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Concussion in adolescent rugby union players: comprehensive acute assessment protocol and development of the SSC concussion passport to monitor long-term health

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ABSTRACT

Introduction Sports-related concussion (SRC) can be challenging to diagnose, assess and manage. Much of the SRC research is conducted on adults. The assessment of SRC should aim to identify deficits using a detailed multimodal assessment; however, most studies investigating the effects of SRC use diagnostic tools in isolation. It is likely that a combination of diagnostic tests will improve diagnostic accuracy. In this study, we aim to investigate how concussion affects adolescent rugby players and how a variety of diagnostic tools interact with each other as participants recover from their injury. The study will also determine the logistics of recording an individual's concussion history on a virtual 'Concussion Passport' that would remain with the individual throughout their sporting career to allow monitoring of long-term health.

Methods and analysis All rugby players (n=211) from the Senior Cup Teams of five schools in Dublin, Ireland will be invited to participate in the study. Baseline testing will be performed at the Sports Surgery Clinic, Dublin (SSC) before the rugby season commences. Participants will be followed up over the course of the rugby season. At baseline and at each postconcussion visit, participants will complete the following: Questionnaire, Sports Concussion Assessment Tool 3, Balance Error Scoring System, Computerised Neurocognitive Testing, Vestibulo-ocular assessment, King Devick test, Graded exercise test, Blood tests, Neck strength, FitBit.

Ethics and dissemination Ethical approval was obtained from the Sports Surgery Clinic Research Ethics Committee (Approval number: SSC 0020). On completion of the study, further papers will be written and published to present the results of the various tests.

Trial registration number NCT03624634.

INTRODUCTION

Sports-related concussion (SRC) is an evolving injury in the acute phase with rapidly changing clinical signs and symptoms and is considered to be among the most complex injuries in sports medicine to diagnose, assess and manage.[1]

In recent years, there has been a significant increase in attention to the consequences of SRC in community level athletes.[2] Much of this research is conducted on adults and there is limited SRC research into the effects of concussion on children and adolescents in rugby.[3–5]

Currently, there are no defined, evidence-based age groups for the management of youth SRC. Davis *et al* recommend that child-specific paradigms for SRC management should apply to children aged 5–12 years and adolescent-specific paradigms should apply to those aged 13–18 years.[6]

Although SRC management guidelines are largely derived from studies in adults,[1] there is evidence that adolescents have poorer outcomes after SRC compared with older athletes.[7–10] It is hypothesised that during the phase of cognitive maturation, the developing brain may be more susceptible to both acute and chronic complications from concussions and/or repetitive head impact.[11]

Adolescents tend to have a greater number of and more severe postconcussion symptoms than younger children and tend to take longer to recover and return to school and sport than younger children. Additionally, students with a greater number of symptoms and more severe symptoms tend to take longer to return to school and require more academic accommodations as well as taking longer to recover and to return to sport.[6] The expected duration of symptoms in this age group is defined as up to 4 weeks vs 10 days in adults>18 years.[6]

In 2014, the US Institute of Medicine and National Research Council released a report titled '*Sports-Related Concussions in Youth:*

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Improving the Science, Changing the Culture', which considers risk factors, screening, detection, treatment and management recommendations and long-term consequences of repetitive concussions in the developing brain.[12] This area was also systematically reviewed at the Fifth International Conference of Concussion in Sports.[6] These studies provide an important foundation for understanding the consequences of concussion in children and adolescents.

The assessment of SRC should aim to identify specific pathologies that may be contributing to the persistence of symptoms using a detailed multimodal assessment, which includes a comprehensive history, symptom score, focused physical examination (including assessment of cervical spine), balance, neck strength,[13–15] vestibular and oculomotor function and a systematic evaluation of exercise tolerance.[1 16 17] This assessment may facilitate classification of phenotypic injury subtypes and coupled with fluid biomarker,[18] proteomic[19 20] and genetic signatures[21 22] may allow development of targeted interventions for cases of persistent symptoms following SRC.[23]

To date, most studies investigating the domains that can be affected as a result of SRC use diagnostic tools in isolation. However, it is likely that a combination of diagnostic tests as compared with individual tests will improve diagnostic accuracy of concussion.[24] Currently there is insufficient evidence to determine the best combination of measures to improve identification of concussion.

In this study, we aim to investigate how concussion affects adolescent rugby players and how a variety of diagnostic tools interact with each other as participants recover from their injury; which in turn will inform the development of a framework for the safe management of schoolboy rugby athletes postconcussion.

In addition, schoolboy rugby players often participate in multiple sports and/or in multiple teams within the same sport over the course of their lives. This study will also determine the logistics and optimal format of recording an individual's concussion history, including number of concussions, severity of concussions, results of investigations and duration of recovery on a virtual 'Concussion Passport' that would remain with the individual throughout their sporting career, which will provide a better platform for future research and ultimately improve how concussion is managed.

Aims and objectives

1. To determine the incidence of SRC in schoolboy rugby in Ireland.
2. To establish a normative data set of clinical, biomarker and physiological markers used in the assessment of a schoolboy rugby population at preseason baseline.
3. To determine the extent and temporal changes in balance, oculomotor function, vestibular function, exercise physiology, biomarkers and neck strength following SRC.
4. To understand the logistics of a detailed screening programme and establish a 'Concussion Passport'.

METHODS AND ANALYSIS

Study design

A prospective cohort study.

Population being studied

All schoolboy rugby players (n=211) from the Senior Cup Teams of five schools in Dublin, Ireland will be invited to participate in the study. The schools are all members of Irish Schools Rugby. Contact will be initially made through the Head Teacher and Head Coach at each school and subsequently the parents/guardians of each player will formally be invited to enrol their son in the study.

Inclusion/exclusion criteria

Inclusion criteria

Participants are eligible to participate if they (1) are aged 15–19; (2) play rugby union and are registered on the Senior Cup Team for their school; (3) can understand and participate in the testing procedures; (4) are able to provide parental/guardian consent for participation.

Exclusion criteria

(1) Unable to attend for preseason screening; (2) History of pre-existing neurological disorder; (3) Unable to give informed consent.

Outcomes

Participants will adhere to the Irish Rugby Football Union (IRFU) concussion guidelines for this age group and no player will return to sport before the mandatory 23 day stand down period. Due to this requirement, timing of return to play (RTP) cannot be used as a measure of recovery. This study will also determine both the normative data in an uninjured population as well as the extent and temporal changes in balance, oculomotor function, vestibular function, exercise physiology, biomarkers and neck strength following SRC in order to adequately power a future intervention study.

Statistical analysis/power calculations

This is a cohort study to determine the logistics, effect sizes and test metrics in order to adequately power a future intervention study.

Investigations

At baseline and at each postconcussion visit, participants will complete the following:

Questionnaire

Participants will complete a questionnaire (online supplementary appendix 1) which included questions on past medical history, injury history, concussion history, playing history, sleep, mood, stress, anxiety, depression, Quality of Life assessment, symptoms checklist, predictive and modifying factor analysis. This questionnaire has been used in studies of Australian football, horse racing jockeys and rugby league.

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Sports Concussion Assessment Tool 3 (SCAT3)

Participants will complete the SCAT3.[25] The SCAT3 includes the following assessments: Glasgow Coma Scale,[26] Maddock's questions,[27 28] Standardised Assessment of Concussion,[29–31] a modified version of the Balance Error Scoring System (mBESS consisting of three stances performed on a hard surface[32]), cervical spine examination and modified neurological examination. There are published normative data on the test.[33–37]

Balance assessment

In addition to the clinical mBESS assessment (see above), each mBESS will be performed on an AMTI Force Platform (BP 400×600), which gives data on variations of centre of pressure.[38] The platform measures the three-orthogonal force and moment components along X, Y and Z-axes at 2000 Hz. This allows accurate calculation of the maximum displacement in the anterior-posterior and medial-lateral direction.

Computerised neurocognitive testing

Participants will complete the CogState Brief Battery, a validated computerised cognitive assessment,[39] which is comprised of four tasks: Processing Speed (simple reaction time), Attention (choice reaction time), Learning (visual recognition memory) and Working Memory (one-back). Participants will perform the test in a quiet room under the supervision of a study investigator. As per test protocol, participants will complete a practice trial for each task before completing the scored test. The primary outcome measure is the speed and accuracy of responses relative to normative data for that age group.

Vestibulo-ocular assessment

To obtain accurate, objective measures of vestibulo-ocular dysfunction participants will be examined using the ICS Impulse Goggles; lightweight (60 g) goggles that allow accurate assessment of oculomotor and vestibular function by recording eye movement in response to testing stimulus.[40 41] The in-built high-speed USB camera can accurately measure fine eye movements that can detect catch-up saccades, nystagmus and skew deviation. In-built sensors measure head movements, providing head position feedback. Finally, calibration lasers provide stimulus for calibration and oculomotor testing.

The following tests will be conducted:

i. Video Head Impulse Test (vHIT)—eye movement response to brief, unpredictable, passive head rotations (head impulses) have been shown to be an important indicator of peripheral vestibular function via assessment of the semicircular canals.[40]
ii. Dynamic Positional Test (Dix-Hallpike test)—provides the ability to diagnose Benign Paroxysmal Positional Vertigo (BPPV) by identifying nystagmus that is evoked from dynamic changes in the patients' body orientation in respect to gravity.[42]
iii. Vestibulo-ocular reflex (VOR)—identifies the presence or absence of saccadic eye movement in order to diagnose vestibular dysfunction. Participants are asked to stare at a fixed point on a wall while the examiner passively moves the patients head approximately 10° in the horizontal plane at 0.5 Hz for 20 s. The test is then repeated in the vertical plane.
iv. Gaze stability—identifies nystagmus that is evoked without stimulus by having the subject stare at a laser pointer in different positions. Performing the same test without vision (vision denied) helps to differentiate if the disorder is central or peripheral.

King Devick test (K-D test)

The K-D test is an assessment of rapid number naming which requires the athletes to quickly read a series of numbers on three test cards. It has been studied as an acute sideline concussion screening tool in rugby union and rugby league.[43–45] Worsening performance on the K-D test from baseline was shown to be a reliable indicator of concussion. Rather than being completed at the sideline, in this study, participants will complete the K-D test at baseline and at each postconcussion visit.

Graded aerobic exercise test

Participants will complete the Buffalo concussion treadmill test; a standardised graded aerobic exercise test that is based on the Balke cardiac protocol.[46 47] Studies demonstrate that this test is safe and can reliably reveal physiological dysfunction in patients with persistent postconcussive symptoms (eg, shorter exercise duration, lower heart rate at test cessation and higher rating of perceived exertion (RPE)). Postconcussion test results can quantify the exercise capacity of these patients allowing the safe prescription of subsymptom, submaximal aerobic exercise as part of an individualised rehabilitation programme.[47 48]

To provide additional physiological data during the treadmill test, participants will wear a metabolic analyser (MetaMax 3B) for the duration of the test.[49]

The test will be performed on a motorised Woodway Pro XL treadmill. Treadmill speed is initially set at 5.3 km/h at 0.0° incline. At 1 min, the incline grade increases to 2.0° while maintaining the same speed. At the start of the third minute and each minute thereafter up to minute 15, the incline grade increases by 1% maintaining the speed at 5.3 km/hour. At 16 min, the gradient remains at 15° and the speed increases by 1 km/hour each minute until test cessation. Each minute heart rate is recorded, participants provide a RPE score and participants are asked to report any symptoms. Metabolic data were sampled at 0.5 Hz. Blood pressure is recorded at the beginning and end of the test. The test is terminated if symptom exacerbation occurs or at volitional exhaustion.

Blood tests

Participants in this study will have blood drawn, labelled and frozen at −80°C at baseline. Participants who sustain a concussion will then have blood serially drawn at each

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assessment time point, labelled and frozen. Baseline samples will be compared with postconcussion samples.

Fluid biomarkers to be analysed include neurofilament light polypeptide, neuron-specific enolase, ubiquitin carboxyl-terminal hydrolase isoenzyme L1, myelin basic protein, S100B, glial fibrillar acidic protein and total Tau protein as well as genotyping the apolipoprotein E allele.[50]

Neck strength

To assess maximal isometric cervical strength, a single-axis load cell strain gauge mounted on a head harness will be used. Scores will be recorded for cervical flexion, extension and lateral flexion.[51]

Participants will be instructed to warm up by (1) actively flexing and extending the neck in the sagittal plane and flexing in the frontal plane in each direction; (2) rotate the head about the vertical axis three times in each direction through full range of motion and (3) isometrically resist cervical flexion, extension and lateral flexion in both directions using their own hand. Participants will sit upright on a stool with the head in neutral position, feet hip width apart and flat on the floor, knees and hips flexed at 90°. Arms are placed by their side holding on to the seat base for stability. The order of testing is randomised. Neck strength will be tested at 0° of rotation for all directions. The line of pull on the harness is horizontal and placed across the frontal and parietal bones above the ear line of the participant's head. Verbal instructions to be given for testing will be a three second count down and then 'pull, pull, pull, pull, pull and relax'. Each isometric contraction will be recorded for three seconds and repeated three times in each direction. Thirty seconds rest between repetitions is given. The strain gauge is reset to zero between each test.

FitBit

Activity and sleep will be monitored for each post-concussion participant using a Fitbit Activity Monitor (Model: Fitbit Charge HR, 2016) which uses a three-dimensional accelerometer to sense user movement. The sensor tracks steps taken and combines it with user data to calculate distance walked, calories burned, floors climbed and activity duration and intensity. It also measures sleep quality by tracking periods of restlessness, how long it takes the wearer to fall asleep and how long they are actually asleep. The data collected will be downloaded at each subsequent visit to Sports Surgery Clinic, Dublin (SSC).

Time frames

Baseline testing will take place at the SSC before the start of the rugby season. Participants will then be followed up over the course of the rugby cup season.

The diagnosis of SRC will be made independent of the study investigators by the school doctor/nurse, the family doctor or at the local Emergency Department. Once diagnosed with concussion, participants will contact the study coordinator to arrange postconcussion testing. The initial tests will be conducted within 72 hours postinjury.

Participants diagnosed with SRC will attend SSC on a weekly basis until fully recovered. Every appointment will include a clinical assessment by a Sports & Exercise Medicine Physician and the full battery of investigations will be repeated. Based on the results of these investigations participants will be prescribed an individualised rehabilitation programme. This is now considered gold-standard management of concussion and is not part of the study in itself. Return to school/learn will be the priority above RTP.

Participants will adhere to the IRFU concussion guidelines for this age group. No participant will RTP sooner than the mandated 23 days.

ETHICS AND DISSEMINATION

In this study, we aim to investigate how concussion affects adolescent Rugby players and how a variety of diagnostic tools interact with each other as participants recover from their injury which in turn will inform the creation of a framework for the safe management of schoolboy rugby athletes postconcussion. By determining the extent of and temporal changes in a variety of assessment tools, we can understand the logistics of a detailed screening programme and help create a 'Concussion Passport'. This concussion passport would remain with the individual throughout their sporting career, will assist clinicians managing the individual, will provide a better platform for future research and ultimately will improve how concussion is managed.

The study participants will be aged 15–19. This raises ethical considerations regarding consent. For this reason, presentations outlining the details of the study will be conducted by the lead study investigators at each school, and all participants and parents/guardians will be emailed a participant information sheet prior to providing informed consent to participation. All participants will provide written informed consent as well as written informed consent from their parent or guardian.

The tests being performed in this are very safe with minimal risk to study participants. The Buffalo Challenge Test is performed on an exercise treadmill. There would be a very small risk of a fall on the treadmill. Also, with any vigorous exercise, there is a very small risk of cardiac arrest. All tests will be performed by medical staff trained in Cardiopulmonary Resuscitation (CPR) with access to full resuscitation equipment as per SSC protocol. Neck strength testing requires maximum isometric contraction using a head harness and a pulley system to measure force. There is a small risk of neck injury, particularly muscle strain, during maximal testing procedure. However, the test is designed to stop on point of head movement or loss of control to enhance safety. Study investigators are mindful of these small risks and will do everything to ensure that no harm comes to the study participants.

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When data collection is completed, further papers will be written presenting the results of each individual test, highlighting temporal changes from baseline and at weekly intervals throughout recovery. Following publication of the results of this study, a more detailed sample size calculation can be performed to adequately power future interventional studies to determine the precise usefulness of each of the individual test platforms used singly and/or in combination.

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Contributors PM, CC, AFM, EF and CF conceived the project and CC is leading the coordination of the trial. PM, CC, AFM, EF, CF, CB and JR developed the protocol. AFM procured the project funding. CC, CF, JR and CB recruited participants. CC, CF, AFM, EF and CB performed baseline and post-concussion testing. CC, PM and CF wrote the manuscript. All authors participated in the trial design, provided feedback on drafts and read and approved the final manuscript.

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Competing interests None declared.

Patient consent Not required.

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