces were recorded simultaneously using a set of standard strain gauge Force Plates. Bowling Action type and Front Knee Action type were determined by established methods. Ball speed was obtained using a hand-held radar gun. Correlative & descriptive statistical analysis was done.

Results: Stride Length ($r=0.32$, $p=0.03$) and Ball Release Height ($r=0.25$, $p=0.01$) positively correlated with ball speed. Semi-Open bowling action and Flexor-Extendor type of Front Knee Action had highest ball speeds. There was no correlation between Ground Reaction Force and other kinematic variables with ball speed.

Discussion and Conclusions: These findings suggest that generating large Ground Reaction Forces is unnecessary for bowling faster. Coaching intervention by biomechanically modifying Bowling Action and Front Knee Action to safer types is compatible with good ball speeds and can play a large role in reducing injury risk. This has implications on coaching strategies and injury prevention for fast bowlers.

References:

Eccentric rate of force development and its relationship with front knee kinematics and peak ball release speed in amateur pace bowlers

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\textbf{Background}: Bowling with an extended front knee upon ground contact and at ball release (BR) strongly associates with peak ball release speed (BRS). A majority of pace bowlers flex the front knee with the onset of large ground reaction forces within the first 50 ms of front-foot contact (FFC). Flexion of the front knee also occurs in pace bowlers with localised quadriceps fatigue. As the front knee flexes under eccentric control of the quadriceps, a greater rate of force development (RFD) may be an important attribute to minimise the amount of knee flexion, and therefore allow the pace bowler to take advantage of a near-extended front knee to bowl faster.

\textbf{Aims}: To investigate the relationship between eccentric RFD, front knee kinematics, and peak BRS in amateur pace bowlers.

\textbf{Methods}: Thirteen amateur male pace bowlers performed an eight-over bowling test. Ball release speed was captured by radar gun. The extension angle of the front knee was calculated at FFC and BR from a 25 fps video camera. The change in knee extension (KE) angle was calculated. On a separate day, subjects completed a countermovement jump (CMJ) test of 20 maximal-effort repetitions; measured by a portable force plate and linear position transducer (600 Hz). The eccentric phase of the CMJ with the greatest jump height was analysed. The eccentric phase represented the last data point of baseline displacement to the lowest displacement recorded during the countermovement of the jump. Peak RFD was calculated in conjunction with time-interval RFD data from 0-30, 0-50, 0-90, 0-100, 0-150, 0-200, and 0-250 ms. The fastest delivery and associated kinematic data were selected for statistical analysis. Pearson correlation coefficients were conducted with statistical significance of $p < 0.05$.

\textbf{Results}: Peak BRS was $119.4 \pm 8.2$ km h$^{-1}$ (mean $\pm$ SD). Front KE angle was $158.1 \pm 4.0^\circ$ at front foot contact and $133.1 \pm 11.7^\circ$ at ball release. The change in KE angle was $-25.0 \pm 13.1^\circ$. All RFD variables were not significantly linked with peak BRS or front knee kinematics ($p > 0.05$). No statistically significant correlations were identified between peak BRS and KE angle at FFC ($r = -0.01$, $p = 0.975$), KE angle at BR ($r = 0.09$, $p = 0.778$), and the change in KE angle ($r = 0.08$, $p = 0.794$).

\textbf{Discussion and Conclusions}: Amateur pace bowlers do not appear to use the mechanical advantage of an extended front knee to bowl faster (i.e., KE angle > 150$^\circ$), and thus other biomechanical variables are more influential to peak BRS. Eccentric RFD data from the CMJ test do not reveal any insights into the ability to limit the amount of front knee flexion between FFC and BR. This may be due to the selection of a bilateral test of vertical force production and attenuation. A physical capacity test such as the single-leg forward hop and land may better replicate the force-vector experienced in the front knee, and could reveal further insights into eccentric RFD and its relationships with front knee kinematics and peak BRS.

\textbf{References}:
1. Worthington, P.J., King, M.A., & Ranson, C.A. JAB, 29(1), 78-84.
Lower limb muscle force estimation for fast bowlers in cricket

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Background: Musculoskeletal modelling is a non-invasive method to understand the effect of motion and external forces on the musculoskeletal systems¹. Subject-specific ligament, muscle and joint contact forces can be estimated using this technique. The information obtained will provide more insight and knowledge, how individual muscles contribute towards the dynamic activity under investigation. This information on the musculoskeletal loading is not possible experimentally and non-invasively. This technique uses experimental data (motion capture data, both kinematics and kinetics) as an input to estimate the internal loading conditions and is being validated by the research community for various activities and sports¹.

Cricket is an international sport, played in many countries across the globe. Lower limb injuries contribute a substantial amount towards injuries sustained by fast bowlers in cricket². The knowledge of muscular loading in lower limb during fast bowling will provide more insight into the mechanism of injury and help in the prevention and management of the injury.

Aims: This study aims to investigate and estimate the muscle and joint contact forces in lower limbs of fast bowlers.

Methods: Ten Indian male state level fast bowlers (Age: 19.70 ± 1.83 yrs, Height: 174.48 ± 6.60 cm, Weight: 68.53 ± 12.68 kg) with no musculoskeletal injury within past six months were chosen. The institutional ethics committee approved the study. Written informed consent was obtained from all the participants or their legal representatives. Experimental data was collected using the full body Plug-in-Gait marker protocol. The bowlers were instructed to ball six deliveries similar to match conditions. The kinematics and kinetics were captured using a Vicon system with 18 infrared cameras and 4 AMTI force platforms. The marker data was processed on Vicon Nexus software and imported into OpenSim³. Gait 2392 model was used and scaled to match the anthropometry of the bowlers. Inverse kinematics and dynamics were used to predict the internal joint loading. Static optimisation was used to estimate muscle loading and joint contact forces.

Results: The present study reported the kinematics, kinetics and muscle loading patterns in lower limbs for Indian fast bowlers. Peak front foot vertical ground reaction forces were between 5.31 – 9.10 BW (body weight). Based on the kinematic and kinetic input, the forces induced in the muscles and their loading pattern for front lower limb were determined. This loading information (muscle activation pattern) will act as an input for subject-specific interventions.

Discussion and Conclusions: This study provides an insight to understand the lower limb muscular loading in fast bowlers. This information can be utilised by the sports scientists and medical professionals to access the injury in more subject-specific manner. This quantitative information on lower limb loading at various joints will help in designing efficient strengthening and rehabilitation protocol for an individual fast bowler.

References:
Epidemiology of junior cricket injuries: a narrative review

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Background: In order to evaluate, interpret and discuss newly collected injury data from junior cricketers, it is important to first understand what is already known about their injury profile. At present, there are no comprehensive literature reviews that report the incidence and nature of junior cricket injuries internationally.

Aims: The aim of this review was to identify and summarise epidemiological studies of injury carried out in junior cricket.

Methods: Five electronic databases (PubMed, Web of Science, CINAHL, SPORTDiscus, Cochrane) and one journal (South African Journal of Sports Medicine) were searched up to December 2017 using keywords linked with ‘cricket’ and ‘juniors’. All studies that reported injury data in players up to the age of 19 years were included. The study characteristics, participant details and study methodology is reported for all selected studies. Injury data are summarised based on player age, level of play, playing position, injured body region and type of injury. Injury incidence proportions are presented for each study and as injuries per 100 participants.

Results: Eight studies met the inclusion criteria. Data were published for junior cricketers aged from under-8 to under-19, with studies originating from South Africa = 5, Australia = 2, and Asia = 1. A higher injury incidence proportion was reported in the South African studies (range from 31.6% to 49.1%) compared to the two Australian studies (4.3% and 11.4%). Injury incidence proportions were observed to increase with increasing age categories. South African studies showed a higher percentage of injuries among bowlers (45.0%, 50.7%, 48.0%, 47.4%) in contrast to Australian junior club cricketers with a higher number of injuries among batters (45.0-53.0%, 34.0%) and fielders (24.0-32.0%; 38.3%). In terms of the most common injury type (muscle strains and ligament sprains) and injured body site (lower limbs and to trunk/back), findings were very similar between all the studies. A considerable difference was observed in participant characteristics (age, level of play) and study methodology (study design, data collection method, setting) between South African and Australian studies.

Discussion and Conclusions: The overall injury rates and the proportion of injuries in different playing positions were very similar between studies conducted within the same country. However, there was a considerable difference in these characteristics when comparing the Australian¹² and South African³⁴ studies, highlighting the potential for important regional differences in injury profiles of junior cricketers. This finding suggests that injury prevention interventions in junior cricket should be tailored according to the nature and pattern of injuries that are evident from specific countries/regions. There was a lack of injury data from countries other than Australia and South Africa, which limits our understanding of junior cricket injuries internationally. Research from other cricket playing nations is needed in future to fully understand the regional differences in injury characteristics observed in this review.

References
Match injuries in Sri Lankan junior cricket: A prospective, longitudinal study

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Background: Understanding the number and nature of injuries in cricket is key to mitigate injury risks and prioritise preventive measures.¹ Current understanding of the incidence, nature and risks of injuries among Sri Lankan cricketers is limited and currently known only for cricketers in the national squad.

Aims: This study aimed to identify the incidence and nature of match injuries among Sri Lankan junior cricketers.

Methods: The study was designed as a longitudinal follow-up survey with prospective in-season data collection. Boys, under-15 (81 school-teams) and under-17 (75 school-teams) age categories, who took part in the 2016 division-1 domestic inter-school cricket tournament across Sri Lanka were eligible. Using a paper-based questionnaire, distributed to school-teams at the start of the 2016 cricket season, respondents recorded any injuries they sustained, including the site, type and mechanism. Match injury incidence rates (match-IIR) (injuries/100 match-player-days) were calculated overall and by position. The injury severity was reported based on the “match time loss” (MTL) and “non-match time loss” (non-MTL) injuries.

Results: From 59 responding school-teams, 573 players were included, with 404 players reporting 744 injuries in 648 matches. The total match-IIR was 28.0 injuries/100 match-player-days (95% CI = 26.0–30.2). For MTL injuries, the match-IIR was 6.1/100 match-player-days (95% CI=5.2-7.1) and for non-MTL injuries, the match-IIR was 21.9/100 match-player-days (95% CI=20.1-23.9). The highest match-IIR was reported among fielders (n=324; 46.0% of all injuries sustained; match-IIR = 12.9) and for non-MTL injuries, the match-IIR was 7.1. Collectively, abrasions and bruises accounted for a large proportion of injuries among fielders (50.7%) and wicket-keepers (39.2%), mainly affecting the knee (27.9%), hand (31.1%) and elbow (18.2%) regions sustained when diving for a catch (56.9%) and being struck by the ball (46.2%). Among batters, bruises accounted for the majority of injuries (32.3%) affecting the thigh (11.4%) and hand (9.7%), sustained by being struck by the cricket ball (51.4%). In addition, facial injuries (eyes, nose, ears, dental) and head injuries contributed to a large proportion of MTL injuries (61.1% and 42.9% respectively). Among bowlers, strains (30.6%) and sprains (17.4%) were the most common injury type mainly affecting the lower back (14.4%) and lower limbs areas, secondary to mechanisms such as overuse or overexertion (31.4%).

Discussion and Conclusions: This study identified a high match injury incidence rate among Sri Lankan junior cricketers, which prioritise potential areas for injury prevention initiatives. Almost half (46.0%) of all injuries were to fielders, and requires specific investigation into their severity and mechanisms, with consideration of both the ground surface and skill acquisition as potential areas to explore. For batters, the use and appropriateness of helmets needs to be considered with possible legislative changes for compulsory helmet use owing to a seemingly high number of facial-organ and head injuries, from being struck by the ball. Further evaluation of injury characteristics by bowling subtypes is also recommended to understand potential differences between injuries in the spin-bowling styles preferred in the South Asian region, compared to fast-bowlers in other regions.

References
Design and Development of a Novel Cricket Injury Prevention Program (CIPP)

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Background: Injury prevention programs (IPP) are effective in reducing injuries among adolescent team sports.1 However, there has been no cricket specific IPP developed despite the high incidence of musculoskeletal injuries among amateur teams.2,3

Objectives: To design and evaluate whether a cricket injury prevention program (CIPP) as a pre-training warm up or post-training cool down can reduce injury rates in amateur cricket players.

Methods: CIPP is a single blinded, cluster randomised controlled trial which includes 36 male amateur club teams having cricket players aged 14-40 years to be randomly assigned to three study arms: warm-up, cool down and control (n= 12 teams, 136 players in each arm). The intervention groups will perform 15-minute CRIPP either as a pre-training warm up or a post training cool down.

Outcomes: The IPP includes four major phases: 1) dynamic stretch and running, 2) strength and agility, 3) balance and core strength and 4) game-based exercises, totaling 14 exercises targeting the body regions most commonly injured in cricket. The novelty of this program is that participants do not need any equipment other than their regular cricket gear. The primary outcome measure will be injury incidence per 1000 player hours and the secondary outcome measures will be whether IPP as a warm-up is better than IPP as a cool down and the adherence to the intervention.

Trial registration number: ACTRN1261700047039

References:
Cricket Injury Epidemiology in the 21st century: What is the burden?

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Background: At the turn of the century, a new format of cricket (T20) was introduced that led to more matches being played over a shorter period of time leaving players with little to no rest in the off season. As a result it has been debated whether T20 cricket has increased the risk of overuse injuries\textsuperscript{1,2}

Aims: The primary aim of this study is to meta-analyse the cricket injury rates in the 21st century. The secondary aims are to explore the risk factors and mechanisms of injury by analysing correlates such as age, format, era of play, country, player-type etc., and qualitative analysis of the published studies.

Methods: Several databases were searched using keywords ‘cricket’ and ‘injur*’. Twenty-four papers reporting cricket injuries fitted the inclusion criteria. Fifteen of these included data on exposure time, which was used to calculate injuries rates and perform sub-group analysis.

Results: The pooled data of 12511 players’ revealed 7627 injuries. After pooling 1.12 million hours of cricket play from 15 studies reporting exposure time, the injury rate was found to be 53.16 (95% CI 51.84 – 54.52) per 10,000 hours of play. There were no statistically significant differences in injury rates based on age, format, era of play, country, player-type and injury definitions. Bowling biomechanics, workload, and lack of warm-up and conditioning were identified as the major risk factors for injury.

Conclusions This systematic review provides a comprehensive picture of cricket injury burden in the 21st century. It unwraps the effects of factors that may influence cricket injuries and the quantification in terms of injury rate allows comparison with other non-contact sports of shorter duration.

References:
Monitoring fast bowlers training load: a practitioners perspective

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Background: The appreciation and application of sport-science support within team sport environments has grown exponentially over recent decades 1. Now, many professional cricket clubs employ fitness and sport-science staff, who engage in the daily monitoring of training load (TL) 2. Training load can be characterised as external (i.e. overs bowled [work done]) or internal, the individual's physiological (i.e. heart-rate) or psychophysiological response to the external load 2,3. Developments in wearable micro-technology has resulted in enhancing practitioners understanding of TL quantification 2,4. Despite routine monitoring, and a plethora of TL data available, little is still known and acknowledged in the literature of current applied practices within professional cricket.

Aims: To describe current training load monitoring practices and perceptions of practitioners and coaches working in professional cricket within the United Kingdom (UK).

Methods: A survey of staff working within professional cricket in the UK, was conducted (July to December 2017). This survey built on many of the TL themes previously surveyed 2,3 and was finalised to contain 23 questions covering three overall themes; training planning (n = 6), club TL practices (n = 5) and TL monitoring, feedback and usefulness (n = 12). This survey was circulated via email – Bristol Online Survey (BOS) weblink. Due to its cross-sectional design, data analysis and presentation is primarily descriptive.

Results: 30 respondents (coaches: n = 8; practitioners n = 22) completed the online-survey. Nineteen of 22 practitioners were strength and conditioning (S&C) coaches and three sport-science/medicine staff. All practitioners worked with senior first-class cricketers, with 54% also working with senior international cricketers. Ten (45%) practitioners also worked with academy cricketers (under 15 to 19 y). Coaches were primarily responsible (87%) for planning cricket specific training, with practitioners primarily responsible (93%) for planning physical training. Practitioners identified six different TL variables (range 1-5) to quantify fast-bowling workloads; well-being (82%), session-rating of perceived exertion (sRPE [59%]), descriptive data (i.e. overs-bowled [50%]), GPS/accelerometry (46%), neuromuscular fatigue (NMF [36%]) and heart-rate (18%), respectively.

Discussion and Conclusions: To our knowledge this is the first study to detail the TL monitoring processes in professional cricket. Despite listing 10 variables to quantify TL in fast-bowlers, practitioners cited six independent variables, typically utilizing 3 ± 1 TL measures. Further, we highlighted that no "gold standard" monitoring parameter appears to be accepted for the monitoring of TL in professional cricket. However, based on frequencies, most practitioners tend to use a combination athlete self-report measures as opposed to wearable technology. This survey provides initial support for the overall usefulness of TL monitoring in professional cricket.

References:
Spin characteristics of two cricket pitches with contrasting soil properties

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Background: Cricket pitch reflection characteristics have previously been defined as “pace” (ratio of peak delivery speed retained after reflection) and “bounce” (ratio of entrance angle retained in the reflection angle)1,2. Soil properties (clay, sand, silt) of the pitch are known to influence the reflection characteristics of medium and fast deliveries1-3. To understand the effect of soil properties on the spinning characteristics of a cricket pitch, the reflection variable “deviation” (angular difference between the angle of incidence and reflection) must also be considered2.

Aims: To measure the spin characteristics of two cricket pitches with contrasting soil properties, while considering the effect of the seam contacting the surface during bounce.

Methods: The soil properties of two pitches were analysed using core samples 16 mm in diameter and 100 mm in depth. A Merlyn by BOLA spin bowling machine was used to deliver 400 spinning deliveries onto a Common Australian Pitch (CAP) and a Bespoke International Pitch (BIP). Three synchronised high-speed cameras operating at 250 fps were used to capture the deliveries through release (overhead) and pitch impact (behind and side-on). A calibration frame (2.4 m × 2.4 m × 0.7 m) with known distances marked every 0.1 m captured entrance and reflection vectors. Peak delivery speed was measured using a Stalker Pro II radar (34.7 GHZ) and peak spin rate using Trackman II X (10.512 GHZ). Siliconcoach Pro8 software (v 1.4.0) was used to post process the two-dimensional high-speed vision and calculate seam azimuth angle at release and reflection pace, bounce and deviation of each delivery after contacting the pitch.

Results: The CAP recorded higher levels of clay and silt compared to the BIP, with sand content being higher for the BIP (BIP = 43.28%, CAP = 7.44%). Reflection pace revealed the BIP was significantly lower than the CAP in cases where the ball impacted on the seam and when it did not (p < .001). Reflection bounce revealed that when the seam impacted the pitch, no significant difference was observed between the CAP and BIP (p = 0.133), however when the seam did not make contact, the BIP showed higher reflection bounce compared to the CAP (p = .045). Reflection deviation revealed the BIP was significantly larger than the CAP in cases where the ball impacted on the seam (p < .001) and when the ball did not impact on the seam (p = .042).

Discussion and Conclusions: Results demonstrate that soil properties influence reflection pace and deviation of a spinning cricket ball. The BIP measured lower than the CAP on all soil property variables except for sand particles. The findings support the notion that a high percentage of sand particles in the soil construct increases the friction on the surface, creating a (spinning) pitch that is more likely to produce larger deviation angles4. This contributes to previous research demonstrating how soil properties affect the reflection pace and bounce of medium and fast bowlers in cricket1,2.

References:
Accuracy of Umpiring decisions for detecting illegal bowling action in Cricket from different positions in comparison with 3D Biomechanics analysis

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Background: Dealing with suspect/illegal bowling actions is a major challenge for the Umpires in cricket—not only is this a difficult skill but the issue is also a sensitive and emotive one for the player and their team. The challenge lies where Umpires have to make initial judgments on the field with a naked eye.¹,²

Aim: To evaluate standard and unorthodox Umpire standing and camera positions with regards to picking up illegal bowling action with naked eye as compared to 3-dimensional biomechanics analysis.

Methods: The study was conducted at the ICC accredited indoor cricket biomechanics laboratory of Centre for Sports Science, India.¹¹⁴ national level umpires were split into 6 groups. Each umpire of a group individually judged the legality of 6 stock deliveries each of a right arm off-spin bowler standing from 4 different positions. In addition to the 2 standard umpire positions at the Non-stiker’s end and Square-leg, 2 new unorthodox standing positions, one at the Right side of the bowling crease and another behind the Wicket-keeper were used. Simultaneous 3D motion capture of the bowler’s action was done using the ICC Standardized Protocol with a cluster based 26 marker-set. 16 Vicon 3D cameras tracked the markers while they bowled from over the wicket. Umpires’ observation results were compared with the lab results and statistical analysis was done to determine which umpiring position had the best accuracy in picking up an illegal delivery by naked eye.

Results: Standard position at the non-stiker’s end had 54% accuracy in picking up illegal deliveries while Square Leg position had the best accuracy of 56.8%. Side of the Bowling crease position was 47.5% accurate while Behind the Wicket-keeper was 56.1%

Discussion and Conclusions: Bowling actions are divided into three clear categories as regards to their conforming to the MCC’s Laws of Cricket Law 21.2 (2017 Code),³ Fair Delivery - the arm and ICC Suspect Bowling Action Policy.⁴ The study was planned as a part of a national Umpire Training Workshop to impart skills required to improve the Umpires’ ability to report suspect bowling action in a confident manner both using the naked eye and from match video. Additionally, it explored the idea of two new unorthodox umpire standing positions with a purpose to show how other angles could be used to better determine an illegal or otherwise bowling action and for later review by video.

References:
2. Aginsky et al., British journal of sports medicine, 44(6), 420-425.
3. MCC 2017 Laws of Cricket Law 21.2 and Law 2.9
4. ICC Regulations for the Review of Bowlers reported with Suspect Illegal Bowling Actions
Reproducibility Assessment of a Musculoskeletal Screening Protocol in Junior Cricket Fast Bowlers, Conducted by a Non-clinician

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Background: The reproducibility of musculoskeletal assessments underlies the accuracy of identifying injury risk factors in sporting populations¹. The reliability and reproducibility of baseline measurements must be ensured in order to decrease intra- or inter-rater error and allow differences greater than this variation to be attributed to the injury risk factor². The reliability of a field-based screening protocol has been assessed in cricketers³, but as with many injury risk studies, the assessments are performed by clinicians. In order to have a broader range of applicability to grassroots or less elite sporting settings, and larger-scale research, it may be beneficial and more efficient for these tests to be performed by non-clinicians, trained to an appropriate standard.

Aims: To investigate the reproducibility of a trained non-clinician in performing musculoskeletal tests at baseline in junior cricket fast bowlers.

Methods: The observer, a sports medicine PhD student with a BSc in Physiology, received one-to-one training from an experienced sports physiotherapist with 12 years’ experience in the field, to perform a musculoskeletal assessment protocol. The cohort of 29 junior fast bowlers included 27 males and 2 females aged between 14.1 and 17.3 years (15.5 ± 0.95 [mean ± SD]), with a mean height of 179 ± 8.3 cm and mean weight of 67.7 ± 11.1 kg. Ethical approval was obtained and approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and the National Research Ethics Service. Each test was performed three times by the researcher, in the following order: passive hip internal rotation, passive hip external rotation, bent knee fallout, passive straight leg raise, passive shoulder external rotation, passive shoulder internal rotation, combined shoulder elevation, and sit and reach. Intraclass correlation coefficients (ICCs) of absolute agreement were calculated (IBM SPSS Statistics) to assess intra-rater reliability for each test and were classified according to Landis and Koch, 1977⁴.

Results: All ICCs were above or equal to 0.946 and the 95% confidence intervals (CI) all fall in the range for almost perfect classification. Therefore, all tests are classified as having excellent agreement and almost perfect reliability. The CI ranges are narrow for most tests, but wider (above 0.1) for passive hip external rotation and sit and reach. The standard error of the mean and critical values were low for all tests, and highest for the passive hip rotation tests, 1.82˚ and 5.05˚ for internal rotation and 1.49˚ and 4.13˚ for external respectively.

Discussion and Conclusions: Intra-rater reliability of the musculoskeletal assessment protocol performed by a trained researcher was almost perfect with relatively low critical values. These results suggest that this protocol is sufficient for use in investigating injury risk in this population, as high observer reproducibility, decreases observer error and the critical value, to allow potential differences in measured outcomes to be attributed to injury risk factors. It is also suggested that non-clinicians can be trained to perform these tests to a high reliability which could allow the translation of research in more elite settings to that of grassroot sport or large-scale research.

References: